8. Historic and Cultural Heritage

Figures

8.1. Cultural Heritage Values

Cultural heritage value can be both tangible, as in the physical fabric of places and objects, and intangible, as in the spiritual significance of sacred sites. This chapter outlines the cultural heritage values of the project area, including sacred sites, Aboriginal heritage places and objects, significant historical places and objects, and culturally significant species.

8.1.1 Sacred Sites

Registered sacred sites are protected under the Sacred Sites Act. The statutory authority responsible for the documentation and protection of sacred sites is the AAPA. The Proponent applied for an Authority Certificate for all works associated with the rehabilitation of the project area and this was granted by AAPA on 19 September 2019 (Appendix redacted to protect culturally sensitive information). The Authority Certificate is a legal document that mandates specific conditions relating to registered sacred sites and restricted work areas.

8.1.2 Aboriginal Places and Objects

Aboriginal archaeological places and objects are afforded automatic protection under the Heritage Act, whether their location is recorded or not. The (former) NT Department of Resources (DoR) commissioned an archaeological investigation of the Rum Jungle Mine site in 2010 (Martin-Stone and Wesley, 2011), and DPIR commissioned further archaeological assessment for the Rum Jungle Rehabilitation Project Stage 2A (Martin-Stone, 2019 – see Appendix). The archaeological surveys were carried out in accordance with the NT Heritage Branch general scope of works for archaeological surveys. Previous archaeological studies have also been undertaken in the region, including a predictive model for the landscape distribution of archaeological sites in the Coomalie region (Guse, 1998), against which the survey results were assessed.

A Heritage Branch search of the NT Archaeological Sites Register showed a large number of Aboriginal places and objects across the Rum Jungle area (Fig 8-1 redacted to protect culturally sensitive information). These places and objects include stone artefact scatters, a quarry, a non-portable grinding place and isolated stone artefacts.

Figure 8-1: Results of Heritage Register searches – Redacted

Several archaeological field surveys have been carried out over time in order to develop an understanding of the cultural heritage profile across the entire project area. The 2010 archaeological survey identified 11 Aboriginal heritage objects (isolated stone artefacts) and 10 Aboriginal heritage places within the Rum Jungle mine site (Martin-Stone and Wesley, 2011). The heritage places range from small artefact scatters to more concentrated occupation sites, including a quarry and artefact production site and an extensive palimpsest. The 2018-19 archaeological survey identified 16 Aboriginal heritage objects (isolated stone artefacts) and three Aboriginal heritage places (stone artefact scatters). The distribution of heritage places and objects is shown in Figure 8-2 (redacted to protect culturally sensitive information).

At the time of the 2018-19 field survey works, some of the survey areas had poor ground visibility due to vegetation growth. This work focussed on the borrow pit locations on FRALT and CCGC land and warrants further investigation prior to ground disturbance to ensure the archaeological resource is appropriately defined and managed. This is manageable within the parameters of the proposed CHMP.

The compilation of mapped cultural heritage sites was used to inform the project design in order to protect and preserve cultural heritage. Of particular interest is the location of infrastructure, such as roads and the new WSFs, which were designed around known cultural heritage features.

No heritage places or objects were identified in the proposed low permeability material borrow area adjacent to RJCS. This result is in line with the expectations of the regional predictive model. Several objects were identified in the proposed granular material borrow area, however these are planned to be avoided through project design.

Figure 8-2: Recorded Heritage Places and Objects – Redacted

The Aboriginal places recorded during the archaeological surveys have high cultural significance to the Traditional Owners and Custodians. When assessing their significance according to the criteria under section 11 of the Heritage Act, the consultant concluded that they are significant for the following reasons:

- The variation within and between sites in terms of artefact material, type and function can tell us about the course and pattern of Aboriginal occupation of the area. They are therefore important to the course of the Territory's cultural history.
- A more detailed understanding of these places has the potential to yield information that will contribute to our understanding of the Territory's cultural history.
- The places have a strong association with the Kungarakan and Warai Traditional Owners, for cultural and spiritual reasons. More detailed understanding of these Aboriginal places has the potential to reveal stronger connections between the lifeways of the old people and their sacred sites.

The Aboriginal places have been assessed as having high cultural significance and moderate archaeological significance on an individual basis. Collectively, the Aboriginal places represent an archaeological landscape of moderate significance.

8.1.3 Historical Places and Objects

Historical places and objects are only afforded legal protection in the NT if they have been nominated, assessed and registered as Declared Heritage Places and Objects. There are currently no Declared Heritage Places and Objects within the project area. The Rum Jungle Uranium Mines were nominated to the (then) NT Heritage Advisory Council in 2001 under the previous *Heritage Conservation Act 1991* (NT) and considered in 2005. The Heritage Advisory Council decided against recommending the mining areas to the Minister for heritage declaration.

The structural remains of mining infrastructure were assessed for their significance by Martin-Stone and Wesley (2011) under the old legislation and again by Martin-Stone under the Heritage Act as part of the current investigations (Martin-Stone, 2019 – see Appendix). These assessments confirmed that the structural remains from the mining period do not meet the significance criteria established in the legislation. Therefore, preservation of the sheds, slabs and other built infrastructure is not required. However, the drill rig, currently located near Main Pit, does meet the criteria to be considered a significant heritage object. It was independently assessed by Jared Archibald, curator of NT history at the Museum and Art Gallery of the Northern Territory (Archibald, 2019). The machine is a Quarrymaster blasthole drill rig, constructed by the American engineering company, Ingersoll Rand. While the drill rig has not been nominated for consideration as a Declared Heritage Object, Archibald recommends that it should be afforded protection from destruction, either by display at a suitable place at the Rum Jungle site, or by transporting it to the grounds of the Batchelor Museum for display and interpretation (Archibald, 2019:4).

A number of World War II (WWII) features, including gun emplacements and dry stone walls have been documented within the project area. As they were recorded in conditions of low visibility, Martin-Stone (2019) recommends documenting their full extent in more suitable survey conditions. The visible remains were assessed as having moderate significance under the terms of the Heritage Act, so while they are not yet afforded legal protection, their preservation would be warranted.

8.1.4 Culturally Significant Species

Consultation with Traditional Owners over time has led to the development of an understanding of culturally significant species and flora specimens. Formal protection for these may be through registration under the Sacred Sites Act as a registered sacred site if this is the case. Individual specimens are only considered to be protected heritage places under the Heritage Act if they display evidence that relates to the past (*i.e.* Traditional Aboriginal) human occupation of the Territory and is in an archaeological place (*e.g.* a 'culturally modified tree' that has been cut with a stone axe for the purpose of extracting native honey or making wooden objects, located within a broader archaeological site).

It is recognised that traditional Indigenous knowledge systems value species in an interconnected ecosystem and particular species may have cultural significance in different ways – for example, in a particular location, or to a particular group of people, or for their medicinal, food, ceremonial or other utilitarian purpose.

Hydrobiology (2013) held meetings in 2012 with 'a range of traditional owner groups' to determine what fauna they used for bush tucker and other purposes – with a focus on riparian habitats. From those discussions, lists were compiled of bush food plants and animals as well as of non-food plant uses (*e.g.* bush medicine, sheet bark for construction *etc.*).

Hydrobiology also gained some insight into the riparian flora and fauna species that have spiritual and/or ceremonial significance. Such species included 'red claw', barramundi, crocodile and 'turtle'. The only riparian plant species discussed in a spiritual context was the White Paperbark (*Melaleuca leucadendra*). Increasing the abundance and general wellbeing of such totem organisms is seen as highly desirable. It is acknowledged by Hydrobiology that it is likely that other important riparian or aquatic plant species also have specific cultural values arising from spiritual beliefs that were not enunciated in open discussion.

Discussions held between the Proponent and some Traditional Owners have led to the identification of 'multi-clumping' (*i.e.* multi-stemmed) Darwin Cycads (*C. armstrongii*), Red Kurrajongs (*Brachychiton megaphyllus*) and Milkwoods (*Alstonia actinophylla*) as being significant to those Traditional Owners. According to observations by EcOz during fieldwork undertaken across the project area in 2018-19, Milkwoods occur sparsely within the *Eucalyptus* woodlands within the mine site and granular material borrow area – this is a normal distribution for the species. Red Kurrajong are common in *Eucalyptus* woodlands. The general distribution and abundance of Darwin Cycads is discussed in Chapter 14 – Terrestrial Flora and Fauna. Multi-stemmed cycads occur sporadically – either as individuals or in groups – predominantly recorded in the mid and/or lower stratum of mixed *Eucalyptus* species woodland habitats in more dry upland areas.

In order to minimise impact to culturally significant species and specimens, the project footprint has been designed around existing vegetation stands as far as possible. Cycad mapping also took place across the WSF location in order to utilise that data as a design constraint.

8.2. Potential Impacts and Risks

The greatest possible protection for heritage value is achieved through avoiding disturbance, and this has been a key goal of the project. Building on the cultural heritage surveys, the project has been designed around known heritage values. Despite implementing design works that aim to avoid disturbance, the potential still exists for impact on places and objects of heritage value. These risks have been identified in the *Risk Register* (GHD, 2019f – see Appendix) and are reviewed in detail below.

The risks have been considered against the likelihood of their occurrence, and against the possible impact on the significance of the assessed heritage values.

8.2.1. Disturbance of Registered Sacred Sites

While the proponent has received an approved Authority Certificate for the management of registered sacred sites under the terms of the Sacred Sites Act, there is a risk that sacred sites may be inadvertently or intentionally disturbed during the course of works. There is also the risk that work practices might cause cultural offence. Due to the degree of cultural significance of sacred sites, the risk rating for disturbance of registered sacred sites is Extreme.

8.2.2. Proliferation of Weeds, impacting Heritage Value

Weeds, especially Gamba Grass, are currently prolific within and surrounding the project area. These changes in vegetation can influence erosion and fires, which may change the character and environmental context of sacred sites and heritage places. While erosion and fires are not considered likely to negatively affect the intangible significance of sacred sites, they do have the potential to cause damage to the fabric of heritage places and objects. These archaeological materials are afforded protection under the Heritage Act.

The proliferation of weeds may negatively impact on the establishment of culturally significant species within the project area. Unless a species is an identified threatened species, there are no legal protections for culturally significant species.

The risk of weeds impacting on known heritage values is assessed as High due to the current status of weed proliferation in the area.

8.2.3. Disturbance of Known Heritage Places / Objects

There is a risk that known places and objects of heritage significance could be inadvertently or intentionally disturbed during the course of works. These could include Aboriginal places and objects, which are protected under the Heritage Act and/or places of historical significance related to WWII and/or the drill rig. These historical places (WWII sites) and object (drill rig) are accepted as having historical significance under the criteria defined in the Heritage Act, however they have not been registered as Declared Heritage Places/Objects. The risk is that disturbance may involve damage, destruction or removal of part of the fabric of these places/objects, leading to a loss of heritage value. For places and objects protected under the Act, there is also the risk of non-compliance with legislative requirements.

The risk of disturbance of known heritage places and objects is assessed as High due to the presence of significant heritage places and objects within the project area and the fact that they are unlikely to be easily recognisable to the untrained eye.

8.2.4. Disturbance of Unidentified Heritage Places / Objects

Due to the variable nature of ground surface visibility during archaeological surveys, it is possible that some heritage places and objects within the project area have not yet been recorded. Therefore, there is a risk that unidentified places and objects of heritage value, including Aboriginal artefacts, historical artefacts and/or human skeletal remains, may be inadvertently or intentionally damaged, destroyed or removed during rehabilitation activities. For Aboriginal places, objects and human remains, there is also the risk of non-compliance with legislative requirements.

The risk of disturbance of unknown heritage places and objects is assessed as High due to the limitations of the data, the presence of significant heritage places and objects within the project area, and the fact that they are unlikely to be easily recognisable to the untrained eye.

8.2.5. Disturbance of Culturally Significant Species

There is a risk that rehabilitation activities may impact on culturally significant flora and fauna species. For the species identified as culturally significant (see Chapter 14 - Terrestrial Flora and Fauna), only the Darwin Cycad is protected. Disturbance could lead to the loss of culturally significant specimens and potentially to non-compliance with legal obligations in relation to threatened species. The risk of disturbing culturally significant species has been assessed as High due to the presence of Milkwoods (though sparse), Red Kurrajong and Darwin Cycads in woodlands within the former mine site and granular material borrow area.

8.2.6. Uncontrolled Fire Onsite

The potential for uncontrolled fire originating onsite, and potentially extending beyond site, poses a risk of impacts to cultural heritage places and objects, and culturally significant flora species. The risk is that fire may alter the characteristics and significance of these heritage values.

This risk has been identified as High due to the potential for lightning strike or ignition from construction activities and the presence of combustible vegetation (especially Gamba Grass) across the area.

8.2.7. Incursion by External Uncontrolled Fire

The risk of incursion by external uncontrolled fire onto site is similar to uncontrolled fire originating onsite, with the same potential to alter the characteristics and significance of heritage values.

The risk of incursion by external uncontrolled fire is considered High due to adverse weather events or arson activities and the proliferation of combustible vegetation (*i.e.* Gamba Grass).

8.2.8. Low Risks

The following risks to cultural heritage sites were identified in the Risk Register and are considered inherently Low risk:

- Increase in dust deposition due to transportation of material along haul roads/access tracks, construction activities or exposure of soils leading to disturbance of (or impact to) cultural heritage sites.
- Dispersion of particulates and dust from exposed surfaces (*e.g.* pits, WRDs, laydown areas, stockpiles, roads) due to wind erosion resulting in dust deposition impacting sacred sites and/or artefacts.
- Vehicles/mobile plant/excavation/material movements creating noise and vibration at elevated levels leading to an altered character of sacred sites or heritage places.

8.3. Mitigation and Management

The proponent has placed the highest priority on the avoidance of impact on cultural heritage values. This has been primarily achieved through designing around known values, in consultation with Traditional Owners and Custodians. The AAPA has approved an Authority Certificate which mandates conditions for the management of registered sacred sites throughout the life of the Project. The rehabilitation design takes into account the contents of the Authority Certificate and avoids impact on all known Aboriginal heritage places and objects (as defined under the Heritage Act), and the significant historical places (WWII sites) and historical object (drill rig).

The primary method for mitigating impact on cultural heritage values will be the development and implementation of a CHMP. The specific measures for mitigating identified risks, through the CHMP, are discussed below.

In addition to the CHMP, the proponent will also establish a Working Group for Traditional Owners, which will provide opportunity for engagement of Aboriginal communities, the planning of business and employment opportunities, and a plan for ongoing stakeholder communication. The CHMP and Working Group will be developed within the framework of the Stakeholder Communication and Engagement Strategy.

The proponent has avoided impact on culturally significant species as far as possible through modified design and will mitigate the impact on individual Darwin Cycad specimens through the Cycad Salvaging Procedure set out in Chapter 14 – Terrestrial Flora and Fauna. The mitigation of the impact of weeds and fire on heritage values will be managed through appropriate management plans.

The risks of dust deposition, noise and vibration having a potential impact on cultural heritage places and objects is considered so low as to not warrant any specific mitigation measures.

8.3.1. Disturbance of Registered Sacred Sites

The design of the project has been developed in consultation with Traditional Owners and Custodians, with particular regard to sacred sites. The design avoids impacting the cultural visual lines of site. Haul roads have been located to shift operations as far away from registered sacred sites as possible.

The proponent has secured a legally binding Authority Certificate and finalised design to conform to its conditions.

The proponent will develop a CHMP which will include Authority Certificate compliance measures, induction procedures for onsite personnel, ongoing consultation with Traditional Owners and Custodians, an internal approvals process prior to ground disturbance, and the erection of visual barriers and access signage where appropriate.

8.3.2. Proliferation of Weeds impacting Heritage Value

The appropriate management of weeds will mitigate the potential for impact on places and objects of heritage value. The proponent will develop and implement a Construction Weed Management Plan, a Bushfire Management Plan and a post-rehabilitation Weed Management Plan that provides for an active and ongoing weed management program for the project area. The proponent will also design and implement a revegetation methodology that aims to minimise weed establishment in rehabilitated areas.

8.3.3. Disturbance of Known Heritage Places / Objects

The project has been designed around the known heritage values to date, including moving haul roads away from recorded archaeological sites. The proponent will also develop a comprehensive CHMP to mitigate the risk of disturbance to known and unidentified heritage places and objects.

The CHMP will be a working guide for onsite personnel and will include measures for:

- compliance with the Authority Certificate conditions for sacred sites;
- further archaeological survey and assessment where required;
- protection measures for known heritage places and objects;
- stop work procedures in the event suspected or actual unidentified human remains, places or objects of heritage value are encountered during works;
- internal approvals prior to any ground disturbance, to ensure known and unknown heritage values are not inadvertently disturbed;
- the implementation of any other early warning assessment criteria that may be warranted;
- ongoing consultation with Traditional Owners; and
- compliance with regulatory approvals processes for any authorised disturbance.

The proponent also proposes to develop a Cultural Heritage Centre onsite as a repository for the curation and exhibition of cultural heritage objects that may be subject to authorised relocation during rehabilitation works. The preservation and interpretation of artefacts in the Cultural Heritage Centre provides an opportunity to offset the impact of disturbance to sites. The CHMP will include temporary measures for the preservation of relocated artefacts, in consultation with Traditional Owners, during the Construction phase.

For the protection of historical places (WWII sites) and the historical object (drill rig) that are not currently afforded legal protection, the CHMP will recommend the avoidance of the WWII sites – this has already been achieved through design – and the relocation of the drill rig to a more suitable place where it can be displayed and interpreted. Options include in the vicinity of the Cultural Heritage Centre onsite or in the grounds of the Batchelor Museum (Archibald, 2019).

8.3.4. Disturbance of Unidentified Heritage Places / Objects

The measures for mitigating impacts on unidentified heritage places and objects will be the same as for known heritage places and objects.

8.3.5. Disturbance of Culturally Significant Species

Due to the listing of Darwin Cycads as a threatened species, and because of their significance to the Traditional Owners, the granular material borrow pits and the WSF have been located in order to minimise the number of Darwin Cycads that will be disturbed by project activities. Ecologists surveyed for Darwin Cycads ~100 m either side of the proposed WSF boundaries. The boundaries were then re-designed to avoid as many Darwin Cycads as possible.

Chapter 14 – Terrestrial Flora and Fauna details how, prior to land clearing within the WSF sites and the granular material borrow area, identified Traditional Owners for whom Darwin Cycads have cultural significance will survey the area to be disturbed and flag any significant individual cycads that are possible to relocate. Those plants will then be relocated within the project area.

8.3.6. Uncontrolled Fire Onsite

The risk of uncontrolled fire onsite impacting on heritage value will be mitigated through the development and implementation of a Fire Management Plan, an Emergency Response Plan and maintaining the availability of emergency response personnel and equipment.

The Fire Management Plan will include proactive mitigation measures including fire breaks, fuel load reduction program, fire detection and suppression systems, housekeeping standards, training of onsite personnel, maintenance of equipment and the implementation of emergency response procedures.

8.3.7. Incursion by External Uncontrolled Fire

The risk of incursion by external uncontrolled fire impacting on heritage value, will be mitigated through the same measures as for an uncontrolled fire onsite (see Chapter 14 – Terrestrial Flora and Fauna).

8.4. Monitoring and Reporting

Appropriate measures for ongoing monitoring and reporting will be developed in a CHMP. The CHMP will include procedures for documenting internal approvals prior to ground disturbance works to ensure that protection of registered sacred sites and known heritage places and objects is upheld.

8.5. Statement of Residual Impact

The proposed final site conditions, shown in Figure 8-3 (redacted to protect culturally sensitive information), demonstrate that the rehabilitation design prevents impact on known cultural heritage values. The rehabilitation success metric is to protect and preserve cultural heritage places and objects *in situ* as priority and to comply with legal requirements for relocation of any objects that may require it. All heritage values that are protected under the terms of the Sacred Sites Act and the Heritage Act will be protected in accordance with those laws. The proponent has made provision for the additional protection of significant historical places (WWII sites), a historical object (drill rig) and culturally significant species.

Figure 8-3: Residual Impact on Heritage Values – Redacted

The conditions within the Authority Certificate, combined with the implementation of additional measures within the CHMP, reduce the residual impact of the initial risk ranking of Extreme for the disturbance of registered sacred sites to a Medium risk ranking. The residual impact of all previously High risk heritage impacts has been reduced to a Medium risk rating, through the implementation of the proposed mitigation measures.

A Medium risk rating may at first glance seem unacceptable, but the rating weighs the severity of the consequences against the probability of a disturbance event. The consequences of damaging highly significant cultural heritage values is recognised as a severe impact, however the application of the proposed mitigation measures significantly reduces the probability of any disturbance event. Therefore, the unlikely outcome of the rehabilitation works having a detrimental effect on heritage significance renders the residual risks acceptable.

8.6. References

Archibald J. (2019) *Drill rig at the Rum Jungle Mine Site near Batchelor, NT.* Unpublished report to In Depth Archaeology.

GHD (2019f) *Rum Jungle Stage 3 EIS Risk Register* – Rum Jungle Project Team.

Guse D. (1998) *Archaeological Site Patterns in the Coomalie Region,* Northern Territory. Unpublished report for Heritage Conservation Branch, NT Department of Lands, Planning and Environment, Quaternary Archaeological Surveys, Darwin.

Martin-Stone K.C. and Wesley D. (2011) *An archaeological and heritage survey of the former Rum Jungle mine site, Northern Territory.* Unpublished report by Earthsea Heritage Surveys to the Department of Resources, Northern Territory.

Martin-Stone, K (2019) *A report on the archaeological survey for Rum Jungle Rehabilitation Project – Stage 2A.* Report by In Depth Archaeology to the Department of Primary Industry and Resources, Northern Territory.

8.7. References included in Appendix

GHD (2019f) *Rum Jungle Stage 3 EIS Risk Register* – Rum Jungle Project Team.

Martin-Stone, K (2019) *A report on the archaeological survey for Rum Jungle Rehabilitation Project – Stage 2A.* Report by In Depth Archaeology to the Department of Primary Industry and Resources, Northern Territory.

9. Terrestrial Environmental Quality

Figures

Tables

9.1. Terrestrial Environmental Values

The Rum Jungle Rehabilitation Project exists within a highly disturbed terrestrial environment, primarily due to historical mining activities. Previous rehabilitation works have improved the terrestrial environment; however, the environmental values of the Rum Jungle Mine site remain impacted by the altered mining landscape, weeds, altered fire regimes and contaminated sites. The project area is comprised of natural undisturbed landforms areas, areas impacted by mining such as the Mt Burton WRD, the Main and Intermediate Pits and their WRDs, and areas where contaminated soils/tailings were both removed from and relocated to during rehabilitation works. The assessment of impacted terrestrial environmental values is complicated by the industrial and rehabilitation history of the site alongside mineralised geology, which has influenced natural soil quality in the area.

This section describes and maps the landforms and soil types that occur in the project area based on land unit mapping and the analysis of surface and sub-surface soil/rock samples collected at the Rum Jungle site.

Chapter 6 – Existing Environmental Condition establishes the compromised environmental values and the conceptual site model that describes the critical contamination linkages. Chapter 10 – Inland Water Environmental Quality describes the most critical contamination source, pathway and receptors along the AMD path. Project objectives are described in Chapter 1 – Introduction and the rehabilitation strategy is described in detail in Chapter 7 – Rehabilitation Strategy.

9.1.1. Regional and Significant Topography

Regional topography, as indicated by DENR (2019) ranges from 135 m Above Ordinance Datum (AOD) to 70 m AOD, with lower lying areas adjacent to ephemeral watercourses. General project topography ranges from 118 m AOD (Mt Burton), 99 m AOD (Mt Fitch) to 88 m AOD at Rum Jungle proper (Section 2968 Hundred of Goyder).

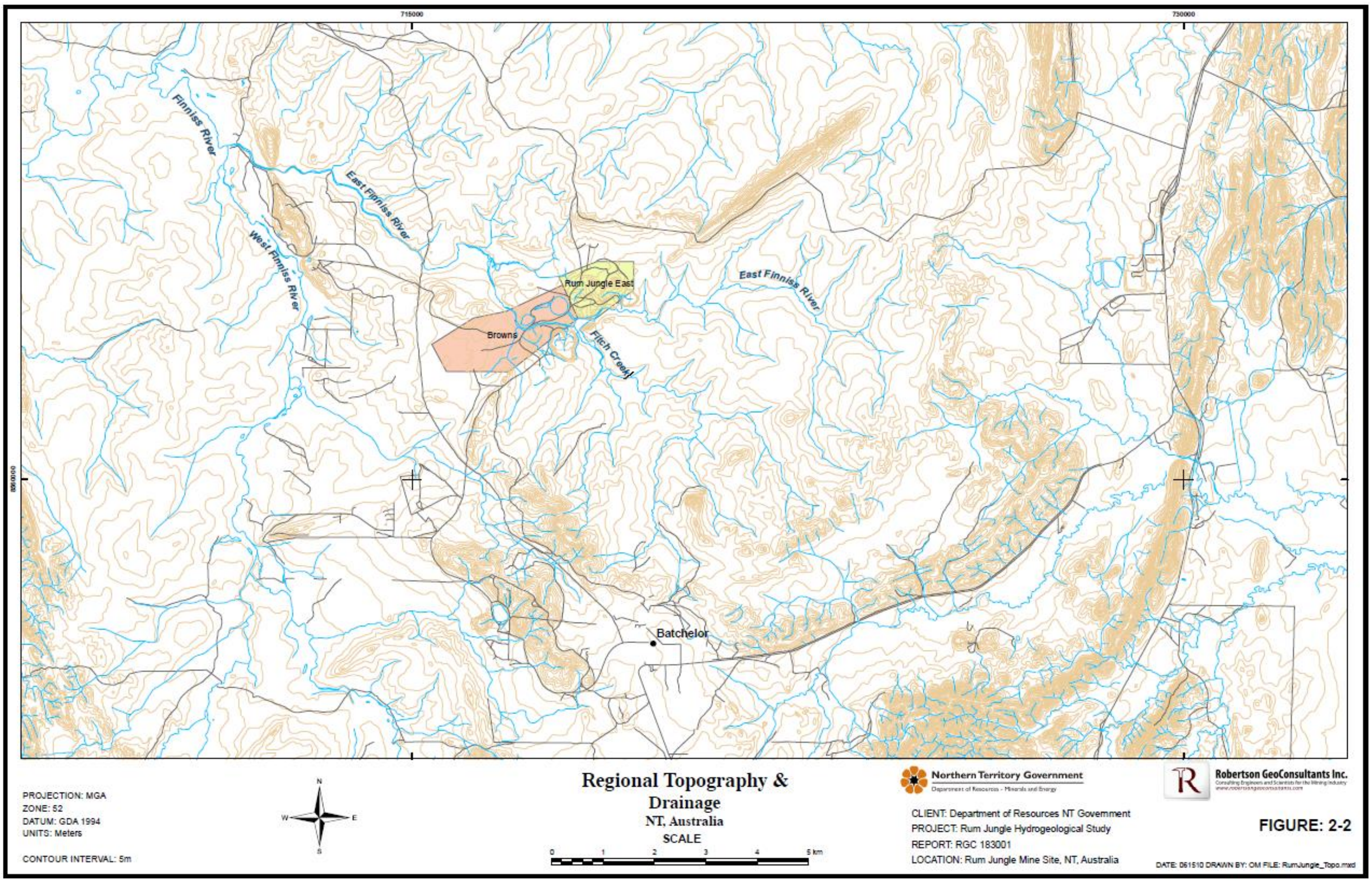

Figure 9-1: Regional topography (RGC, 2011)

9.1.2. Geology

The project area is located within the north-western section of the Pine Creek Orogen and features two dome-like Archean basement highs: the Rum Jungle Complex (to the north) and the Waterhouse Complex to the south (Ahmad *et al.*, 2006).

The Rum Jungle and Waterhouse Complexes consist primarily of granitic intrusions that are now overlain by a Paleoproterozoic sequence of metasedimentary and subordinate metavolcanic rocks called the Mount Partridge Group (and repetitive clastic-carbonate sequences of the Namoona Group). From oldest to youngest, the three major formations of the Mount Partridge Group are the Crater Formation, Coomalie Dolomite and Whites Formation. The Mount Partridge Group has been folded, faulted and metamorphosed to greenschist facies, but the original stratigraphic succession has been preserved (Ahmad *et al.*, 2006). Brittle failure associated with deformation has produced several faults that follow the northeast-southwest structural trends of the Rum Jungle Mine site. Additional information is in Chapter 5 – Regional Setting. A map of the local geological units is at Figure 9-2.

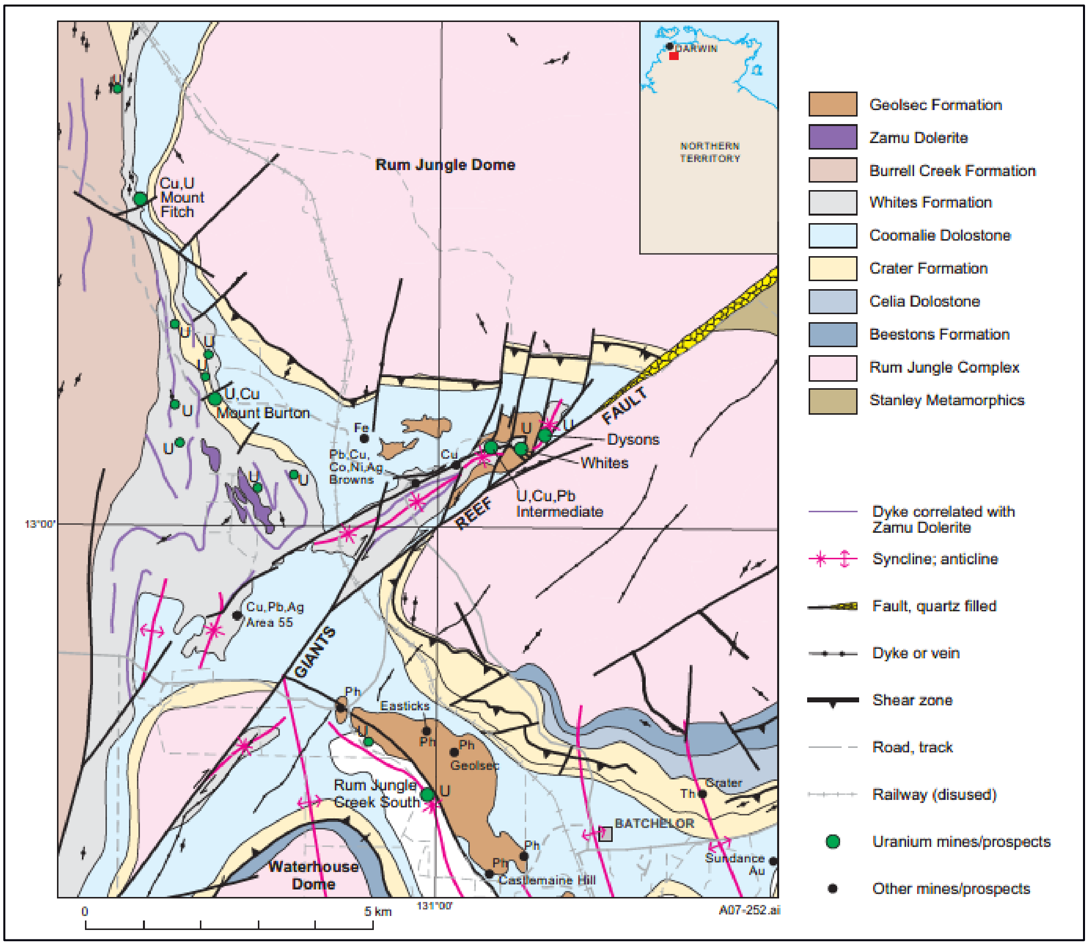

Figure 9-2: Geology of the Rum Jungle Mineral Field showing uranium and other minerals (Ahmad and Hollis, 2013)

9.1.3. Soil Types and Land Units

According to Robertson GeoConsultants (2011) the underlying soils across the Rum Jungle Mine site vary depending on historic anthropogenic influences and underlying bedrock formations. The soil profile of the western portion is typically characterised by clayey granular cover material (derived from naturally sourced material), overlaying waste rock or remnant contaminated material. Below that is residual cobble/gravel soils transitioning to extremely weathered breccia, dolostone or argillite overlying more competent bedrock. Bedrock is generally around 5 m below current surface, becoming shallower towards ridgelines and in localised pockets.

The eastern portion is characterised by more clayey natural deposits in excess of 5 m thick in the northern and northeast section. The north-eastern zone, characterised by cleared vegetation, was once an old borrow area for the 1980s rehabilitation clay material and was also used as a storage location for the WTP filter cake material. Towards the south of the eastern portion, the arid patch of land characterises an old borrow area, from which materials were stripped down to residual soils, leaving present-day soil of granular/cobble material that transitioning to extremely weathered dolostone bedrock at around 5 m. Further south is dominated by Giants Reef Fault, which expresses to the surface in the east and marks the boundary of granite derived shallow residual sand/gravel deposits; granite bedrock is typically encountered within approximately 2.5m of the surface south of Giants Reef Fault.

Land systems

Christian and Stewart (1968) define a land system as 'an area or group of areas throughout which there is a recurring pattern of topography, soils and vegetation'. These have been mapped across the NT by the government and are at a significantly smaller scale than a bioregion (*i.e.* bioregions constitute many different land systems). NTG mapping at 1:250,000 scale shows that six different land systems occur within the project footprint. These systems – as well as adjacent ones – are mapped in Figure 9-3, and their characteristics are outlined in Table 9-1. Finer scale, land unit mapping only covers a minor proportion of the project footprint and so has not been included in this report.

Table 9-1: Land system characteristics for the Rum Jungle project footprint

Name	Class	Landform	Soil	Vegetation*
Effington	Alluvial floodplains	Level to gently undulating alluvial floodplains of dominantly sandy alluvium	Kandosolic, Tenosolic and Chromosolic Redoxic Hydrosols. Uniform gradational and texture contrast sandy soils.	Mid-high woodland of *Melaleuca viridiflora, C. polycarpa, Melaleuca nervosa, E. bigalerita, C. latifolia* over *Chrysopogon fallax, Pseudopogonatherum spinescens, Eriachne triseta*.
Flatwood		Level to gently undulating alluvial floodplains of dominantly silty alluvium	Kandosolic and Chromosolic Hydrosols. Mottled yellow earths and duplex soils.	Mid-high open woodland of *Melaleuca viridiflora C. polycarpa, Melaleuca nervosa, C. latifolia, C. grandifolia* over *Chrysopogon fallax, Pseudopogonatherum spinescens, Eriachne* spp.
Gully	Granite plains and rises	Undulating terrain developed on granite, schist, and gneiss.	Kandosols and chromosols. Red massive earths and mottled yellow duplex soils.	Woodland of *C. confertiflora, C. foelscheana, E. chlorostachys, Terminalia canescens* and *Petalostigma* species over perennial grasses (*Heteropogon triticeus, Themeda australis, Sorghum plumosum*).
Bend	Sandstone plains and rises	Undulating low strike ridges and rises on folded Burrels Creek greywacke, sandstone and siltstone.	Kandosols and rudosols. Skeletal soils and shallow, gravelly loams.	Mid-high woodland of *C. latifolia, C. foelscheana, E. polysciada, E. tectifica, Erythrophleum chlorostachys* over tropical tall grass (*Sorghum* spp., *Heteropogon* spp., *Chrysopogon* spp.).
Bustard		Very low ridges and hills on Lower Proterozoic sediment and intervening alluvial flats.	Kandosols. Lithosols with minor shallow yellow massive earths and earthy sandy soil.	Low shrubland of Eucalypt spp., *Xanthostemon paradoxus* and *Buchanania* spp.
Woodcutter		Very gently upland surface; probably developed on Tertiary sediments overlying carbonate-rich Lower Proterozoic rocks.	Kandosols. Deep red massive earths and yellow massive earths.	Mid-high woodland of *Erythrophleum chlorostachys, E. miniata, C. confertiflora, C. papuana* and *Petalostigma* species over perennial grasses (*Heteropogon triticeus, Chrysopogon latifolius* and *Imperata cylindricus*).

** C. = Corymbia, E. = Eucalyptus*

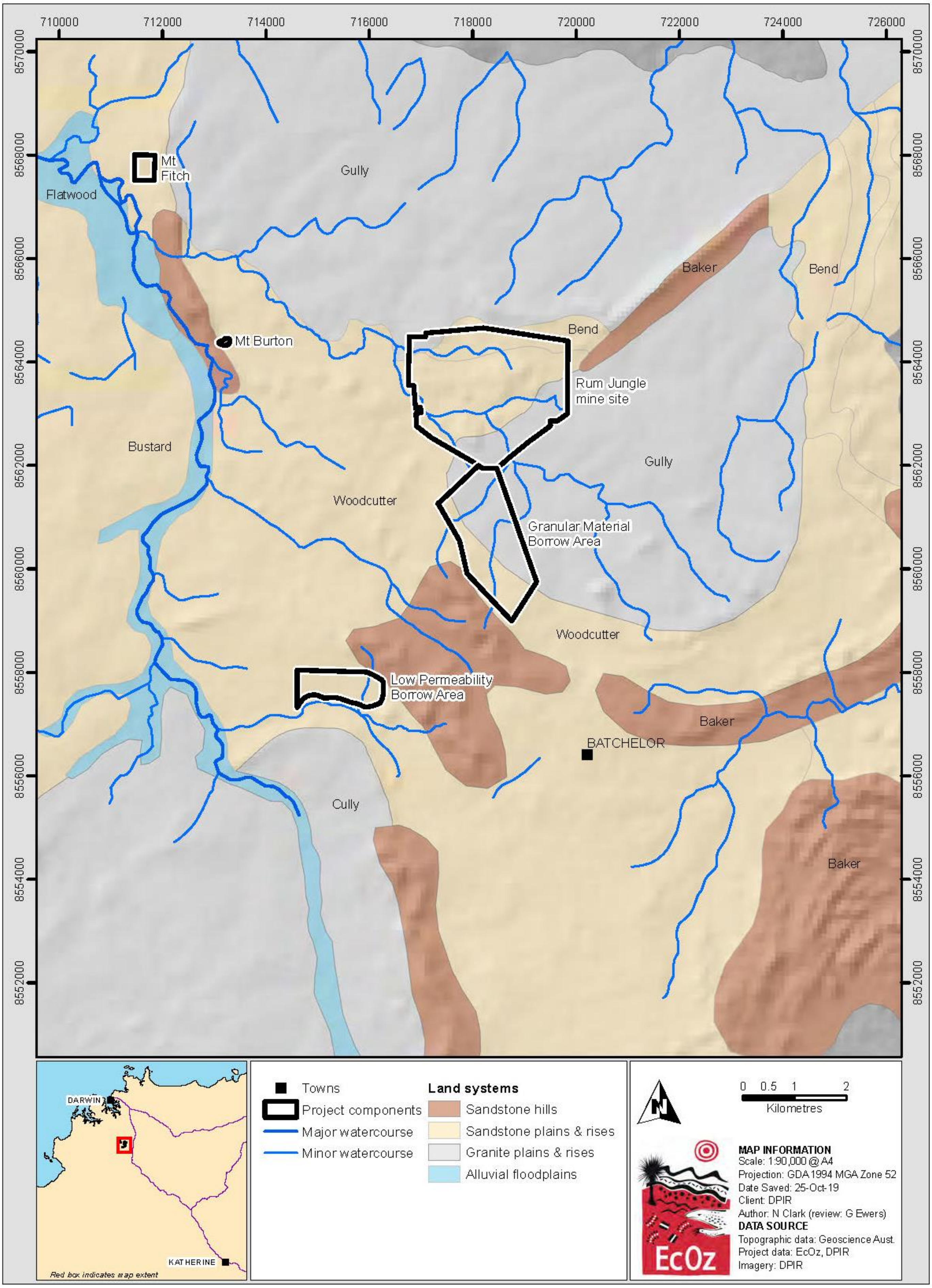

Figure 9-3: Map of land systems within the project footprint

The identification and evaluation of risks posed by 'contaminated soils' are complicated by the presence of naturally elevated background concentrations of several metallic elements. However, unacceptable soil contamination or soil conditions exist in several areas. These areas are described in Chapter 6 – Existing Site Condition.

A range of elevated metal and particularly copper concentrations remain in sub-soils and/or have migrated into previously placed cover soils at the Copper Extraction Pad and the Dyson's (backfilled) Pit. Presently, these areas do not support good quality vegetation and dieback on these rehabilitated surfaces has occurred. Vegetation dieback effects are partially and varyingly attributable to the legacy of low soil pH and the increased solubility of ecotoxic heavy metals, including copper, manganese, zinc and aluminium under acidic soil conditions in these areas. Other elements critical to vegetation health also become less available at lower soil pH, including phosphorous and calcium (Ryan, 1985).

White sulphate salts precipitate throughout the Dry season and provide a clear indication of where the surface expression of seepage occurs from all WRDs. The most obvious areas of impact include the seepage zone on the northern face of Intermediate WRD (which extends into the EFDC), much of the perimeter toe drain around Main WRD, the former 'Sweetwater Dam' area (located near the confluence of Fitch Creek and the EBFR) and seepage expressions in drainage channels on the southern faces of Dyson's (backfilled) Pit and Dyson's WRD, which contribute to the EBFR further upstream. These salt-affected areas and ephemeral water channel reaches are a key contributor to 'first flush' impact events to the EBFR at the commencement of each Wet season.

CSA Global (2011 – see Appendix) characterised the distribution of metals in surface and near-surface soils, fluvial sediments and some deeper soil and waste material profiles. The works involved the collection and analysis of soils by field XRF and supporting laboratory analyses to calibrate XRF results. A series of 'Cut-off' or 'Threshold' values were selected to distinguish between naturally elevated metallic elements of the Rum Jungle site and areas of soil contamination.

Further detail on-site contamination processes is available in Chapter 6 – Existing Environmental Condition.

9.1.4. Existing WRD Condition

The existing WRDs at the Rum Jungle site are physically stable showing little sign of erosion however they are not chemically stable with AMD produced within these WRDs being the primary terrestrial environment contamination source. Earlier rehabilitation works have significantly improved the site condition; however, further improvements are required in order to meet the project objectives. Further information on the geochemical characterisation of the waste rock is available in Chapter 6 – Existing Environmental Condition, Section 6.3.1. – Waste Rock and in two Appendix documents (Jones, 2019; RGC and Jones, 2019 – see Appendix for both).

Impact assessment for geochemical risk is covered in Chapter 10 – Inland Water Environmental Quality; the Terrestrial Environmental Quality is strongly linked to these geochemical aspects of the site.

9.2. Potential Impacts and Risks

Potential impacts to the terrestrial environment have been identified over several Qualitative Risk Assessment (QRA) workshops which have included the majority of the project's technical specialists, lead engineers and earthworks contractors. The results of these workshops are documented in the *EIS Risk Register* (GHD, 2019f – see Appendix) and have informed the design and project delivery plans.

Eleven significant potential impacts on the terrestrial environment were identified: six classified as Medium initial risks, four as High initial risks and one as an Extreme initial risk.

9.2.1. Erosion and Movement of Sediment

While the project area is currently physically stable, the proposed Stage 3 works will disrupt the existing site landforms and introduce the risks of erosion and sediment transport. Planned rehabilitation earthworks will expose the historic mining landforms and disturb the location of potential borrow pits. Vegetation clearing also has the potential to impact on the established soil structure and expose the underlying soil to wind and rain. The installation and use of erosion and sediment control structures, river crossings and restoration of the original EBFR flow path could result in unwanted impacts if poorly designed or executed.

As noted in the *EIS Risk Register* (GHD, 2019f – see Appendix) two significant potential impacts related to erosion and movement of sediment were identified (Table 9-2).

Table 9-2: Erosion and movement of sediment risks

Event	Impact	Initial Risk Rating
Clearing riparian vegetation, due to the construction of water crossing (s)	Loss of stabilising vegetation leading to erosion of banks and impacts to channel morphology.	Medium
Clearing land for haul roads, borrow pits, laydown areas, waste storage facility.	Erosion from cleared land causing sediment entrainment	Medium

9.2.2. Long-term Stability of Landforms and Revegetation Success

A key outcome of the proposed works will be that the project area is stable over a long timeframe and does not require further significant rehabilitation. Therefore the geophysical stability of constructed landforms and the success of revegetation activities is key to the overall success of the works.

An unstable landform could lead to denudation of the WSF surface and its effectiveness becoming compromised. The establishment of vegetation is also a key requirement within the rehabilitation success metrics as an indicator of a long-term stable and non-polluting environment. The stability and creek bank structure of the reconstructed portion of the EBFR is also at risk if works are not competently executed.

As noted in the *EIS Risk Register* (GHD, 2019f – see Appendix) seven significant potential impacts related to long-term stability of landforms and revegetation success were identified (Table 9-3).

Table 9-3: Long-term stability of landforms and revegetation success

Event	Impact	Initial Risk Rating
Emissions of dust from exposed surfaces due to wind erosion, excavation and material handling and vehicle movements on haul roads	Reduction of success on revegetation	Medium
Emissions of radionuclides within dust emissions from exposed surfaces due to wind erosion, excavation and material handling and vehicle movements on haul road	Reduction of success on revegetation	Medium
Clearing land for haul roads, borrow pits, laydown areas, waste storage facility	Loss of soil in borrow pit area and in the capping areas which is no longer capable of supporting revegetation and/or require to clear more land	High
Increased concentration of contaminants when plants uptake metals and/or salts, due to roots extending into waste material on top of the WSF	No establishment of vegetation on the WSF	High
Failure of the WSF	Failure to meet rehabilitation success metrics and/or stabilise landforms	Extreme
Implementation of design is incomplete, due to external factors	Failure to meet rehabilitation success metrics and/or stabilise landforms. Need to go back to EIS and submit a different scope of work	High
Failure of the designed and implemented revegetation program	Failure to meet rehabilitation success metrics and/or to stabilise landforms	High

9.2.3. Introduced Contamination Risks

During the execution of Stage 3 works a range of equipment and supporting material will be brought onto the project area. This includes hazardous chemicals such as fuel, lime and additives to be used in the WTP. The storage and utilisation of this hazardous material introduces the potential for introduced contamination if not effectively handled.

As noted in the *EIS Risk Register* (GHD, 2019f – see Appendix) one significant potential impact related to introduced contamination was identified (Table 9-4).

Table 9-4: Introduced contamination risks

Event	Impact	Initial Risk Rating
Spills or loss of containment associated with storage of bulk hazardous materials	Contamination of soils, impact on flora and fauna and potential contamination of surface water	Medium

9.1.1 Residual Contamination Risks

The primary goal of the proposed works is to mitigate the pre-existing AMD contamination in the historic WRDs. Residual contamination could result from uncontrolled contaminated water flows or misplacement of excavated material. If waste rock is emplaced either un-neutralised or insufficiently neutralised it could also lead to further contamination of the project area. Further information on the management of residual contamination risks is detailed within Chapter 7 – Rehabilitation Strategy and Chapter 10 – Inland Water Environmental Quality.

As noted in the *EIS Risk Register* (GHD, 2019f – see Appendix) one significant potential impact related to residual contamination was identified (Table 9-5).

Table 9-5: Residual contamination risks

Event	Impact	Initial Risk Rating
Historic and introduced contamination of soils	Contamination of soils, impact on flora and fauna and potential contamination of surface water	Medium

9.3. Mitigation and Management

Through the application of planned controls, the residual risk for each identified impact has been reduced to either Low or Medium. A hierarchy of controls principle (see Chapter 15 – Human Health and Safety, Section 15.2.3) was used to focus on the most effective measures to reduce either the consequence or likelihood of events. Those controls are summarised below.

9.3.1. Erosion and Movement of Sediment

An Erosion and Sediment Control Plan (ESCP) will be developed to manage risks during Stage 3 works. At a minimum the ESCP will include:

- surface water and sediment collection sump for each work area.
- site-specific erosion and sediment control measures (*e.g.* rip-rap, conveyance channels, contouring).
- management inspections of operational areas.
- water monitoring including pH and turbidity.
- minimisation of areal extent of active work surface at WRDs and the WSF using cellular deconstruction or construction methodology, respectively.
- progressive stripping and rehabilitation.
- controlling slope gradients.

A Vegetation Clearing Procedure and an Air and Dust Management Plan will also be developed and implemented. Topsoil and revegetation substrate materials storage is to be avoided if possible to preserve soil structure. If storage is required, it will be carried out in a manner that minimises loss of nutrients, biological activity and structure.

To minimise erosion risks and to better blend WSF landforms into the surrounding environment, the batter gradients are designed at approximately 1 Vertical to 4 Horizontal (1:4, or 25%). Progressive capping and revegetation will improve surface water runoff quality from completed surfaces during the Construction phase.

After the implementation of the above planned controls, the residual risk of both identified potential impacts was considered to be Low.

9.3.2. Long-term Stability of Landforms and Revegetation Success

The WSF location has been selected to ensure that it is in an area that:

- is not prone to flooding in a 1:100 Average Recurrence Interval (ARI) event;
- has suitable foundation geotechnical stability;
- requires minimal clearing of established vegetation; and
- minimises handling of radiological soils by covering the major remnant ore stockpile *in situ*.

The WSF cover system is as *per* the Leading Practice Sustainable Development in Mining Series AMD Handbook (DIIS, 2016) and the design and construction methodology includes material placement and compaction. The integrity of the WSF has been improved by erosion minimisation through selection of appropriate capping materials, final landform geometry and revegetation systems. Competent supervision and independent QA/QC control will ensure the final landform conforms to geotechnical design specifications.

Modelling has been undertaken to assess the WSF cover system required from the perspective of minimising the oxygen/water ingress and mitigating erosion; while ensuring long-term stability, visual amenity and maximising the chance of revegetation success. The resulting design includes:

- 0.5 m low permeability barrier layer,
- 2.0 m store and release layer (growth material),
- internal capillary breaks/drainage layers.
- topsoil for inoculation of symbiotic soil microbes and nutrients,
- rock mulching to improve erosion protection,
- surface water drainage systems to safely convey plateau area catchment down to natural surface, and
- sufficient depth and drainage properties for root development (estimated as 2 m) for local species.

For new landforms, other than the WSF, are also to be designed by competent, experienced engineers. The design process will result in a set of construction ready drawings and technical specifications for each work area for the implementation team to deliver. The reconstructed EBFR path will require specialist input to develop the final design that allows for both the safe conveyance of surface water through site but also the restoration of aquatic fauna passage upstream. In order to reduce the landform stability risk through the EBFR channel, the reconstructed EBFR will have surface water flows progressively reintroduced through this system in order to allow for a period under lower flow conditions for vegetation establishment and landform stabilisation. The 5 year Post-construction monitoring and maintenance phase will see intensive monitoring of the newly established landforms in order to identify triggers that may require an action response.

Landform stability and revegetation success are intrinsically linked as vegetation performs the long-term role of stabilisation and reduces the risk of erosion in conjunction with the geotechnical properties of the built cover materials. The two most significant threatening processes for revegetation success are bushfire and weed invasion. Additionally, a lack of plant-available moisture, high radiant heat, poor soil nutrient and microbiological activity will act to the detriment of revegetation attempts. The Ecological Rehabilitation Strategy set out in Chapter 7 – Rehabilitation Strategy details the methodology that will be trialled and developed over the revegetation phase for each of the domains.

Following the implementation of planned controls, the six risks relevant to long-term stability of landforms and revegetation success have been reduced to an acceptable level and are classified with residual risks of Low or Medium.

9.3.3. Introduced Contamination Risks

Where possible, the storage of hazardous materials onsite will be reduced or eliminated. The potential option of utilising existing storage at the Browns Oxide Mine is being explored; however no agreement has been reached for the use of this site.

Where it is not possible to eliminate the use of hazardous materials, a Hazardous Materials Management Plan will be developed. This Plan will conform to the requirements of relevant Australian Standards with regards to covering, bunding, spill kits, appropriate training, sealed filling and storage areas, storing away from sensitive receptors, storing chemicals separately and ensuring appropriate emergency response procedures are in place. This is a key element which will be audited as a component of the HSE MS.

The final decommissioning and demolition of storage areas will require an assessment by the contaminated lands consultant to determine if any remediation actions are required at that time. Following the implementation of controls the residual risk rating is classified as Low.

9.3.4. Residual Contamination Risks

Significant investigations have been completed to determine the location and extent of contaminated materials, including contaminated soils, waste rock and tailings. These investigations have informed the design of the rehabilitation plan on which this EIS is built. Key outcomes of the characterisation work include the required liming application rate and dosing methodology for waste rock treatment, WRD deconstruction and contaminated soil removal methodology and spatial limits, material movement schedule to reduce Wet season hazards and the placement location and methodology for specific materials.

In addition to the significant volume of characterisation work, Stage 3 work area controls, design elements and scheduling considerations, further planned controls include the QA/QC requirements for geotechnical and geochemical construction technical specifications. This will be complemented by onsite supervision and independent QA/QC oversight.

Managing contaminated soils

In order to benchmark current soil conditions and to evaluate the suitability of proposed rehabilitation cover materials in terms of potential human health risks, GHD and DPIR developed a series of plausible end land-use scenarios and a range of assumptions to quantify human exposure rates to potential soil contaminants. Although only generalised future land uses can be defined until a potential change of land use is nearer, factors that have direct and varying implications on health risk assessment calculations (*e.g.* duration of occupation; incidental soil ingestion rates) were calibrated to incorporate higher levels of conservatism. By incorporating this conservatism, the requirement to define exact future land use modes is diminished, and any improved understanding of the forward land use patterns can be used to reduce these levels of precautionary conservatism.

The primary rehabilitation objective is to improve the EBFR water quality to within LDWQOs as described in Chapter 10 – Inland Water Environmental Quality. The second rehabilitation objective is to restore cultural values for the Rum Jungle site, which includes future land uses as described in the Land Use Plan (see Figure 6-8 or Figure 7-2).

The site Remediation Action Plan has been tailored to isolate soils known to have been impacted by mining activities that exceed modified health investigation levels (HIL), for both site maintenance activities (Stage 3 – modified HIL-D) and temporary occupation (Stage 4 and Stage 5 – modified HIL-C). Prior to Stage 3, an EPA Accredited Auditor (Contaminated Land), will assess the comprehensiveness of the Remediation Action Plan. These guideline values will not be applied to areas that have no history of mining impact as they are likely to carry natural mineralisation.

During the removal of contaminated soils from the radiological soils zone, the Copper Extraction Pad area and the sulphate impacted soil zone, appropriate surveying and supervision of excavations will be undertaken. Once the proposed horizontal limits and depth are reached for each zone, validation samples will be collected prior to the installation of the minimum cover thicknesses as described in Chapter 7 – Rehabilitation Strategy. Not all contaminated unsaturated zone soils from the existing WRD and Copper Extraction Pad footprints will be relocated to the WSF. The depth of excavation will be 2 m below the natural surface and then the footprints will be lime amended and backfilled with clean fill to above the natural surface. This will form a 2-3 m thick layer of clean fill that isolates human receptors from the potentially AMD-impacted soils at depth. This is described in detail in Chapter 7 – Rehabilitation Strategy.

Once remediation works are completed, a validation report will be produced by an appropriately qualified consultant. An Accredited Auditor (Contaminated Land) will be involved throughout the project delivery from the review of designs, EIS including rehabilitation strategy and Appendix technical reports. The Auditor will be involved in endorsement of the sampling and validation plan for the delivery of Stage 3 works. Once rehabilitation works are completed, an Accredited Auditor (Contaminated Land) will endorse the site for its intended future land use including the scope of works for future management activities or any potential land-use restrictions. Further information regarding soil conditions, including the extent and management of contaminated soils is detailed within Chapter 7 – Rehabilitation Strategy.

9.4. Monitoring and Reporting

Planned controls detailed in the EIS Risk Register will be incorporated into operational systems for Stage 3 works including Plans, Procedures and Technical Specifications.

9.4.1. Erosion and Sedimentation Processes

An ESCP will be operational during the execution of Stage 3. The Wet season monitoring requirements for this will include:

- visual inspections on active work areas including the sediment control ponds for each work area. Triggers will be established for maintenance on these ponds.
- water quality monitoring on all working area Sediment Control ponds to determine overflow pH and turbidity are within allowable criteria.
- water quality monitoring at established sites upstream and downstream of the Rum Jungle site and within the EBFR to ensure that Construction WQOs are met.
- management inspections of operational areas to ensure that ESCP specifications are being met.

Additional pre-Wet season preparation works will be included into the operational cycle including sediment trap maintenance, installation of erosion control features where required on operational areas and installation of clean water diversion berms where required to reduce surface water catchment reporting to open work area faces.

9.4.2. Long-term Stability and Revegetation Success

The landforms, especially the WSF, will be monitored for vegetation and erosion, including post-Wet season drainage repair, to identify the need for remedial action. To demonstrate that the landforms are stable and non-eroding (as *per* the rehabilitation success metrics), the following monitoring and reporting activities will be undertaken:

- during (or immediately following) completion of construction -
  - production of a WSF Construction Report demonstrating that was built in accordance with agreed design specifications (including QA/QC results as *per* its Quality Assurance and Control Plan)
  - documentation that the reinstated EBFR is built in accordance with agreed design specifications
- during the Stage 3 Post-construction Stabilisation and Monitoring phase a monitoring plan where landforms and vegetation systems are intensely monitored and repaired as required. The QA/QC Plan for this phase will contain triggers for geotechnical stability, erosive stability, vegetation performance and water quality.

Further information can be found in Chapter 7 – Rehabilitation Success.

9.4.3. Introduced and Residual Contaminated Sites

During excavation and transport of contaminated materials technical specialists will be present to provide supervision. Validation samples will be collected and analysed by an appropriately accredited laboratory, as *per* the approved Remediation Action Plan. Excavations will cease once *in situ* soil results meet rehabilitation success criteria or if the excavation reaches a total of 2 m depth as outlined in Chapter 7 – Rehabilitation Strategy. At the completion of works, a Soil Validation Report will be produced by an appropriately qualified and experienced contaminated land specialist with input from other technical disciplines as required. The Validation Report and remediation process will be subject to audit by an Accredited Auditor (contaminated sites).

Stage 3 monitoring will also include incident reporting and routine inspections to identify new contamination processes that may have occurred due to the presence and operation of the bulk fuel storage facility and WTP chemicals. Areas of introduced contamination will be treated as a contaminated site and fit within the planned contaminated sites remediation framework.

9.5. Statement of Residual Impact

One of the primary objectives of the project is to mitigate the pre-existing contamination of the site due to historic mining practices. The residual impact of the project is expected to improve the terrestrial environment on the site.

While there is a risk of adverse impact during the execution of Stage 3 works, the measures described in this chapter will ensure that, to the extent that is reasonably possible, potential impacts will be identified and managed effectively. With implementation of the planned controls the residual risk rating of the identified potential impacts have been reduced to either Medium (three risks) or Low (six risks).

The potential impact of weed invasion and uncontrolled bushfire will remain a long-term risk for the project as they are for surrounding properties at present.

9.6. Reference

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9.7. References included in Appendix

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10. Inland Water Environmental Quality

Figures

Tables

10.1. Introduction

This chapter details existing water quality impacts at the former Rum Jungle Mine site and the predicted improvements in groundwater and surface water quality during the Construction phase of rehabilitation and post-rehabilitation.

10.1.1. Chapter Organisation

This chapter is organised as follows:

- Section 10.1. Introduction.
- Section 10.2. Environmental Values and Water Quality Objectives.
- Section 10.3. Existing Water Quality Impacts.
- Section 10.4. Simulated Current Conditions.
- Section 10.5. Predicted Water Quality Improvements.
- Section 10.6. Potential Negative Impacts and Risks.

10.1.2. Chapter Objectives

The overall objective of this chapter is to detail aspects of the proposal that pertain to Inland Environmental Water Quality, *i.e.* local groundwater and the East Branch of the Finniss River (EBFR), and selected aspects of hydrological processes as *per* the EIS ToR provided by the NT EPA.

Specific chapter objectives are to:

- Summarise relevant environmental values that are proposed to be restored by achieving the Locally-Derived Water Quality Objectives (LDWQOs) for the EBFR post-rehabilitation and other rehabilitation measures.
- Summarise existing water quality impacts to illustrate the severity of the environmental issues onsite and identify current and historic sources of Acid and Metalliferous Drainage (AMD).

- Summarise numerical modelling results that enable contaminant pathways between AMD sources and the receiving environment to be discerned for current conditions.
- Summarise predictive modelling results that constrain the extent and the timing of future improvements in groundwater and surface water quality after rehabilitation works have been completed.
- Summarise the net benefits (positive impacts) of the Proposal with respect to local groundwater quality and water quality of the EBFR within the site and downstream.
- Discuss potential risks and potential negative impacts to groundwater and surface water quality and the following related topics:
    - Risk mitigation and management strategies.
    - Monitoring and reporting.
    - Residual (unmitigated) negative impacts.

10.1.3. Preferred Rehabilitation Strategy

Sulphide-bearing materials onsite are classified based on their potential to produce AMD. Non-Acid Forming (NAF) materials and three categories of Potentially Acid Forming (PAF) materials have been identified: PAF-I (the most AMD-generating type), PAF-II and PAF-III based on conventional Acid Base Accounting (ABA) (DIIS, 2016). Additional testing was needed to determine the existing acidity content of the sulphide-bearing materials, which is the contained acidity that has already been produced by oxidation that has occurred since these materials were placed in the 1950s and 1960s.

Existing acidity in waste rock is available to be released immediately upon contact of the rock with water and hence is of direct relevance to the handling of this material during the construction period and beyond. Robertson GeoConsultants (RGC) and David Jones Environmental Excellence (DJEE) (2019 – see Appendix) provides a comprehensive assessment of the physical and geochemical characteristics of waste rock in the WRDs and Dyson's (backfilled) Pit based on extensive field investigations conducted in 2014 and data compiled from previous geochemical investigations, including SRK (2012).

PAF-I materials in Main and Intermediate WRDs and Dyson's (backfilled) Pit are predicted to generate the most AMD due to their higher sulphide content and low Acid Neutralising Capacity (ANC). PAF-II and PAF-III materials are also predicted to generate substantial AMD and therefore also require containment to prevent sulphide oxidation or mitigate potential impacts downgradient. Further details on best practice approaches to AMD prevention and/or mitigation are provided in the Leading Practice Sustainable Development in Mining Series AMD Handbook (DIIS, 2016).

Rehabilitation of the former Rum Jungle Mine site will mainly involve:

- Preventing future AMD from the highest-sulphide PAF-I and PAF-II materials in the Intermediate WRD and shallow zones of Dyson's (backfilled) Pit and, where possible, a proportion of higher PAF material in the Main WRD, by submerging these materials in the saturated zone of Main Pit.
- Preventing future AMD from residual PAF-II and PAF-III materials in the Main and Dyson's WRDs by re-locating these materials to a new, purpose-built WSF northeast of Main Pit.
- Reducing the severity and extent of residual AMD-impacted groundwater that may discharge to the EBFR by installing and operating a Seepage Interception System (SIS) for 10 years (during the (combined) Construction and Post-construction Stabilisation and Monitoring phases, respectively).
- Improving groundwater quality in the former ore stockpile area and in the Copper Extraction Pad area by installing and operating a series of groundwater recovery bores.

Waste rock re-location to the Main Pit and WSF will be completed over approximately five years (see Chapter 2 - Proposal Description). Re-located PAF materials will be amended with lime to neutralise existing acidity and reduce the future mobility of metals in porewater (RGC and Jones, 2019). The SIS will be installed in Year 1 and will operate for at least five years following the completion of the WSF, *i.e.* Year 2 to 10, or until such time that the SIS is no longer required to achieve LDWQOs for the EBFR. The SIS will consist of groundwater recovery bores near the Main and Intermediate WRDs. Near-surface seepage will also be collected along the western toe of the Main WRD *via* the existing ditch and an interceptor trench could be installed near the Intermediate WRD. The key objective of operating the SIS is to achieve LDWQOs for the EBFR during the Construction phase of rehabilitation and reduce future (post-rehabilitation) loads to the EBFR from residual AMD-impacted groundwater when the SIS is no longer operating.

For the EIS it was assumed the SIS will operate until end of Year 10 when the SIS and the water treatment system would be decommissioned. However, the decision to cease pumping will not be made until at least five years of SIS performance monitoring data has been interpreted and reported upon in accordance with a Waste Discharge License

(WDL) that the Proponent will apply for and maintain during the Construction phase of rehabilitation. When the SIS is turned off, residual AMD-impacted groundwater may discharge to the EBFR. Groundwater impacted by saline drainage, *i.e.* high magnesium and sulphate concentrations but low metals, from backfill materials in the Main Pit and PAF materials contained in the WSF may also report to the EBFR. However, contaminant loads to the EBFR are predicted to be low enough at this time that LDWQOs for copper (Cu) and other metals will be achieved for most of the Wet season. Full details on the overall rehabilitation strategy are provided in Chapter 7 – Rehabilitation Strategy and referenced throughout this chapter, as necessary.

10.1.4. Supporting Documents

This chapter is directly supported by *Groundwater and Surface Water Modelling Report, Rum Jungle Stage 2A*, *RGC Report 183008/1, November 2019* (2019, see Appendix):

Other relevant reports and sections of the *Water Management Plan* (DPIR, 2019 – see Appendix) are referenced throughout the chapter as needed.

10.2. Environmental Values and Water Quality Objectives

10.2.1. Environmental Values

Hydrobiology (2016) identifies environmental values in the EBFR and Finniss River based on Wet season and Dry season sampling in 2014 and 2015 for terrestrial vertebrates, riparian vegetation, aquatic Tetrapods and aquatic biota. Aquatic biota, including macroinvertebrates, diatoms, mussels and fishes are identified as the environmental value that is most affected by elevated metal concentrations due to AMD flowing downstream from Rum Jungle. Other less-affected environmental values, *e.g.* irrigation water quality *etc.*, would therefore be adequately protected by achieving LDWQOs for the EBFR. Further details are provided in Hydrobiology (2016) and in Chapter 12 - Aquatic Ecosystems, and are not repeated here.

10.2.2. Locally-Derived Water Quality Objectives (LDWQOs)

Recommended LDWQOs for the EBFR and Finniss River from Hydrobiology (2016) are summarised in Table 10-1. Default trigger values from ANZG (2018) are provided for purposes of comparison. The locations of the river zones listed and the routine water quality monitoring points used to provide the data to support the LDWQOs are shown in Figure 10-1. LDWQOs are only applicable to the EBFR and are total concentrations intended to be achieved at any time of the year during the Construction phase of rehabilitation and post-rehabilitation.

Table 10-1: Recommended LDWQOs for EBFR and Finniss River from Hydrobiology (2016)

River Zone	Applicable Location	Colour Code (Figure 10-1)	EC µS/cm	SO_4 mg/L	Mg mg/L	Al µg/L	Cu µg/L	Co µg/L	Fe µg/L	Mn µg/L	Ni µg/L	Zn µg/L
Default ANZG trigger value - 80% protection level												
n/a	Any location if LDWQO not available	-	-	-	-	150	2.5	-	-	3,600	17	31
East Branch of the Finniss River												
1	Fitch Creek and EBFR upstream of mine site	-	190.7	594	33.2	117	3.4	2.8	300	140	20	26.1
2	EBFR at gauge GS8150200	Purple	2,985	1,192	86.6	236	60.2	89	300	795	130.4	210.5
3	EBFR at gauge GS8150327	Blue	2,985	997	86.6	150	27.5	25.9	300	443	43.1	180
3	EBFR at gauge GS8150097	Blue	2,985	997	86.6	150	27.5	25.9	300	443	43.1	180
4	EBFR near confluence with Finniss River	Light Green	427	761	33.2	117	7.9	3.6	300	228	32.5	180
Finniss River												
6	Finniss River at gauge GS8150204	Red	190.7	594	33.2	117	3.4	2.8	300	140	20	26.1
7	Finniss River	Dark Green	190.7	594	33.2	117	3.4	2.8	300	140	20	26.1

See Hydrobiology Pty. Ltd. (2016) for additional details on LDWQO development

Trigger values for EC, SO_4, Mg, Co, and Fe are not available from ANZG (2018)

LDWQOs for the EBFR were developed in accordance with the methodology outlined in ANZECC/ARMCANZ (2000) and are consistent with ANZG (2018). The LDWQOs for Zone 2 (within the mine site) represent a 70% aquatic ecosystem protection level. This "relaxed" protection level, *i.e.* < 80%, reflects the limited value of aquatic ecosystems within Zone 2 and is pragmatic according to Hydrobiology (2016) given severity of current water quality impacts due to AMD and the history of the site. Further details on these ecosystems and the rationale for the reduced protection level for Zone 2 is provided in Chapter 12 – Aquatic Ecosystems and references therein. LDWQOs for Zones 3 to 7, *e.g.* 27.5 µg/L Cu, represent approximately 80% protection levels for aquatic ecosystems (all taxa) (see Hydrobiology, 2015).

Concentrations of SO_4 and Mg in the EBFR from 2010 to 2018 rarely exceed the LDWQOs developed by Hydrobiology but concentrations of most metals exceed the LDWQO at certain times of the year (see Section 10.4.15). Predicted post-rehabilitation SO4 and Cu concentrations in the EBFR are compared to LDWQOs in Section 10.6.

10.2.3. Construction Phase Water Quality Objectives

The Proponent intends to achieve the LDWQOs in Table 10-1 during the Construction phase of rehabilitation. The LDWQOs will be adopted as trigger values in a WDL and any exceedances will be reported upon in accordance with the requirements of the WDL. Reporting will involve a notification to the NT EPA and all exceedances will be documented in an annual Monitoring Report. The LDWQOs are applicable to the EBFR (in any zone) and apply to river flows and/or treated water that is present in the EBFR channel during the Wet season or Dry season unless other trigger values are agreed to in the WDL.

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

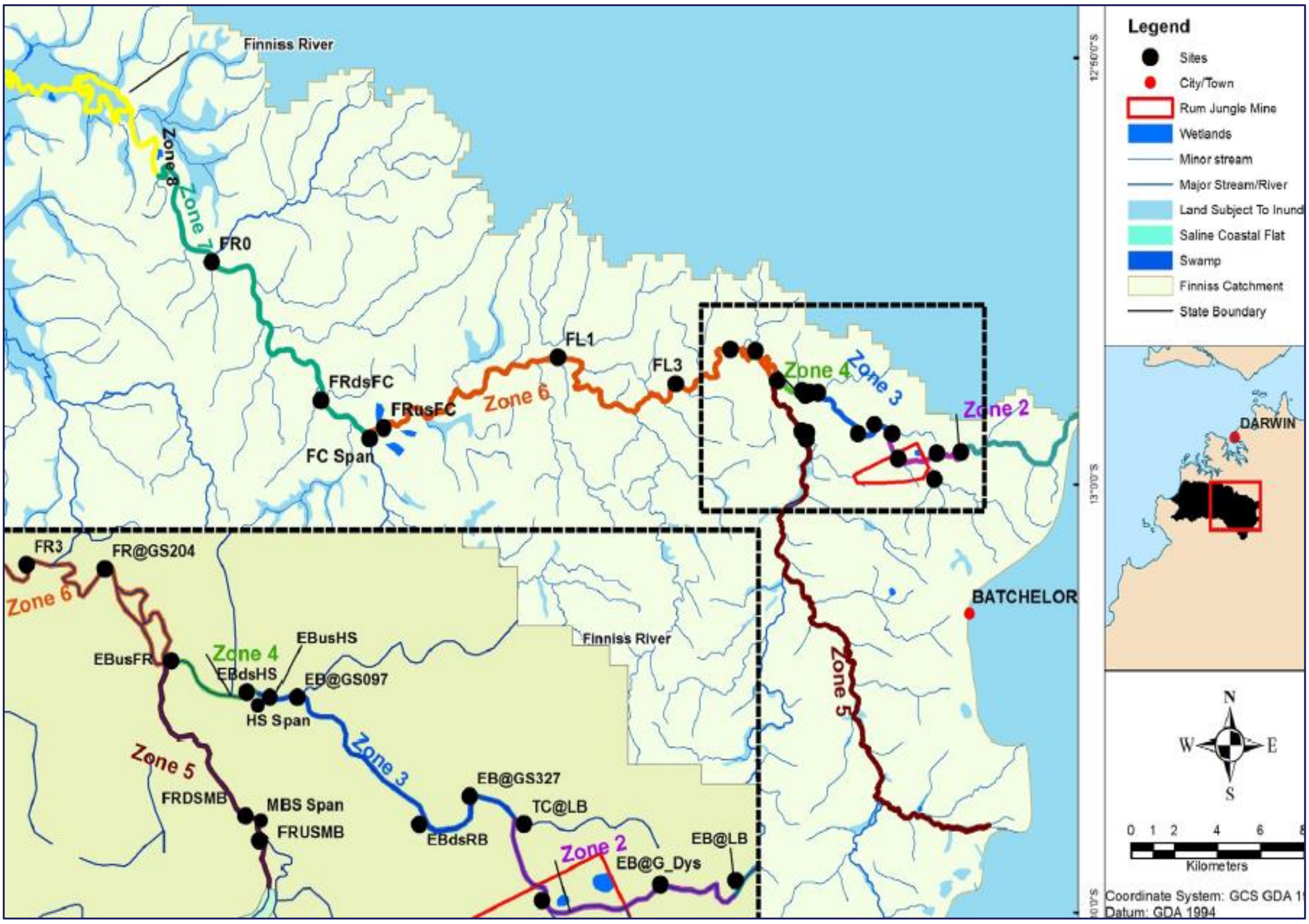


Figure 10-1: Surface water monitoring locations and river zones for the EBFR and Finniss River from Hydrobiology (2016)

10.3. Routine Water Monitoring

10.3.1. Streamflow Gauging Stations

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

Combined flows from Intermediate Pit and through the EFDC are measured at gauge GS8150200. Gauge GS8150200, and downstream gauges GS8150327 and GS8150097, are shown in Figure 10-2 with catchment areas for each gauge. Each of these gauges is operated by the NTG as part of regional monitoring. Other gauges have been operated by the NTG in the past to monitor flows in and out of the pits (GS8150212 and GS8150213) but these gauges are not currently operated. Further details on the streamflow gauges currently operated are summarised below:

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

Gauges GS8150200, GS8150327 and GS8150097 record water level heights (in metres, m) at an irregular time step, with the highest monitoring frequency occurring in flood conditions when the water level is changing rapidly. The measured water levels are converted to equivalent discharge rates using a rating curve defined for each gauge. Discharge is reported in cubic metres *per* second (m^3/s). Streamflow data for each gauge seem to be reasonably reliable and no major issues with data quality were identified by RGC while developing the site-wide water and load balance model (WLBM) (RGC, 2019, for further details).

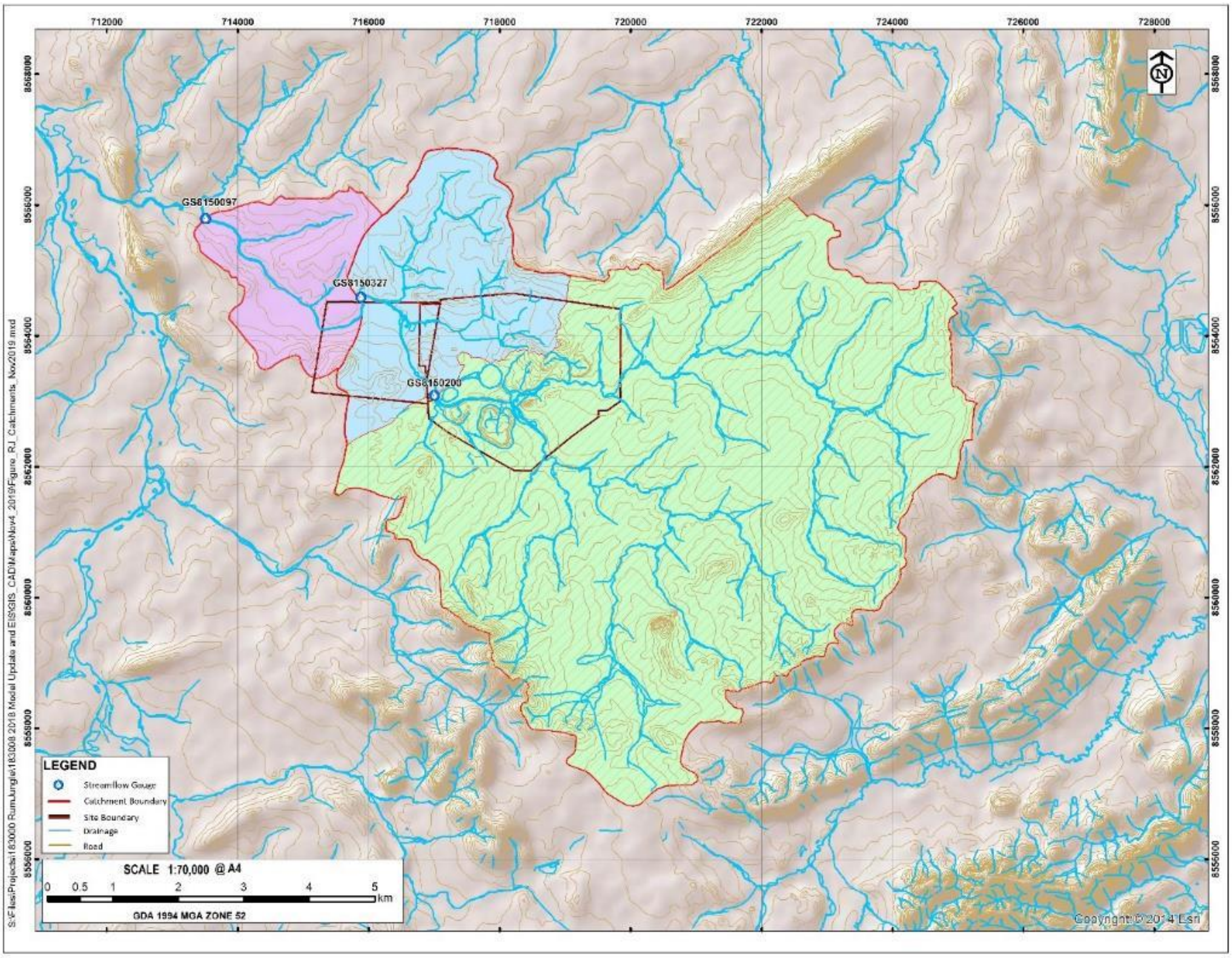


Figure 10-2: Streamflow gauge locations and catchment areas

10.3.2. Surface Water Quality Monitoring

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

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

10.3.3. Groundwater Monitoring Network

Groundwater monitoring bores are shown in Figure 10-3 with key site features and the mine site boundary. The groundwater monitoring network consists of a series of historic bores referred to by their Registration Number (RN) and the more recently installed MB10, MB12, MB14, MB17 and MB18 bore series. The MB prefix stands for

"Monitoring Bore" and the integer denotes the year the bore was installed. Most of the bores were installed with 80 mm PVC casing and machine-slotted PVC screens. An "S" denotes a shallower bore at a particular location and a "D" denotes the deeper bore, *e.g.* MB10-08S and MB10-08D. Most of the S and D bores were installed as paired installations, meaning the shallower bore was installed in a second, separate borehole nearby after the deeper bore was completed. Bores MB10-9S and MB10-9D are an exception as these bores were installed as a nested installation with 50 mm PVC casing in a single open borehole (RN022108) that was drilled in 1983. Several monitoring bores in the Copper Extraction Pad area were also installed in existing exploration holes (see RGC, 2016a).

Screened intervals and lithologies for monitoring bores are summarised in the tables below (Section 10.4) and additional details are provided in RGC (2019). Most of the RN bores were installed in the 1980s to support previous rehabilitation planning. Many of the RN bores are shallow (< 5 m deep) and therefore dry for part of the year when groundwater levels are below the bottom of the screen. The MB10 bores were installed in areas under-represented by the historic RN bores, either near the WRDs or downgradient to define the extent of groundwater quality impacts north of the central mining area towards the EBFR. The MB12 and MB18 bores were installed in the Copper Extraction Pad area to delineate the spatial extent and depth of groundwater quality impacts in this area. The MB14 (Old Tailings Dam area) and MB17 bores (near northern site boundary) were installed to characterise groundwater conditions near the WSF footprints proposed during previous project stages. Each of the MB bores was installed and developed under RGC supervision and further details are provided in RGC (2016) and references therein.

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

10.3.4. Groundwater Level Monitoring

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

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

10.3.5. Groundwater Quality Monitoring

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

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

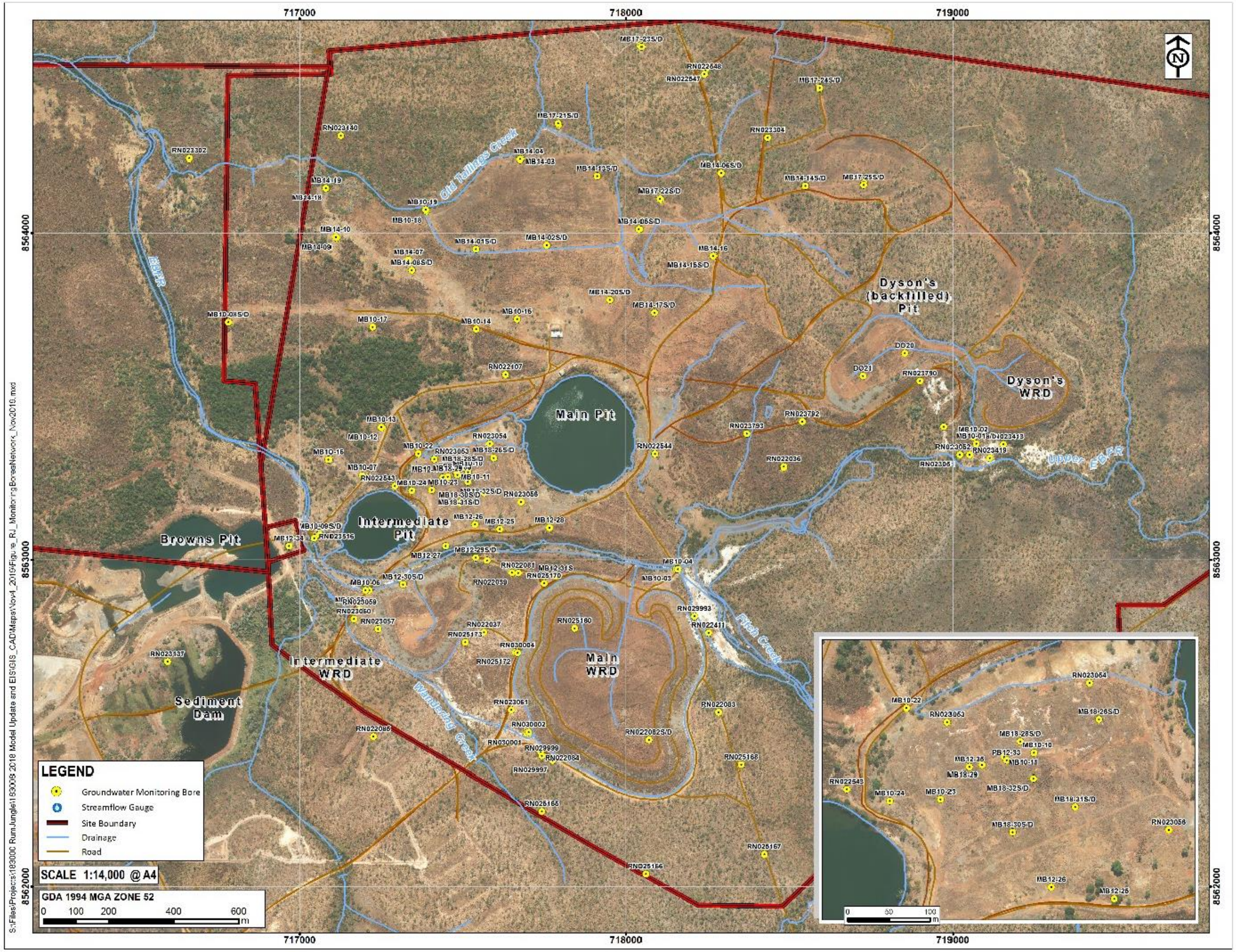


Figure 10-3: Groundwater monitoring network

10.3.6. Pit Water Monitoring

Pit water quality profiling was undertaken periodically since rehabilitation in the 1980s to characterise the degree of stratification and mixing in Main Pit and Intermediate Pit due to inflows from the EBFR (see Lawton and Overall, 2002a,b). Additional profiling was done in 2008 (see Tropical Water Solutions, 2008) and by EMU in 2014. Samples of pit water at surface and flowing from Intermediate Pit have also been routinely collected by the DPIR and/or EMU. Monitoring was suspended in 2018 and has not been undertaken since. Samples from the pits are also collected as part of routine monitoring undertaken by the operators of the adjacent Browns Oxide site for their WDL. Pit water levels in Main Pit and Intermediate Pit are monitored monthly or every two weeks by the DPIR as part of routine groundwater monitoring. Pit water levels in the Browns Oxide Pits are not routinely monitored but some data from 2008 to 2011 are available (see RGC, 2012a).

10.4. Existing Water Quality Impacts

10.4.1. Groundwater Quality Impacts

Observed SO_4 and Cu concentrations in groundwater (and inferred plumes) are shown in Figure 10-4. Further details on the derivation of these plumes is provided in RGC (2019). Groundwater quality impacts in key areas of the site are discussed below. Representative water quality results are discussed and additional water quality observations are provided in RGC (2016) and RGC (2019).

Background water quality

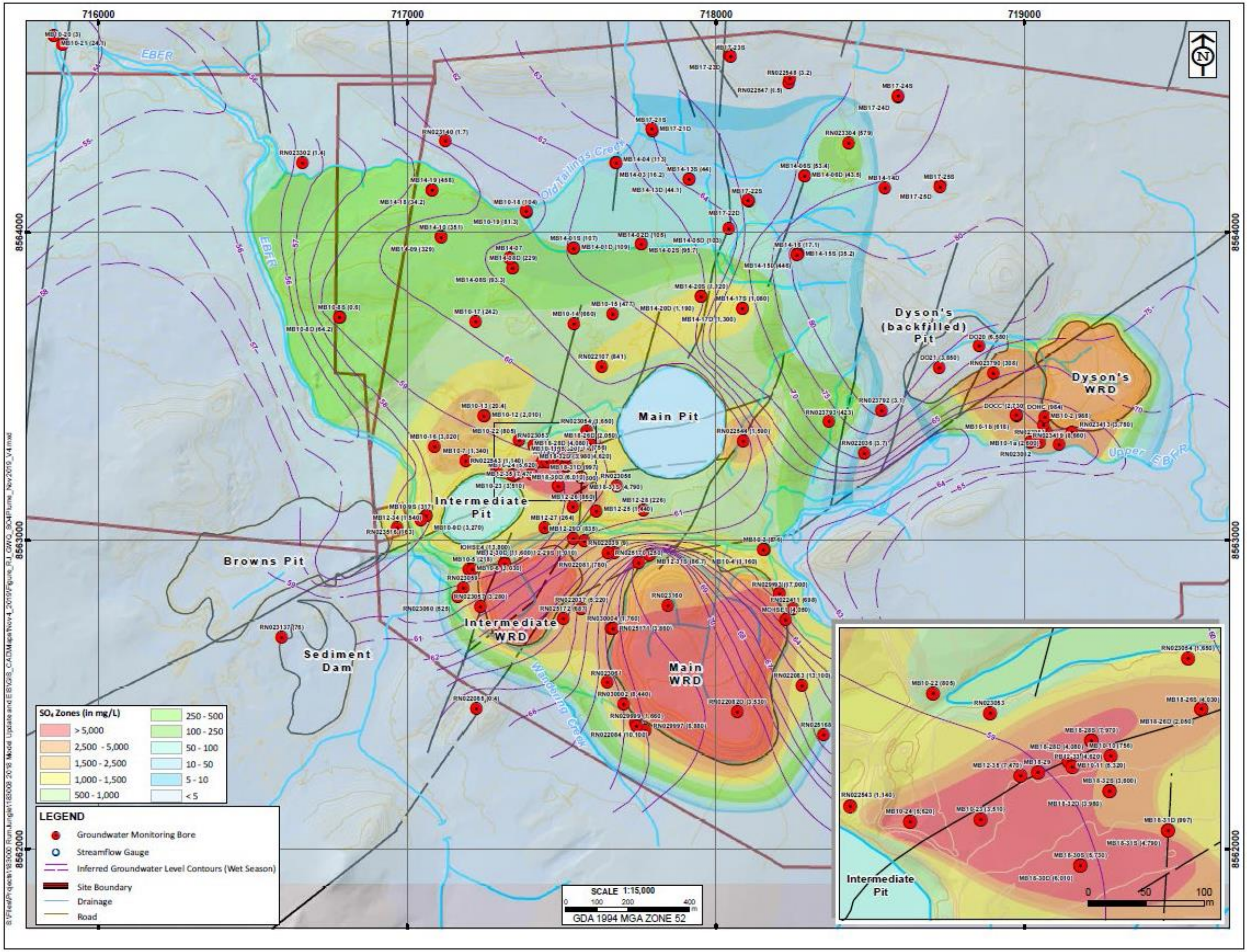
Groundwater not impacted by AMD within the former Rum Jungle Mine site is typically circum-neutral to slightly alkaline and characterised by alkalinity values up to 200 mg/L as $CaCO_3$, depending on the screened lithology. SO_4 concentrations in unimpacted groundwater typically range from 1 to 5 mg/L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

Groundwater quality in Dyson's Area

Dyson's Area is located upstream of the central mining area near the eastern site boundary. The upper EBFR is unimpacted before it flows through Dyson's Area towards the confluence between the upper EBFR and Fitch Creek about 1 km downstream near the Main WRD. The AMD sources in this area are Dyson's WRD and Dyson's (backfilled) Pit. Representative seepage and groundwater quality observations in Dyson's Area are provided in Table 10-2.

Groundwater quality impacts in Dyson's Area are summarised below:

- **Dyson's WRD**
    - Dyson's WRD contains PAF-II (15%), PAF-III (40%) and NAF (45%) waste rock removed from Dyson's Pit during mining (see RGC and Jones, 2019). Dyson's WRD is unlined and was constructed on or near the floodplain of the upper EBFR. The base of the dump is therefore often inundated by the creek during the Wet season and there are multiple seepage areas where AMD reports directly to the EBFR. The top of Dyson's WRD was covered during initial rehabilitation in the 1980s but the batters (side-slopes) of the dump were not covered (see Allen and Verhoeven, 1986). As a result, there is substantial infiltration of rainfall through the batter slopes.
    - Seepage from Dyson's WRD is acidic (pH < 5) and is characterised by elevated SO_4 and metal concentrations. However, metal concentrations in seepage from Dyson's WRD are much lower than in seepage from Dyson's (backfilled) Pit (and the other WRDs) due to the lower sulphide content of the PAF-III and NAF waste rock in this dump. This lower sulphide content is related to the mineralogy of the Dyson's ore body which was mined solely for uranium during the initial stages of mining operations.
    - Groundwater from bores RN023413 and RN023415 (screened in the EBFR channel) are impacted primarily by seepage from Dyson's WRD. Groundwater from these bores is characterised by elevated SO_4 and moderate metal concentrations, *e.g.* up to 2.6 mg/L Cu. Groundwater from other bores in this area, *e.g.* MB10-2, is typically characterised by elevated SO_4 concentrations but lower metal concentrations, depending in part on the proximity of the bore to Dyson's WRD.


716000
717000
718000
719000
8564000
8563000
8562000
EBFR
Old Tailings Creek
Dyson's (backfilled) Pit
Dyson's WRD
Upper EBFR
Main Pit
Intermediate Pit
Intermediate WRD
Browns Pit
Sediment Dam
Main WRD
Wandering Creek
SO4 Zones (in mg/L)
> 5,000
2,500 - 5,000
1,500 - 2,500
1,000 - 1,500
500 - 1,000
250 - 500
100 - 250
50 - 100
10 - 50
5 - 10
< 5
LEGEND
Groundwater Monitoring Bore
Streamflow Gauge
Inferred Groundwater Level Contours (Wet Season)
Site Boundary
Drainage
Road
SCALE 1:15,000
0 100 200 400 m
GDA 1994 MGA ZONE 52
Intermediate Pit
0 50 100 m

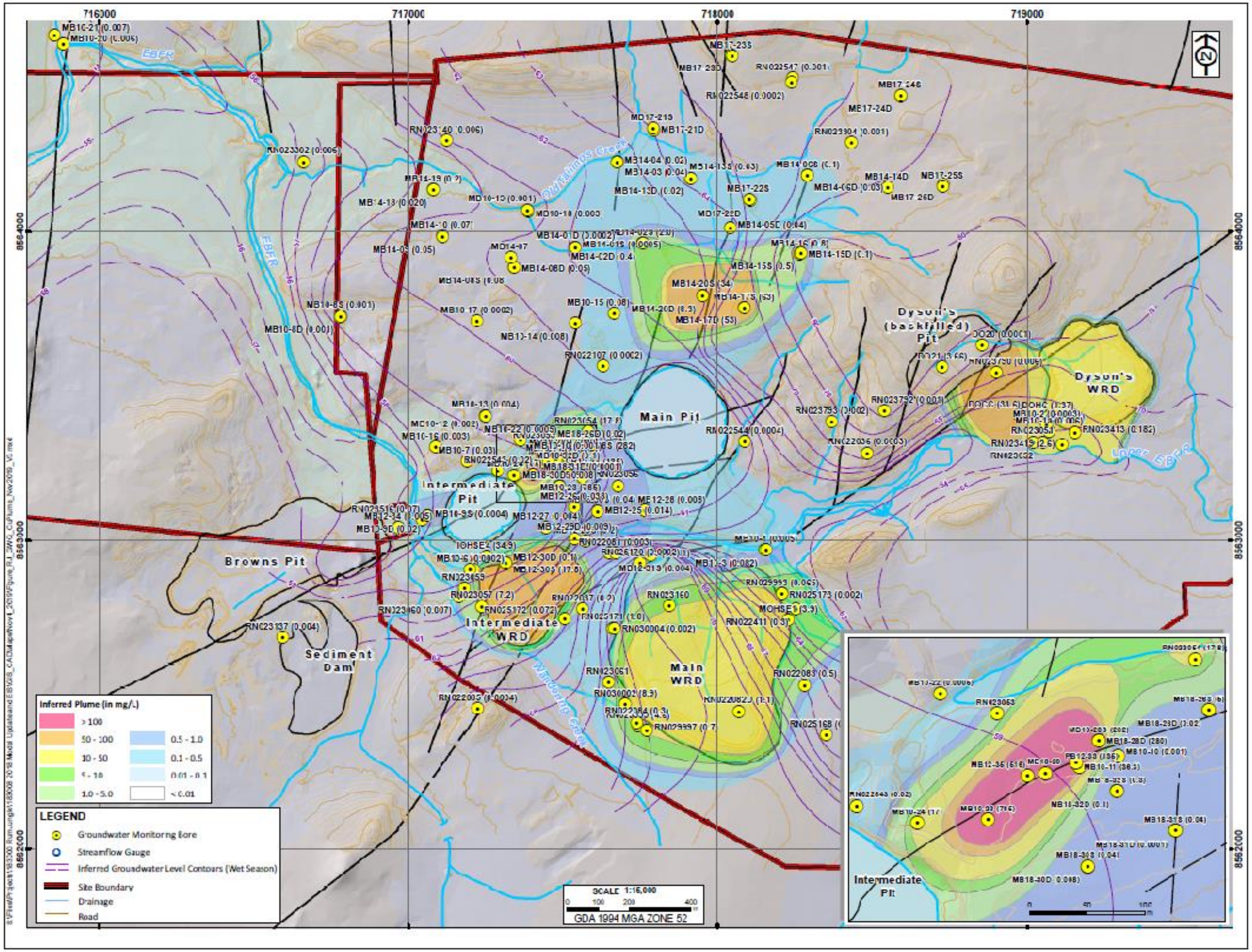


Figure 10-4: Observed Sulphate concentrations (upper) and Copper concentrations (lower) in groundwater with inferred plume (mg/L)

- **Dyson's (backfilled) Pit**
    - Dyson's Pit was mined to 47 m below ground surface (bgs) and partially backfilled with tailings during mining operations. These tailings were placed hydraulically (as a slurry) and have since consolidated. Dyson's Pit was further backfilled with well-consolidated historic tailings removed from the Old Tailings Dam area during initial rehabilitation in the 1980s. Tailings were hauled from the Old Tailings Dam area by truck and placed on the historic tailings. The shallow (above-grade) zone of Dyson's Pit was then backfilled in 1984 with leached, low-grade ore (from Intermediate Pit) and contaminated soils removed from the Copper Extraction Pad area. The backfilled pit was later covered to reduce rainfall infiltration, with a rock-lined drain along the centre-line conveying rainfall runoff to the upper EBFR (see Allen and Verhoeven, 1986).
    - Shallow backfill materials in Dyson's Pit are a mix of PAF-I (70%), PAF-II (20%) and PAF-III (30%) materials (see RGC and Jones, 2019). These materials are separated from deeper tailings by a drainage layer underlain by a geosynthetic layer. The drainage layer between the tailings and shallow backfill materials conveys seepage to a toe drain along the southern batter of the backfilled pit. This seepage is predominantly derived from drainage from shallow backfill materials in the pit that are recharged by rainfall infiltration through the cover.
    - Seepage from Dyson's Pit reports directly to the upper EBFR *via* a surface channel that originates from the toe drain and/or to groundwater that ultimately discharges to the EBFR. Seepage is characterised by elevated concentrations of SO_4 and most metals, including Cu, Co and Mn. Metal concentrations in seepage are comparable to seepage from the Intermediate WRD, as the backfill materials are predominantly low-grade ore removed from the Intermediate ore body for heap leaching (see Davy, 1975). Groundwater from bore MB10-1b is impacted by seepage from Dyson's (backfilled) Pit. This bore is screened in the drainage channel that conveys seepage from shallow backfill materials to the upper EBFR. Groundwater is often acidic and characterised by elevated SO_4 and metals, particularly in the Wet season when seepage expresses from the nearby toe drain.
    - Tailings in deeper portions of Dyson's Pit are not considered a significant source of AMD because they are submerged year-round and therefore not oxidizing (see RGC, 2016). Most of the AMD generated by PAF materials in Dyson's WRD and Dyson's (backfilled) Pit reports directly to the EBFR or to groundwater that ultimately discharges to the EBFR within Dyson's Area. Impacted groundwater, for instance, does not appear to be transported westward beyond Dyson's Area due to local topography and/or the low permeability of bedrock, *e.g.* Rum Jungle Complex and Geolsec Formation to the west.

Table 10-2: Representative groundwater quality and seepage water quality observations for Dyson's Area and near the Main WRD

			Dry Season						*Wet Season*					
Bore ID	**Screened Lithology**	**Screened Interval, m bgs**	**Sampling Date**	**Field pH**	**SO_4, mg/L**	**Cu, mg/L**	**Fe, mg/L**	**Zn, mg/L**	**Sampling Date**	**Field pH**	**SO_4, mg/L**	**Cu, mg/L**	**Fe, mg/L**	**Zn, mg/L**
Dyson's WRD														
Toe seepage	n/a	n/a	Dec-11	4.4	332	4.0	0.9	0.1	Apr-12	4.3	984	1.4	0.6	0.2
Dyson's (backfilled) Open Pit														
Toe seepage	n/a	n/a	Dec-11	3.8	2,990	29.0	0.1	0.9	Apr-12	4.0	2,730	31.6	0.1	1.0
Near Dyson's WRD														
MB10-1a	Saprolite	1.4 to 3.4	-	-	-	-	-	-	Feb-12	6.3	2,600	0.006	7.4	0.1
MB10-2	Rum Jungle Complex	12.7 to 18.7	Sep-12	6.9	815	0.0018	1.1	0.004	Feb-12	6.9	988	0.0003	1.4	0.010
RN023413	Laterite	1.3 to 1.8	Oct-11	3.5	2,730	0.7	133.0	0.2	Apr-09	-	3,780	0.2	126.0	0.3
RN023419	Alluvium	1.2 to 1.7	-	-	-	-	-	-	Apr-09	-	8,660	2.6	29.6	0.8
Near or within Dyson's (backfilled) Pit														
DO20	Tailings	16.0 to 19.0	-	-	-	-	-	-	Sep-11	5.2	6,580	0.0001	435.0	0.1
DO21	Shallow backfill and tailings	14.7 to 17.7	-	-	-	-	-	-	Sep-11	4.7	3,850	3.7	145.0	1.6
MB10-1b	Alluvium	2.2 to 3.7	Nov-10	3.5	2,720	31.7	0.400	1.000	Mar-12	4.5	618	1.7	0.048	0.047
RN023790	Geolsec Formation	10.0 to 16.0	Sep-12	7.1	264	0.025	0.0	0.002	Apr-11	7.1	308	0.006	0.2	0.017
West of Dyson's Area (towards the Main Pit)														
RN022036	Geolsec Formation	7.0 to 12.0	Sep-12	6.5	3	0.0094	0.006	0.003	Feb-12	6.4	4	0.0003	0.002	0.002
RN023792	Geolsec Formation	20.0 to 26.0	Sep-12	7.3	3	0.003	0.034	0.000	Feb-12	7.2	3	0.001	0.006	0.002
RN023793	Whites Formation	13.2 to 19.2	Sep-12	5.8	424	0.022	0.6	0.005	Apr-11	5.9	423	0.002	0.2	0.003

Note: Values in red are lower than the indicated reporting limit

Groundwater quality near the Main WRD

The Main WRD is the largest of the historic dumps in terms of footprint area and volume. It is unlined and contains a mixture of PAF-I (15%), PAF-II (35%), PAF-III (25%) and NAF (25%) waste rock removed during mining the Main ore body together with a small volume of PAF waste rock re-located from the Main North WRD during rehabilitation in the 1980s (see RGC and Jones, 2019). The Main WRD was re-graded and covered at that time to prevent AMD by reducing rainfall infiltration and oxygen ingress.

The cover was considered effective, at least initially, although its performance was found to have deteriorated in the 1990s (Taylor *et al.*, 2003). A contemporary assessment of cover performance assessment has not been done. Annual metal loads do not appear to be increasing over time though so the existing cover system is still having a beneficial effect.

Representative seepage and groundwater quality observations near the Main WRD are provided in Table 10-3. Key observations are summarised below:

- Seepage from the Main WRD reports to groundwater and to a collection ditch along the western toe of the dump near the main access road to the site. Seepage samples from the ditch are acidic (pH 3 to 4) and characterised by highly-elevated concentrations of SO_4 and most metals. This seepage occurs in the Wet season and often persists during the early Dry season and is likely comprised of toe seepage and AMD-impacted groundwater that upwells to the ditch. Seepage from this ditch reports to Fitch Creek near the head of the EFDC (near bores MB10-3 and MB10-4).
- Groundwater near the Main WRD can be characterised by 10,000 to 15,000 mg/L SO_4 and up to 20 mg/L Cu. Concentrations in groundwater can exceed concentrations observed in toe seepage (AMD) from the collection ditch near the eastern toe, implying residual impacts due to more concentrated AMD that formed in the past (before 1980s rehabilitation) or the occurrence of AMD that is more concentrated than the AMD that reports to the ditch (see RGC, 2016). Groundwater from most bores is, however, characterised by much lower Cu concentrations than observed at bores RN022083 and RN022084, implying attenuation in the aquifer and that Cu is not transported far beyond the perimeter of the Main WRD.
- Groundwater impacted by AMD from the Main WRD reports to the EBFR *via* Fitch Creek or the EFDC and may also be transported northward beneath the EFDC *via* deeper flowpaths in the bedrock aquifer. This suggests a portion of the AMD generated by the Main WRD could report to groundwater downgradient near the Intermediate WRD and possibly the EBFR downstream of GS8150200 should it upwell. However, Cu concentrations in groundwater migrating northeast from the Main WRD, *e.g.* near bores RN022081 and MB12-31S, are relatively low, suggesting groundwater-borne Cu loads are relatively low in this direction.

Table 10-3: Representative groundwater quality and seepage water quality results, Main WRD Area

Bore ID	Screened Lithology	Screened Interval, m bgs	*Dry Season*						*Wet Season*					
			Sampling Date	Field pH	SO_4, mg/L	Cu, mg/L	Fe, mg/L	Zn, mg/L	Sampling Date	Field pH	SO_4, mg/L	Cu, mg/L	Fe, mg/L	Zn, mg/L
Main WRD														
Toe seepage	n/a	n/a	Aug-10	3.7	5,190	4.4	4.8	7.1	May-12	3.3	4,050	3.9	3.5	6.5
Main WRD (East)														
RN022082D	Rum Jungle Complex	37.0 to 52.0*	Oct-12	4.4	6,100	1.8	9.5	6.2	Feb-12	4.3	3,530	1.1	5.9	5.5
RN022083	Rum Jungle Complex	10.0 to 16.0	Oct-14	6.0	9,190	0.0	0.0	0.01	Feb-14	6.1	13,100	0.5	0.0	0.02
RN022411	Alluvium	0.3 to 1.5	-	-	-	-	-	-	Feb-11	4.2	698	0.3	3.6	1.0
RN022417	Rum Jungle Complex (wtr)	0.4 to 2.5	-	-	-	-	-	-	Apr-09	-	3,230	20.1	1.8	6.7
RN025168	Rum Jungle Complex (wtr)	6.5 to 9.5	-	-	-	-	-	-	Apr-09	6.1	2	0.004	0.2	0.01
RN029993	Clay	1.0 to 7.2	Sep-12	6.0	16,300	0.0	2.2	0.14	Feb-12	6.0	17,000	0.1	0.1	0.05
Main WRD (Southwest)														
RN022084	Rum Jungle Complex	10 to 16	Oct-14	5.0	8,680	9.5	2.7	12.9	Feb-14	6.3	10,100	0.3	1.8	0.2
RN025165	Rum Jungle Complex	5.2 to 8.2	Oct-10	6.2	98	0.01	3.8	0.1	-	-	-	-	-	-
RN029997	Quartz gravels	1.0 to 3.3	Oct-10	5.2	8,880	0.7	0.4	1.0	-	-	-	-	-	-
RN029999	Quartz gravels	1.0 to 7.8	Oct-10	3.8	1,660	4.6	-	2.8	-	-	-	-	-	-
RN030002	Rum Jungle Complex	1.0 to 8.4	Oct-10	3.8	8,440	8.9	6.2	15.7	-	-	-	-	-	-
RN030004	Sandstone	1.5 to 2.9	Aug-10	7.2	1,760	0.002	0.2	0.0	-	-	-	-	-	-
Main WRD (Northwest)														
RN025170	Whites Formation	5.9 to 8.9	Oct-10	7.2	326	0.0043	0.40	0.035	Feb-12	6.9	250	0.0002	0.02	0.001
MB12-31S	Laterite	1.7 to 7.7	Oct-14	7.2	122	0.073	0.02	0.007	Apr-15	7.2	87	0.004	0.01	0.005
RN022081	Coomalie Dolostone	40.7 to 43.9	Sep-10	7.0	787	0.000	0.4	0.005	Feb-14	7.3	780	0.003	0.1	0.002
RN022039	Coomalie Dolostone	12.0 to 18.0	Sep-10	5.1	4	0.00	0.2	0.03	Feb-14	5.7	9	0.01	0.1	0.02
Main WRD (West)														
RN022037	Rum Jungle Complex (wtr)	16.0 to 22.0	Aug-10	6.2	5,680	0.2	0.2	0.2	Feb-12	6.1	5,220	0.2	1.2	0.2
RN025172	Rum Jungle Complex	1.7 to 4.7	Sep-12	5.6	3,110	0.0	0.4	0.2	Feb-14	5.6	687	0.1	0.1	0.1
Main WRD (North)														
RN025169	Laterite	2.8 to 5.8	-	-	-	-	-	-	Feb-14	6.4	91	0.1	0.004	0.01
RN025171	Laterite	2.8 to 5.8	-	-	-	-	-	-	Feb-13	5.7	3,860	1.8	1.0	0.6
MB10-3	Saprolite	2.0 to 3.5	Dec-10	3.8	1,160	3.6	0.6	1.4	Mar-15	5.6	874	0.1	9.8	0.8
MB10-4	Rum Jungle Complex	9.3 to 15.3	Dec-10	6.8	1,090	0.002	0.2	0.01	Mar-15	6.5	1,160	0.005	0.4	0.01

* Below the top of the Main WRD

Note: Values in red are lower than the indicated reporting limit

Groundwater quality near the Intermediate WRD

The Intermediate WRD is much smaller than the Main WRD and contains only PAF-I and PAF-II (the most AMD-generating PAF types) material according to RGC and Jones (2019). Metal concentrations in seepage from the Intermediate WRD, including Cu, Co, Fe, Mn, Ni, and Zn are typically (much) higher than in seepage from the Main WRD and Dyson's WRD, most likely due to consistently higher sulphide content and the polymetallic nature of waste rock in the Intermediate WRD compared with the other WRDs.

The Intermediate WRD is unlined and most of it was re-graded and covered during initial rehabilitation in 1985 to reduce rainfall infiltration and oxygen ingress. However, the northern toe of the dump was not re-graded or covered due to insufficient funds (see Allen and Verhoeven, 1986). The ungraded toe of the dump terminates at the EFDC and appears to convey a substantial volume of toe seepage directly to the EFDC. This is evidenced by a pool of seepage in the EFDC that is sustained in the Dry season by toe seepage and/or groundwater discharge. This seepage is often routinely sampled to characterise water quality. Since the seepage face is submerged during the Wet season seepage samples cannot be collected during this period of the year.

Seepage (AMD) from the Intermediate WRD is particularly detrimental to EBFR water quality due to its proximity to the EFDC and the propensity for seepage to occur throughout the Dry season and accumulate in the EFDC, thereby contributing to a "first flush" event each year. However, most of the AMD generated by the Intermediate WRD likely reports to groundwater beneath the dump *via* basal seepage and may migrate towards Intermediate Pit *via* deeper flowpaths beneath the EFDC.

Representative seepage and groundwater quality observations near the Intermediate WRD are provided in Table 10-4. Most of the groundwater near the Intermediate WRD is characterised by elevated SO_4 but low concentrations of most metals, including Cu. Bores MB12-30S and MB12-30D are exceptions, as these bores are screened at the toe of the Intermediate WRD near the edge of the EFDC. Low concentrations of Cu and other metals suggest attenuation of metals in groundwater or that the most impacted groundwater in this area has not been identified.

Of interest are potentially high concentrations in deeper groundwater beneath the Intermediate WRD that may migrate northward beneath the EFDC towards Intermediate Pit based on the prevailing hydraulic gradients in this area. Further drilling in this area is needed to determine whether impacted groundwater exists at depth and whether it is being transported northward. This is a critical area of the site as the extent of residual AMD-impacted groundwater near the EFDC is a key factor in determining post-rehabilitation Cu loads in the EBFR (see Section 10.5). Additional monitoring bores and recovery bores (for pump testing) are warranted (see RGC, 2019).

Table 10-4: Representative groundwater and seepage water quality results, Intermediate WRD

Bore ID	Screened Lithology	Screened Interval, m bgs	*Dry Season* Sampling Date	Field pH	SO_4, mg/L	Cu, mg/L	Fe, mg/L	Zn, mg/L	*Wet Season* Sampling Date	Field pH	SO_4, mg/L	Cu, mg/L	Fe, mg/L	Zn, mg/L
Unimpacted groundwater														
RN022085	Coomalie Dolostone	1.5 to 7.5	Nov-09	7.1	0.6	0.0010	0.02	0.0025	Jan-09	7.2	0.4	0.0004	0.02	0.0005
Intermediate WRD														
Toe seepage	n/a	-	Aug-10	3.3	13,800	34.9	349	156	Apr-15	4.4	3,840	17.8	145.0	29.1
Intermediate WRD (North)														
MB10-5	Laterite/fill	2.0 to 5.0	Nov-10	6.6	463	0.019	0.200	0.800	Apr-15	6.9	218	0.001	0.004	0.005
MB10-6	Whites Formation	13.5 to 25.5	Nov-10	7.2	931	0.0027	0.200	0.000	Apr-15	7.2	1,030	0.0002	0.012	0.002
MB12-25	Whites Formation	12.9 to 18.9	Oct-14	6.6	1,570	0.057	**0.06**	0.007	Feb-14	6.5	1,440	0.014	**0.01**	0.042
MB12-29S	Laterite	7.0 to 10.0	Nov-12	6.7	1,010	0.200	**0.10**	0.060	-	-	-	-	-	-
MB12-29D	Coomalie Dolostone	14.9 to 17.9	Nov-12	7.3	835	0.009	0.020	0.008	-	-	-	-	-	-
MB12-30D	Whites Formation	12.3 to 18.3	-	-	-	-	-	-	Apr-15	6.2	11,600	0.1	5.6	1.1
MB12-30S	Whites Formation/waste rock	1.5 to 7.5	-	-	-	-	-	-	Apr-15	4.4	3,840	17.8	145.0	29.1
RN023057	Whites Formation (wtr)	1.8 to 2.6	-	-	-	-	-	-	Apr-09	-	3,280	7.2	40.8	4.6
RN023060	Whites Formation (wtr)	4.2 to 5.1	Aug-11	6.5	596	0.008	0.126	0.007	Feb-12	6.5	525	0.007	0.032	0.008
Intermediate WRD (Southeast)														
RN025173	Rum Jungle Complex	5.1 to 8.1	Aug-10	6.1	3,800	0.040	0.200	0.045	Feb-12	6.1	3,790	0.002	0.020	0.005
RN022037	Rum Jungle Complex	16.0 to 22.0	Aug-10	6.2	5,680	0.2	0.2	0.2	Feb-12	6.1	5,220	0.2	1.2	0.2

Note: Values in red are lower than the indicated reporting limit

Groundwater quality in the Copper Extraction Pad area

An experimental heap leaching operation was conducted in the Copper Extraction Pad area from 1965 to 1971. The heap leaching process initially involved piling low-grade (< 2% Cu content) sulphide ore from the Intermediate ore body onto a low-permeable pad and then spraying the top of the pile with an acidic (pH 2) mixture of mill process water, barren liquor and pit water from Main Pit. Liquor drained from the sulphide pile (nominally pH 1.5) was then pumped onto a pile of oxide ore to leach additional copper before the pregnant liquor was pumped to launders for copper recovery by cementation (see Davy, 1975, for further details).

Substantial losses of metalliferous liquor containing an estimated 1000 mg/L Cu occurred during the operation, primarily from an unlined storage ditch adjacent to the heap leach pad (see Davy, 1975). Overflow from the ditch and excess barren liquors (pH < 2) were also discharged to Copper Creek, which flowed northwest to the EBFR. In 2010, near-undiluted liquor was identified during a hydrogeological field investigation in this area (see RGC, 2011). Cu concentrations of up to 1000 mg/L Cu are observed in several monitoring bores in this area, *i.e.* MB10-23 and MB12-35 (see Table 10-5).

The liquor in the Copper Extraction Pad area appears to be restricted to a narrow zone of the bedrock aquifer that may correspond to a fault that is oriented east-to-west across the area between Main Pit and Intermediate Pit. Cu concentrations in some areas have not been substantially diluted since liquor was lost in the 1960s, implying that impacted water may reside in a system of cavities that may not be interconnected and could be isolated from groundwater in the surrounding bedrock aquifer. This suggests the liquor does not report to Intermediate Pit or to the EBFR and is therefore a localised groundwater quality issue. However, some load from this area (however small) cannot be completely discounted with the information available. Several recovery bores screened in bedrock near the fault zone are planned to improve groundwater quality in this area (see Section 10.4.2).

It had originally been inferred from a limited number of bores (RGC, 2016) that the copper plume extended to fully cover the projected footprint of the former Copper Extraction Pad. However, recent groundwater quality sampling, within the southern side of the pad area, from bores MB18-30S/D, MB18-31S/D and MB18-32S/D show elevated sulphate concentrations (range from 1000 to 6000 mg/L) but low copper concentrations in the range of 0.0001 to 0.3 mg/L. The northern side of the pad area show elevated concentrations for both sulphate and copper (particularly at MB18-28S, MB18-29, MB10-11, MB12-35 and MB12-33) with ranges from 750 to 8500 mg/L SO_4 and 53 to 560 mg/L Cu, respectively. Therefore, it has been concluded that the high copper plume is limited to the northern side of the pad area with an approximate length of 325 m and width of 120 m, while the SO_4 plume is inferred to cover the full extent of the Copper Extraction Pad area. Figure 10-5 shows the refined extent of the copper plume in this area (see RGC, 2019, for further details and explanation).

Table 10-5: Representative groundwater and seepage water quality results, Central Mining Area

Bore ID	Screened Lithology	Screened Interval, m bgs	*Dry Season* Sampling Date	Field pH	SO_4, mg/L	Cu, mg/L	Fe, mg/L	Zn, mg/L	*Wet Season* Sampling Date	Field pH	SO_4, mg/L	Cu, mg/L	Fe, mg/L	Zn, mg/L
Bores neart the Main Pit														
RN022544	Whites Formation	35.2 to 44.5	Sep-10	7.5	3,880	0.0008	2.0	0.010	Mar-11	6.5	1,590	0.0004	1.8	0.006
RN022107	Coomalie Dolostone	12.8 to 14.8	Aug-10	6.2	1,300	0.0005	3.800	0.4480	Mar-15	8.5	841	0.0002	0.010	0.0004
Bores near the former Copper Extraction Pad														
MB10-10	Whites Formation	16.0 to 32.0	Dec-10	6.7	71	0.001	2.0	0.013	Feb-14	6.7	756	0.001	1.8	0.015
MB10-11	Whites F. (sand-filled cavity)	31.5 to 34.5	Dec-10	5.0	5,600	137.0	36.3	9.2	Feb-14	5.5	5,320	36.3	3.4	5.4
MB10-22	Coomalie Dolostone	12.6 to 24.6	Dec-10	7.7	944	0.0014	0.4	0.005	Apr-15	7.8	805	0.0005	0.2	0.002
MB10-23	Coomalie Dolostone	13.0 to 25.0	Dec-10	3.5	5,190	506	13.0	10.5	Apr-15	4.0	3,510	785	36.5	12.0
MB10-24	Coomalie Dolostone	4.0 to 16.0	Oct-14	3.5	1,050	52.6	0.6	1.4	Apr-15	3.6	5,620	17.3	0.3	0.4
MB12-35	Coomalie Dolostone	22.1 to 34.1	Oct-14	4.4	8,500	511	79.1	11.6	Feb-14	4.2	7,470	516	92.2	11.1
MB18-26D	Whites Formation	42.0 to 60.0	-	-	-	-	-	-	Jan-19	6.3	2,050	0.019	12.2	0.2
MB18-26S	Whites Formation	12.0 to 18.0	-	-	-	-	-	-	Jan-19	5.1	4,030	5.4	72.1	3.0
MB18-28D	Whites Formation	42.0 to 60.0	-	-	-	-	-	-	Jan-19	4.2	4,080	280	0.3	8.8
MB18-28S	Whites Formation	12.0 to 24.0	-	-	-	-	-	-	Jan-19	4.9	7,970	282	101	12.7
MB18-30D	Whites Formation	42.0 to 60.0	-	-	-	-	-	-	Jan-19	6.2	6,010	0.008	24.4	0.1
MB18-30S	Whites Formation	13.7 to 19.7	-	-	-	-	-	-	Jan-19	5.9	5,730	0.040	116	0.7
MB18-31D	Whites Formation	42.0 to 60.0	-	-	-	-	-	-	Jan-19	6.5	997	0.0001	8.9	0.007
MB18-31S	Whites Formation	18.0 to 24.0	-	-	-	-	-	-	Jan-19	6.1	4,790	0.044	18.9	0.1
MB18-32D	Whites Formation	42.0 to 60.0	-	-	-	-	-	-	Jan-19	5.9	3,980	0.1	87.2	0.8
MB18-32S	Whites Formation	12.0 to 24.0	-	-	-	-	-	-	Jan-19	5.6	3,600	0.3	60.0	1.1
PB12-33	Whites Formation	14.1 to 32.1	Nov-12	4.7	5,480	225.0	6.9	8.9	Feb-14	5.3	4,620	135.0	2.8	7.7
Bores near the Intermediate Pit (or immediately north)														
MB10-12	Coomalie Dolostone	12.6 to 24.6	Dec-10	7.2	2,520	0.001	0.200	0.001	Mar-15	7.2	2,010	0.002	0.014	0.009
MB10-13	Coomalie Dolostone	48.8 to 60.8	Dec-10	8.1	35	0.000	0.200	0.000	Mar-15	7.8	20	0.004	0.004	0.004
MB10-16	Coomalie Dolostone	13.5 to 22.5	Aug-11	6.9	3,070	0.000	1.1	0.003	Feb-14	7.1	3,020	0.003	2.4	0.017
MB10-7	Coomalie Dolostone	9.0 to 18.0	Aug-11	7.3	1,410	0.000	**0.020**	0.002	Mar-15	7.3	1,340	0.026	**0.010**	0.022
RN022543	Coomalie Dolostone	23.0 to 33.0	Oct-12	7.6	1,380	0.000	0.026	0.0	Feb-14	7.5	1,140	0.018	0.014	0.1
Bores near the EFDC (north side)														
MB12-26	Whites Formation	9.0 to 11.0	Oct-14	6.4	973	0.069	**0.02**	0.006	Feb-14	6.4	860	0.038	**0.01**	0.015
MB12-27	Coomalie Dolostone	8.7 to 11.7	Oct-14	7.3	302	0.015	0.092	0.001	Feb-14	7.3	264	0.004	0.012	0.004
MB12-28	Coomalie Dolostone	9.4 to 15.4	Oct-14	6.9	337	0.023	0.1	0.003	Feb-14	6.7	226	0.008	0.1	0.024
MB10-14	Coomalie Dolostone	14.2 to 16.2	Dec-10	6.1	737	0.018	**0.20**	0.015	Mar-12	6.6	660	0.008	**0.02**	0.013
MB10-15	Coomalie Dolostone	12.4 to 24.4	Dec-10	6.6	554	0.0	**0.2**	0.1	Apr-11	7.4	477	0.1	**0.2**	0.1
MB10-17	Coomalie Dolostone	20 to 26	Dec-10	6.7	288	0.001	**0.2**	0.000	Mar-11	6.9	242	0.000	**0.2**	0.003
Bores west of the Intermediate Pit														
MB10-9D	Coomalie Dolostone	46.3 to 62.3	Dec-10	6.7	2,910	0.056	7.6	0.1	Mar-15	6.5	3,270	0.018	2.1	0.1
MB10-9S	Coomalie Dolostone	23.4 to 29.4	Dec-10	7.5	236	0.012	0.2	0.002	Mar-15	7.3	317	0.000	0.1	0.003
MB12-34	Coomalie Dolostone	48.7 to 60.7	Oct-14	7.2	1,630	0.002	0.7	0.005	Feb-14	7.0	1,540	0.005	0.7	0.005
RN023516	Alluvium	3.1 to 3.9	Sep-12	5.5	197	0.1	0.2	0.2	Feb-13	5.4	163	0.1	0.6	0.2

Note: Values in red are lower than the indicated reporting limit

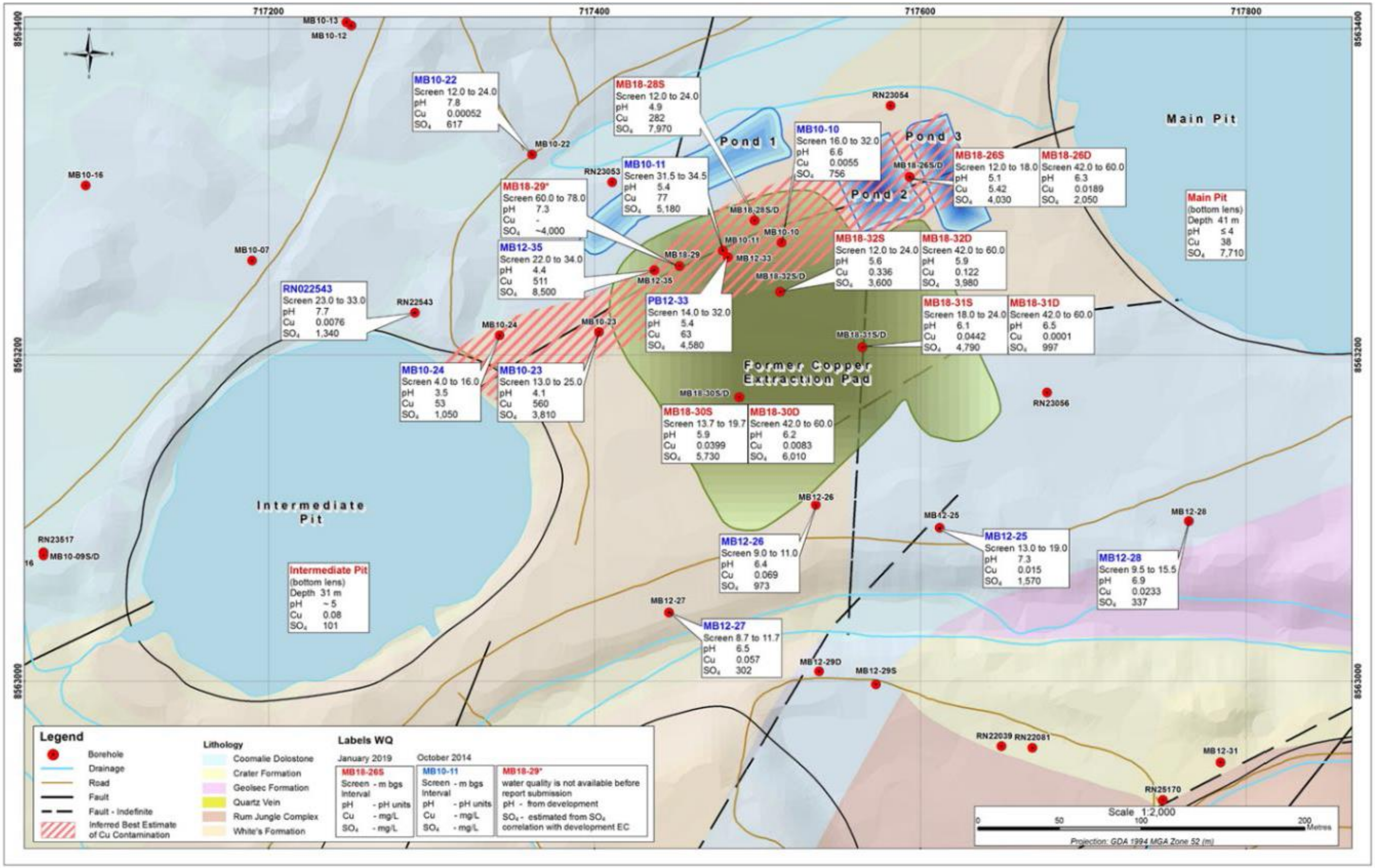


Figure 10-5: Water quality observations and inferred Copper plume in Copper Extraction Pad area

Groundwater quality in the Old Tailings Dam area

Tailings were discharged to the Old Tailings Dam area during historic mining operations in the 1950s and 1960s. Tailings accumulated behind a series of small impoundments near Old Tailings Creek and were subsequently eroded during the Wet season (see Davy, 1975). Most of the tailings that were in the Old Tailings Dam area were re-located to Dyson's Pit during initial rehabilitation in the 1980s and the area was subsequently covered and re-vegetated. Some small amounts of residual tailings have been identified but they are not considered a significant AMD source to groundwater.

Groundwater in the Old Tailings Dam area is characterised by elevated SO_4 concentrations but metal concentrations tend to be low (see Table 10-6), likely due to attenuation (neutralisation) in groundwater in the Coomalie Dolostone. Groundwater in the former ore stockpile area near the Main Pit is an exception, as elevated Cu concentrations are observed in groundwater from bores MB14-20S/D and MB14-17S/D. These concentrations are attributed to seepage from a surface ore stockpile (north east of Main Pit) that was removed during initial rehabilitation in the 1980s and are unrelated to historic tailings.

Elevated Cu concentrations in groundwater in this area may also come from AMD generated by local waste rock and/or ore that was covered during initial rehabilitation. Impacted groundwater (at least with respect to metals) appears to be restricted to the former ore stockpile area and is unlikely to account for a substantial load to Main Pit or the EBFR. A recovery bore is planned as part of the rehabilitation project to improve local groundwater quality in this area (see Section 10.4.2).

Table 10-6: Representative groundwater and seepage water quality results, Old Tailings Dam Area and Downstream near EBFR

Bore ID	Screened Lithology	Screened Interval, m bgs	*Dry Season* Sampling Date	Field pH	SO_4, mg/L	Cu, mg/L	Fe, mg/L	Zn, mg/L	*Wet Season* Sampling Date	Field pH	SO_4, mg/L	Cu, mg/L	Fe, mg/L	Zn, mg/L
Unimpacted groundwater														
RN023302	Coomalie Dolostone	9.5 to 12.5	Aug-10	7.1	1	0.000	0.200	0.014	Feb-12	7.2	1	0.006	0.002	0.002
RN023140	Coomalie Dolostone	11.0 to 16.0	Aug-10	7.1	2	0.000	0.200	0.012	Feb-12	7.2	2	0.006	0.002	0.002
Bores to the northwest of the Main Pit														
MB14-05D	Coomalie Dolostone	21.6 to 27.6	Dec-14	7.3	101	0.005	0.020	0.001	Apr-15	7.5	103	0.036	0.002	0.002
MB14-06D	Coomalie Dolostone	18.0 to 24.0	Dec-14	7.6	44	0.007	0.020	0.002	Apr-15	7.5	44	0.028	0.002	0.003
MB14-15D	Geolsec Formation	21.0 to 42.0	Dec-14	6.9	604	0.0	0.020	0.021	Apr-15	7.1	446	0.1	0.002	0.007
MB14-17S	Fill/Lat./Geolsec Formation	2.1 to 7.1	-	-	-	-	-	-	Apr-15	5.1	1,080	62.6	0.1	8.3
MB14-17D	Geolsec Formation	21.0 to 28.0	-	-	-	-	-	-	Apr-15	5.2	1,300	52.7	0.020	8.5
MB14-20S	Saprolite	2.0 to 8.0	-	-	-	-	-	-	Mar-15	4.8	1,120	33.6	0.1	6.3
MB14-20D	Coomalie Dolostone	21.0 to 27.0	Dec-14	6.2	1,360	3.7	**0.04**	4.2	Mar-15	6.1	1,190	8.3	**0.01**	6.1
RN022547	Coomalie Dolostone	17.0 to 23.0	Aug-10	7.1	0	0.000	0.4	0.018	Feb-12	6.8	1	0.001	9.9	0.009
RN022548	Coomalie Dolostone	27.9 to 30.5	Aug-10	7.4	1	0.000	1.8	0.004	Feb-12	7.4	3	0.000	2.1	0.001
RN023304	Coomalie Dolostone	20.9 to 26.4	Aug-10	7.1	667	0.000	0.200	0.014	Mar-12	7.1	579	0.001	0.044	0.001
Bores in the former Old Tailings Dam area														
MB10-8S	Laterite	20.0 to 23.0	Nov-10	7.2	4	0.001	0.2	0.000	Feb-12	7.7	64	0.001	0.2	0.002
MB10-8D	Geolsec Formation	5.6 to 14.6	Dec-10	7.5	29	0.000	**0.200**	0.000	Feb-12	6.8	1	0.001	**0.002**	0.003
MB10-18	Saprolite/alluvium	2.0 to 8.0	Dec-10	7.3	109	0.001	**0.200**	0.000	Feb-12	7.3	104	0.003	**0.002**	0.017
MB10-19	Coomalie Dolostone	12.5 to 24.5	Dec-10	7.4	80	0.000	**0.200**	0.000	Feb-12	7.5	81	0.001	**0.002**	0.006
MB14-01S	Saprolite	2.0 to 6.5	Dec-14	7.2	172	0.003	**0.020**	0.001	Apr-15	7.4	107	0.001	**0.002**	0.001
MB14-01D	Coomalie Dolostone	25.8 to 31.8	Apr-15	7.4	109	0.000	**0.002**	0.001	Apr-15	7.4	109	0.000	**0.002**	0.001
MB14-02S	Rum Jungle Complex	2.0 to 8.0	-	-	-	-	-	-	Apr-15	6.0	96	2.0	**0.002**	0.6
MB14-02D	Coomalie Dolostone	23.1 to 29.1	Dec-14	7.5	122	0.0	**0.020**	0.0	Apr-15	7.2	105	0.4	**0.002**	0.2
MB14-03	Saprolite	17.8 to 22.8	Dec-14	7.3	21	0.00	**0.020**	0.004	Apr-15	7.4	16	0.04	**0.002**	0.001
MB14-04	Saprolite	2.3 to 8.3	Dec-14	7.2	62	0.01	**0.020**	0.001	Apr-15	7.6	113	0.02	**0.002**	0.004
MB14-06S	Siltstone	2.0 to 8.0	-	-	-	-	-	-	Apr-15	6.5	53	0.1	**0.002**	0.1
MB14-06D			Dec-14	7.6	44	0.0	**0.020**	0.0	Apr-15	7.5	44	0.0	**0.002**	0.0
MB14-08S	Lat./Sap./Coomalie Dolostone	2.0 to 5.0	-	-	-	-	-	-	Apr-15	7.2	93	0.1	**0.002**	0.031
MB14-08D	Coomalie Dolostone	17.5 to 23.5	-	-	-	-	-	-	Apr-15	7.2	229	0.05	**0.002**	0.004
MB14-09	Coomalie Dolostone	10.0 to 16.0	-	-	-	-	-	-	Apr-15	6.7	329	0.05	**0.002**	0.010
MB14-10	Saprolite	2.2 to 5.2	-	-	-	-	-	-	Apr-15	6.7	351	0.1	**0.002**	0.009
MB14-13S	Lat./Sap./Coomalie Dolostone	2.0 to 8.0	-	-	-	-	-	-	Apr-15	6.3	44	0.03	0.048	0.009
MB14-13D	Coomalie Dolostone	13.0 to 18.0	-	-	-	-	-	-	Apr-15	6.9	44	0.02	**0.002**	0.002
MB14-15S	Geolsec Formation	11.0 to 14.0	-	-	-	-	-	-	Apr-15	6.1	35	0.5	0.004	0.2
MB14-16	Laterite/Fill	2.0 to 7.0	-	-	-	-	-	-	Apr-15	5.3	17	0.8	0.012	0.3
MB14-18	Coomalie Dolostone	11.0 to 17.0	-	-	-	-	-	-	Apr-15	7.3	34	0.02	0.02	0.002
MB14-19	Saprolite	2.0 to 6.2	-	-	-	-	-	-	Apr-15	7.0	458	0.2	**0.002**	0.016
RN023302	Coomalie Dolostone	9.5 to 12.5	Aug-10	7.1	1	0.0003	0.2	0.0	Feb-12	7.2	1	0.01	**0.002**	0.002
Bores downstream near EBFR (GS8150327)														
MB10-20	Alluvium	2.9 to 6.9	Dec-10	5.7	529	0.00	0.4	0.02	Feb-14	5.4	3	0.01	1.2	0.01
MB10-21	Rum Jungle Complex	12.0 to 32.0	Dec-10	6.9	3	0.00	**0.200**	0.01	Feb-14	6.9	24	0.01	**0.002**	0.01

Note: Values in red are lower than the indicated reporting limit

Groundwater quality downstream near the EBFR

Groundwater quality near the EBFR adjacent to the Old Tailings Dam area (at bores MB10-8S/D) is characterised by relatively low SO_4 and most metals related to AMD. These low concentrations are consistent with only modest AMD impacts to groundwater migrating west towards the EBFR from the Old Tailings Dam area and/or residual impacted groundwater from the central mining area (at least towards GS8150200), most likely due to attenuation in groundwater in the Coomalie Dolostone.

Further downstream (near gauge GS8150327), groundwater from bores MB10-20 and MB10-21 is characterised by low SO_4 and metal concentrations. Gauge GS8150327 was installed in 2010 to record loads in the EBFR coming from the entire mine site area, including groundwater flows downstream of gauge GS8150200 and flows from Old Tailings Creek. Bore MB10-21 is screened in low-permeable bedrock that conveys minimal groundwater flows, suggesting minimal cross-boundary flows of groundwater impacted by recharge from the nearby EBFR (see RGC, 2016).

10.4.2. Pit Water Quality Impacts

Main Pit water quality

Pit water quality data for Main Pit are summarised in Table 10-7. The Main Pit was originally mined to about 111 m bgs. It was subsequently partially backfilled with 900,000 m^3 of tailings, largely originating from Rum Jungle Creek South, in the final years of ore processing on the site.

The Main Pit was used to store process water during mining operations and was later flooded with impacted groundwater when mining ceased and the pit was no longer de-watered. The top 20 m of highly-contaminated pit water was treated in 1985 by pumping water to a WTP in which the pH was raised to 8.7 to 9.0 by the addition of hydrated lime (Allen and Verhoeven, 1986). This resulted in the precipitation of most metals. Before treatment, pit water was acidic (pH 2.5) and characterised by elevated SO_4 and metal concentrations, *e.g.* 55 mg/L Cu. Water treatment raised the pH of the mixed top layer to about pH 5, although the target pH was 8.7 to 9 and decreased Cu concentrations in the treated layer (< 20 m deep) to less than 1 mg/L. A layer of untreated pit water was left at the bottom of Main Pit.

In 1990, the top of the untreated layer was 22 m below the pit lake surface. The thickness of the layer of untreated water (or "bottom lens") has since been progressively reduced ("eroded") by annual flushing and mixing by upper catchment water *via* the EBFR. On average, the depth of the bottom layer appears to have decreased by 1.2 m *per* year since 1985. In 2014, the top of the layer of untreated pit water was estimated to be at 41 m below the water level in the pit, or about 20 m lower than in 1990. This implies the depth has likely further decreased since 2014 to very near the bottom of the pit, implying there could be less than 0.03 Mm^3 of untreated pit water remaining. A pit water quality profile has not been done since 2014 so the current volume of untreated pit water cannot be determined with high precision. However, in 2014, the top of the layer was likely 3 to 5 m above the tailings surface at the bottom of the pit and it is plausible that the untreated layer is now thinner or may not be present at all.

Intermediate Pit water quality

Pit water quality data for Intermediate Pit are summarised in Table 10-8. The Intermediate Pit was mined to about 57 m bgs. The Intermediate Pit was not used to store process water during mining operations but was characterised by elevated SO_4 and metals, in part due to flows from Main Pit and rainfall runoff from the former heap leach pad nearby.

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

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

Table 10-7: Pit water quality profiling results, Main Pit

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

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

* Total metal concentrations

Table 10-8: Pit water quality profiling results, Intermediate Pit

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

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

* Total metal concentrations

10.4.3. EBFR Water Quality Impacts

Observed streamflows (discharge) in EBFR

Figure 10-6 shows daily average discharge in the EBFR at gauges GS8150200, GS8150327 and GS81500987 since 2010. For additional clarity, observed daily discharge in the EBFR for the last three water years of the simulation period are provided in Figure 10-7.

Observed streamflows in the EBFR vary predictably in response to intra-annual variability in rainfall and typically vary by several orders-of-magnitude over the course of a year. Sustained flows in the EBFR typically start in December or January and persist until May when flows begin to substantially recede. No appreciable flows are observed from July to October. For the purposes of deriving annual flows the water year is defined as July 1st to June 30th.

EBFR water quality upstream of mine site

Upstream of the mine site (in the upper EBFR and Fitch Creek), the EBFR is typically circum-neutral in pH and characterised by less than 5 mg/L SO4, 10 to 20 mg/L Mg and very low concentrations of most metals, *e.g.* 0.001 to 0.002 mg/L Cu-t. Al-t and Fe-t concentrations in the EBFR upstream commonly exceed the LDWQOs for Zone 2 (0.236 mg/L Al and 0.300 mg/L Fe) due to high concentrations of naturally-occurring iron and aluminium in soils. Some of the natural loads are related to particulate matter and/or suspended sediments that are included in total metal concentrations.

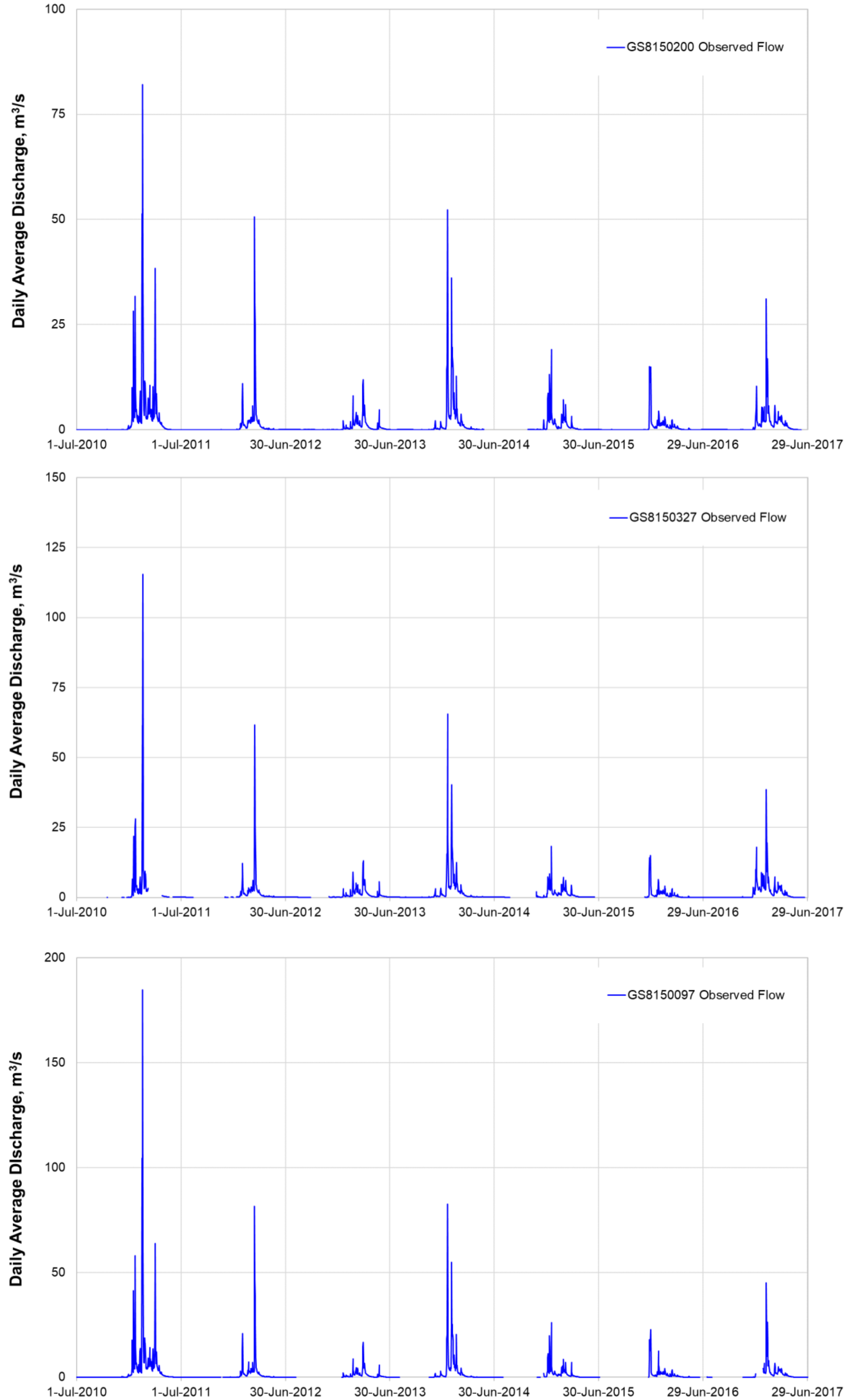


Figure 10-6: Daily average discharge in EBFR at GS8150200, GS8150327 and GS8150097, July 2010 to July 2017

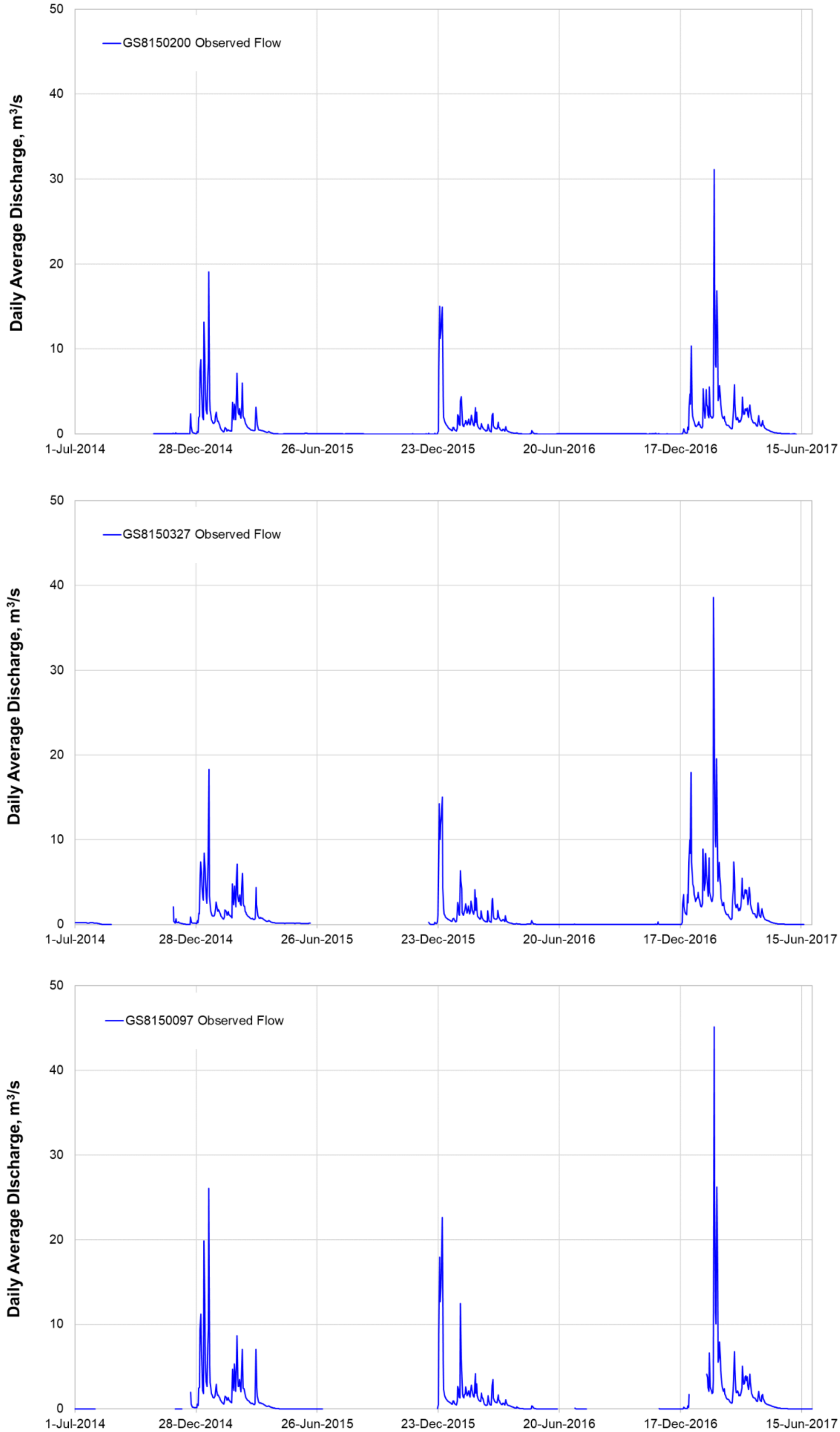


Figure 10-7: Daily average discharge in EBFR at GS8150200, GS8150327 and GS8150097, July 2014 to July 2017

EBFR water quality in Dyson's Area and EFDC

Elevated SO_4 and metal concentrations are initially observed in the upper EBFR in Dyson's Area and in Fitch Creek near the Main WRD; Zone 2 LDWQOs can be exceeded at both locations. This is consistent with streamflow surveys from April 2012 and May 2012 that show elevated SO_4 and metal concentrations due to AMD in the upper EBFR in Dyson's Area, in Fitch Creek and in the EFDC (Figure 10-8). Those surveys also suggest a major load contribution to the EFDC from the Intermediate WRD, as metal concentrations in the EBFR often increase substantially along the reach of the EFDC adjacent to Intermediate WRD. Streamflows in Fitch Creek and the upper EBFR, or in the EFDC, are not routinely monitored so it is difficult to provide a rigorous assessment of when exceedances occur. However, it is evident from available water quality observations that Zone 2 LDWQOs are consistently exceeded in the EBFR throughout the site.

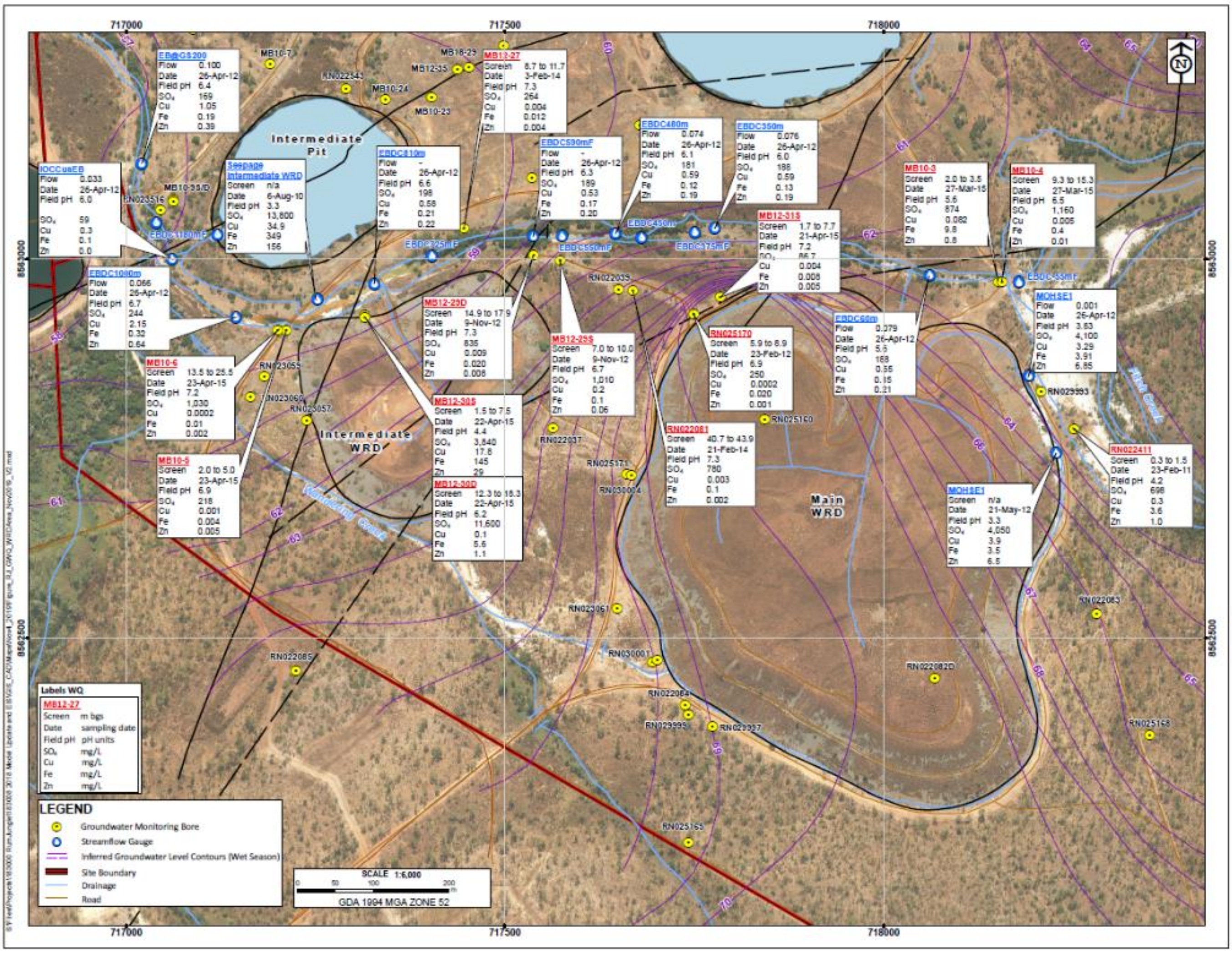


Figure 10-8: Groundwater and surface water quality observations near EFDC

EBFR water quality downstream, 2010 to 2018

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

Observed SO_4 and Cu concentrations in the EBFR at gauges GS8150200, GS8150327 and GS8150097 from 2009 to 2018 are shown in Figure 10-9, Figure 10-10, and Figure 10-11, respectively. LDWQOs for the applicable Zones 2 and 3 are shown for reference. Other parameters for which LDWQOs have been developed are shown in Figure 10-

12. Total and filtered (<0.45 µm) concentrations are shown if both are available. These data were collected by the DPIR as part of its routine annual monitoring program for the site.

LDWQOs for Al, Cu, Co, and Fe are commonly exceeded in the EBFR at gauges GS8150200, GS8150327 and GS8150097, regardless of the flow in the EBFR. This is, in part, due to naturally-occurring suspended sediments that are included in total metal concentrations. LDWQOs for SO_4, Mg and Zn are rarely exceeded if there is appreciable flows in the EBFR. The greatest impact from the site therefore occurs during the start of the Wet season when pools of highly contaminated (by metals and acid) water that have accumulated in the site drainage lines during the Dry are flushed out into the EBFR. Hourly measurements of pH, EC and turbidity in the EBFR at gauge GS8150200 from October 1st, 2017, to July 1st, 2018, are shown in Figure 10-13 to illustrate this seasonal cycle. The same sets of data for gauges GS8150327 and GS8150097 are shown for comparison in Figure 10-14 with hourly discharge rates plotted on the secondary y-axis.

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

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

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

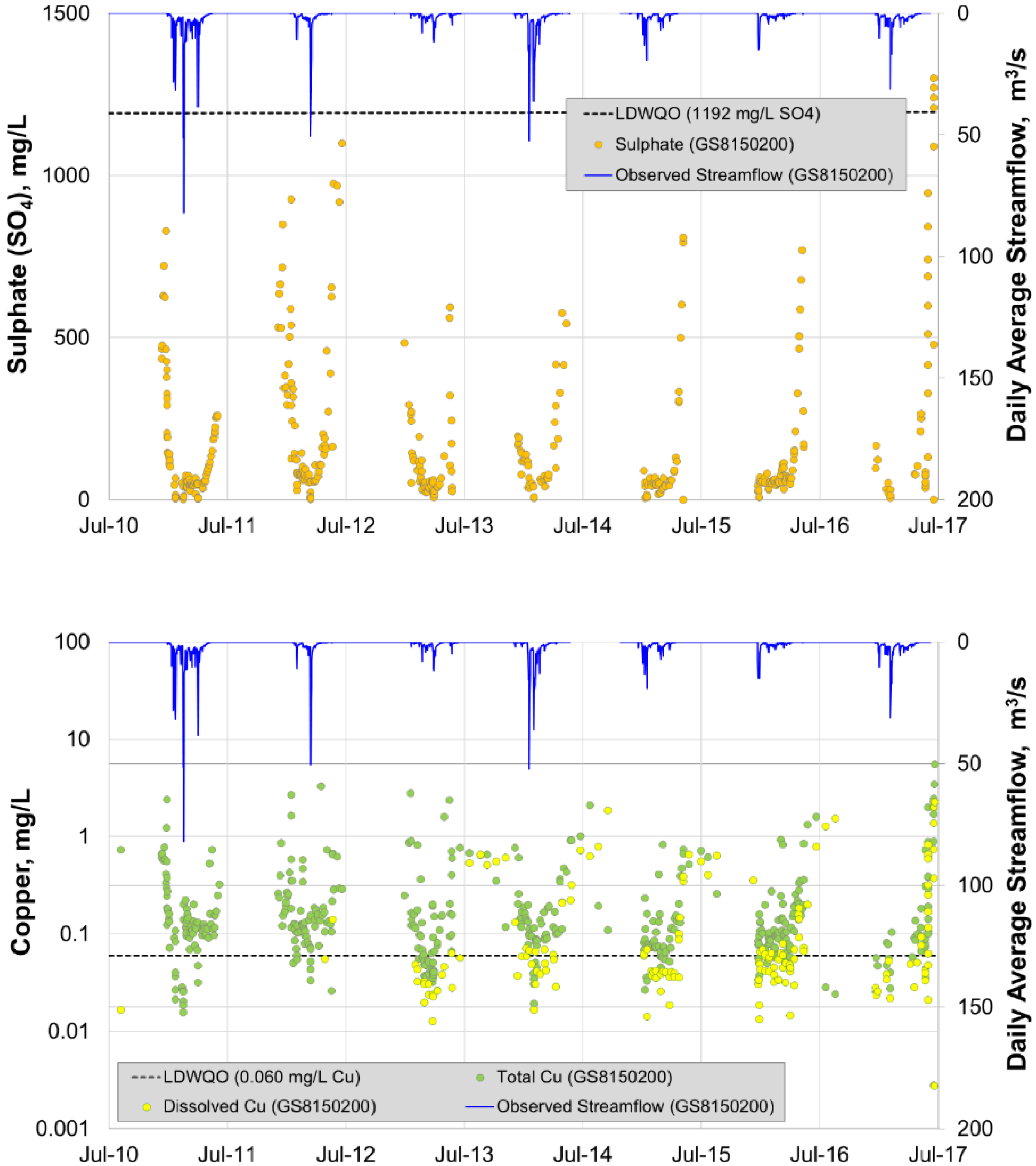
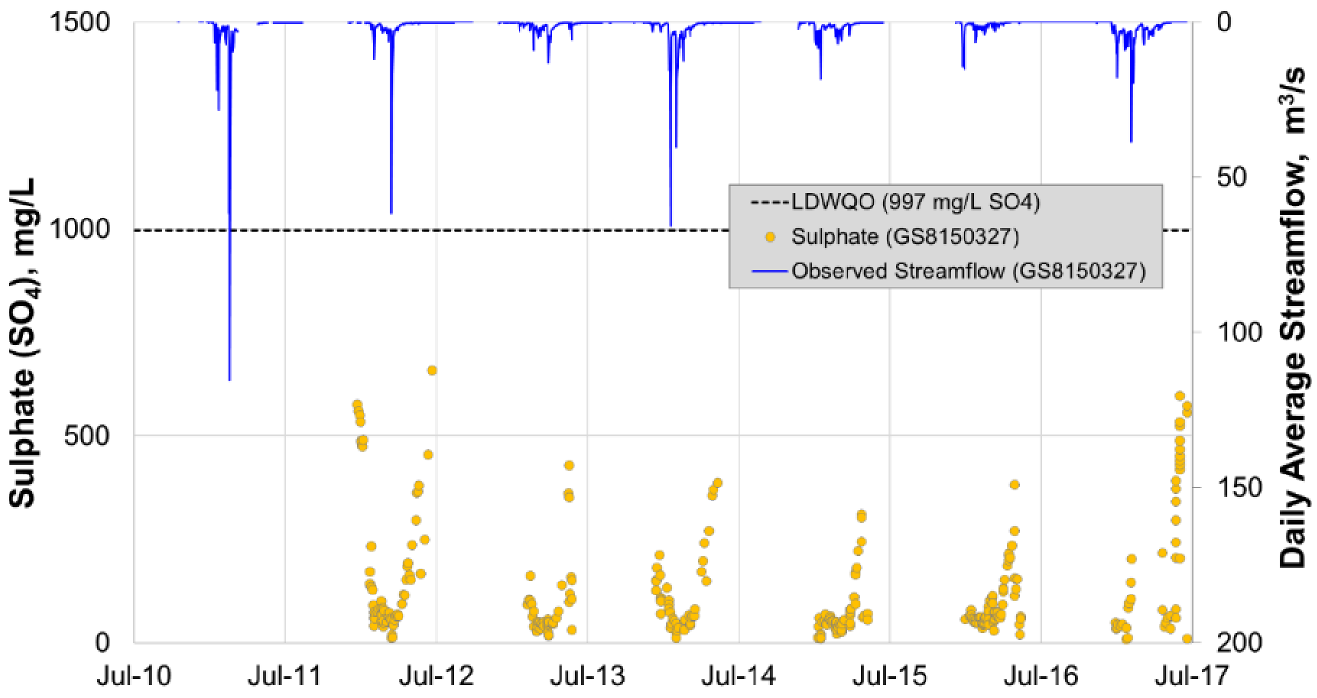


Figure 10-9: Observed Copper and Sulphate concentrations in the EBFR at gauge GS8150200, July 2010 to July 2017



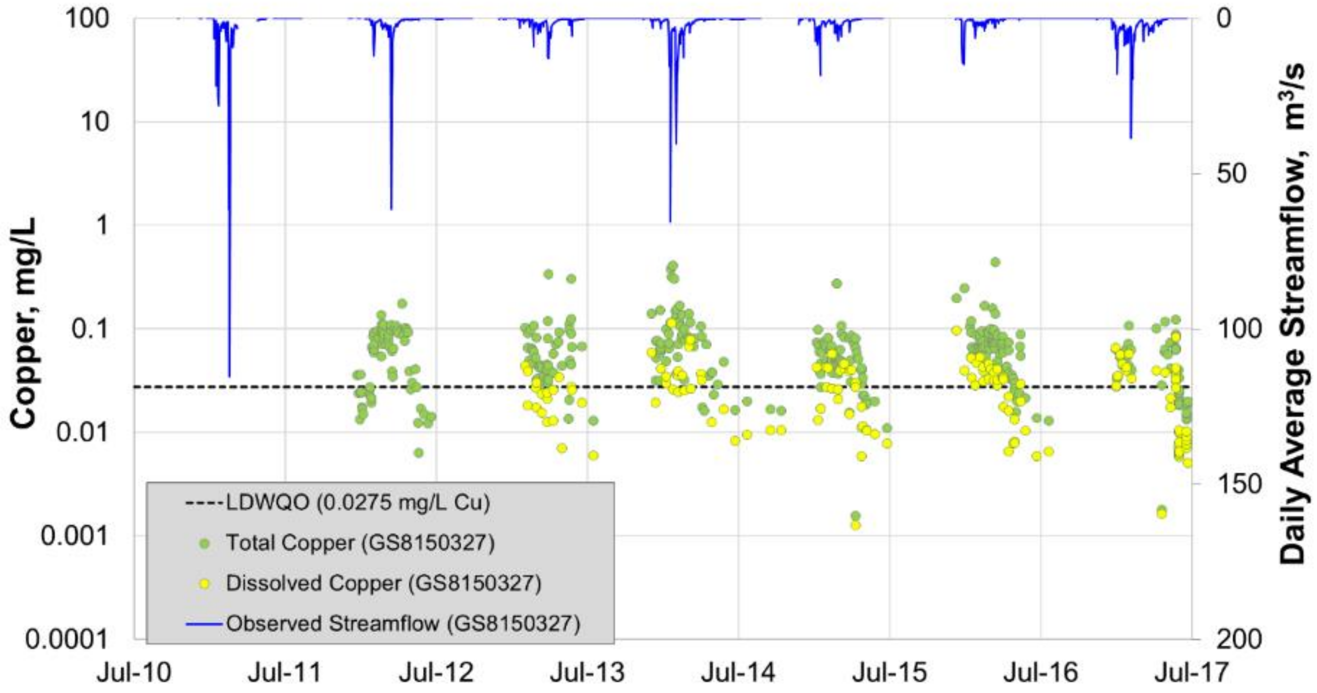
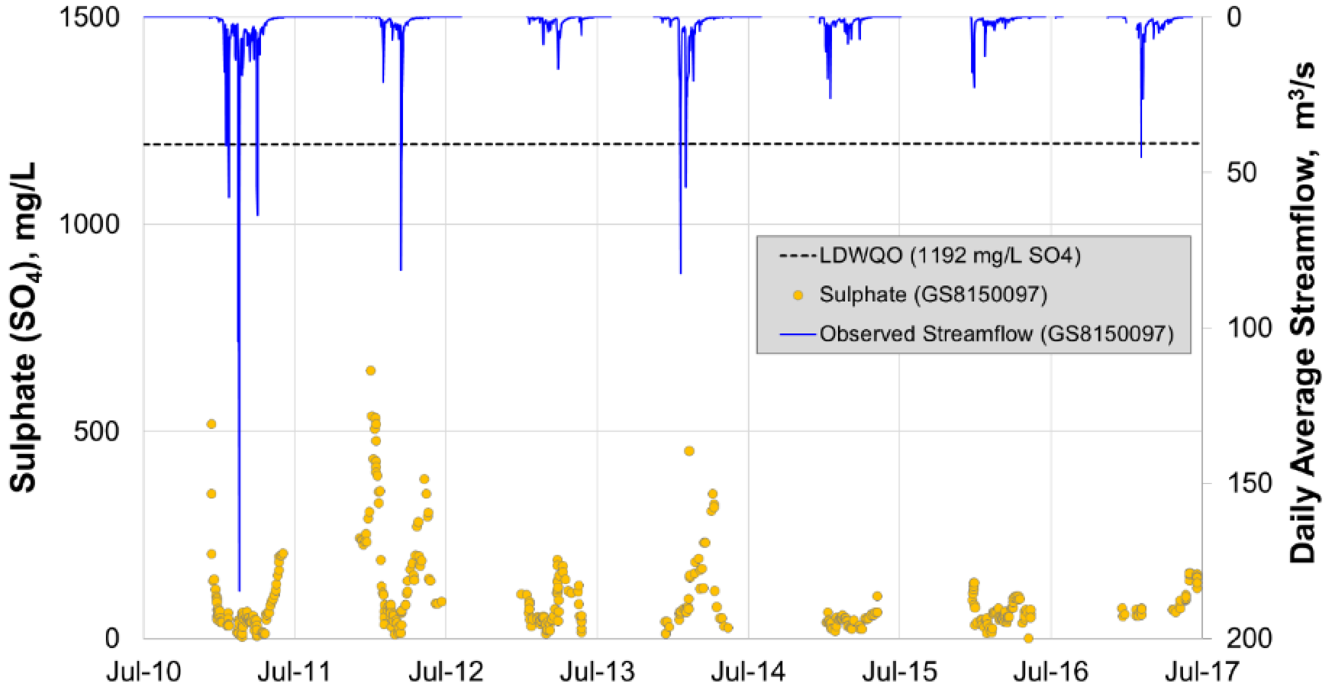


Figure 10-10: Observed Copper and Sulphate concentrations in the EBFR at gauge GS8150327, July 2010 to July 2017



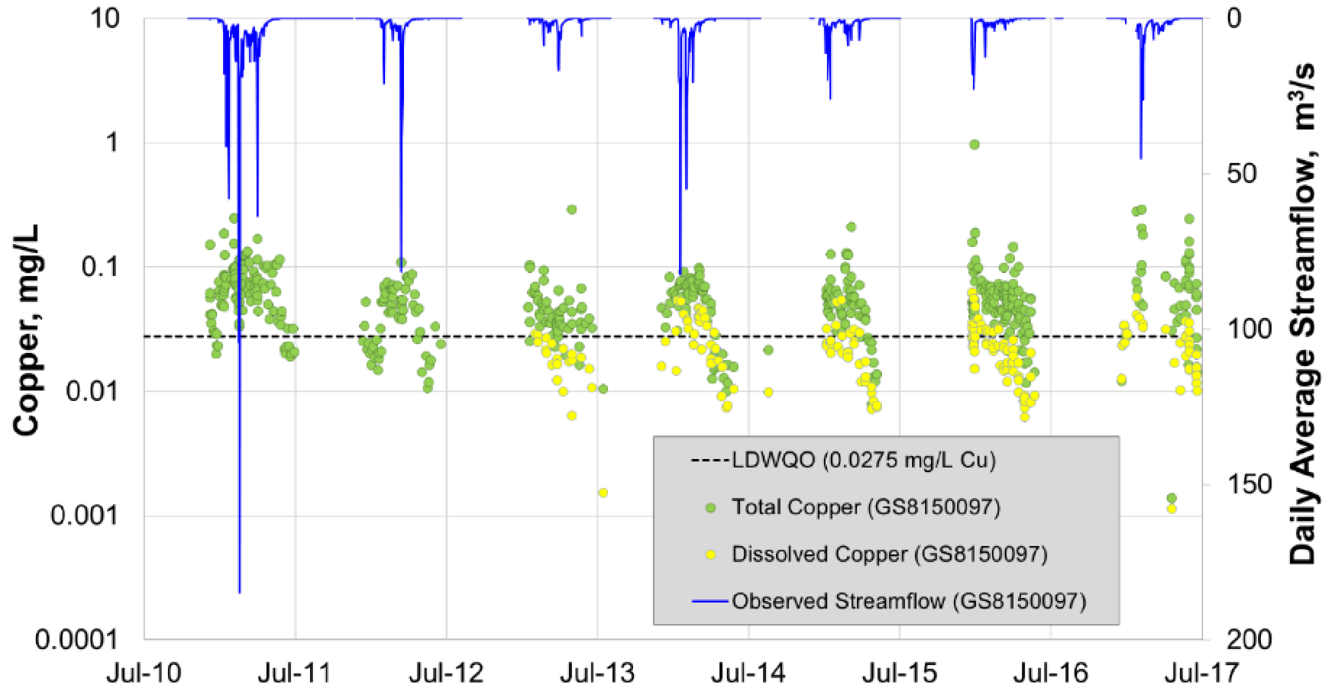


Figure 10-11: Observed Copper and Sulphate concentrations in the EBFR at gauge GS8150097, July 2010 to July 2017

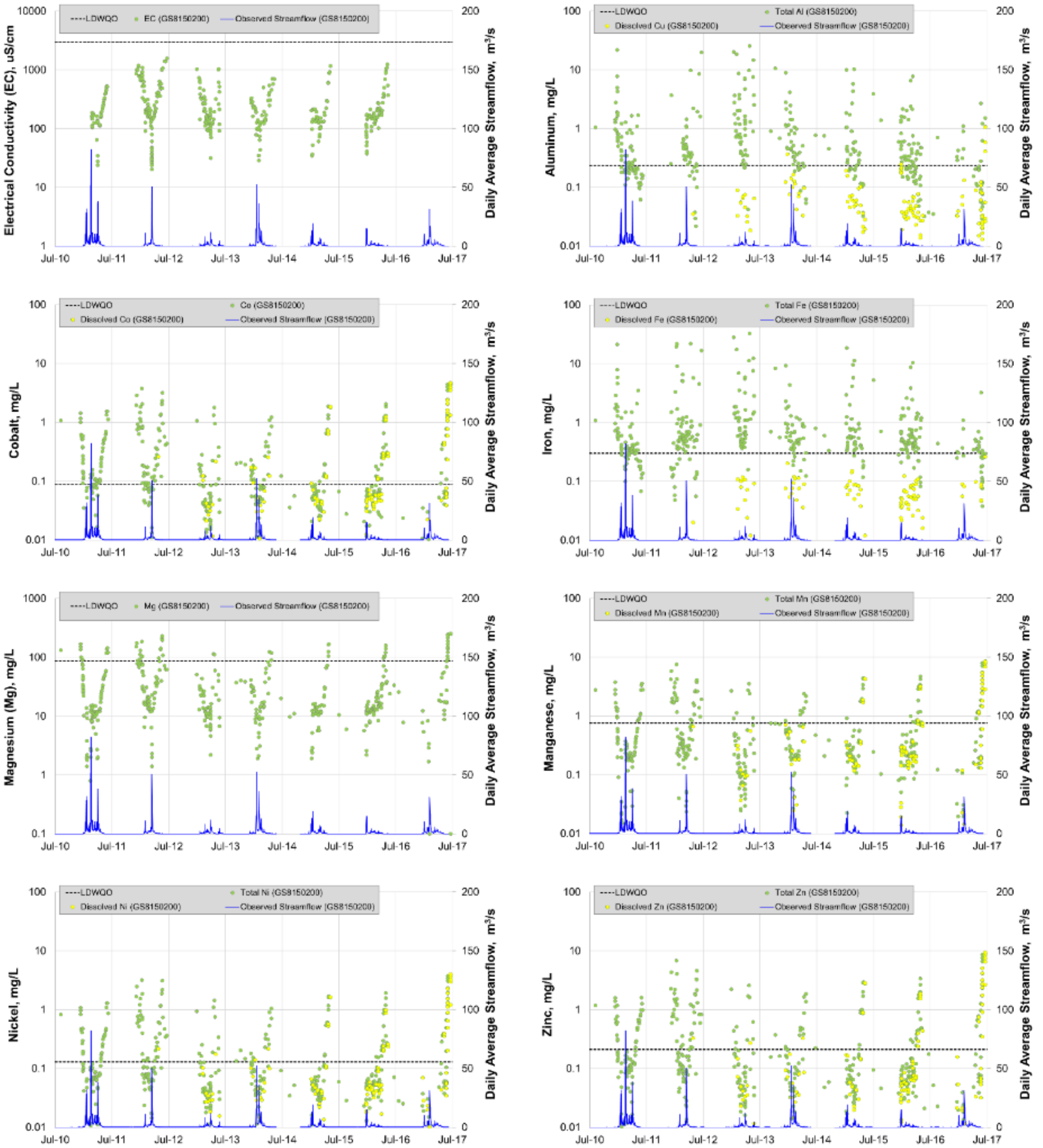


Figure 10-12: Observed EC and metal concentrations in the EBFR at gauges GS8150200, 2010 to 2017. Note: only parameters for which there is a LDWQO are shown

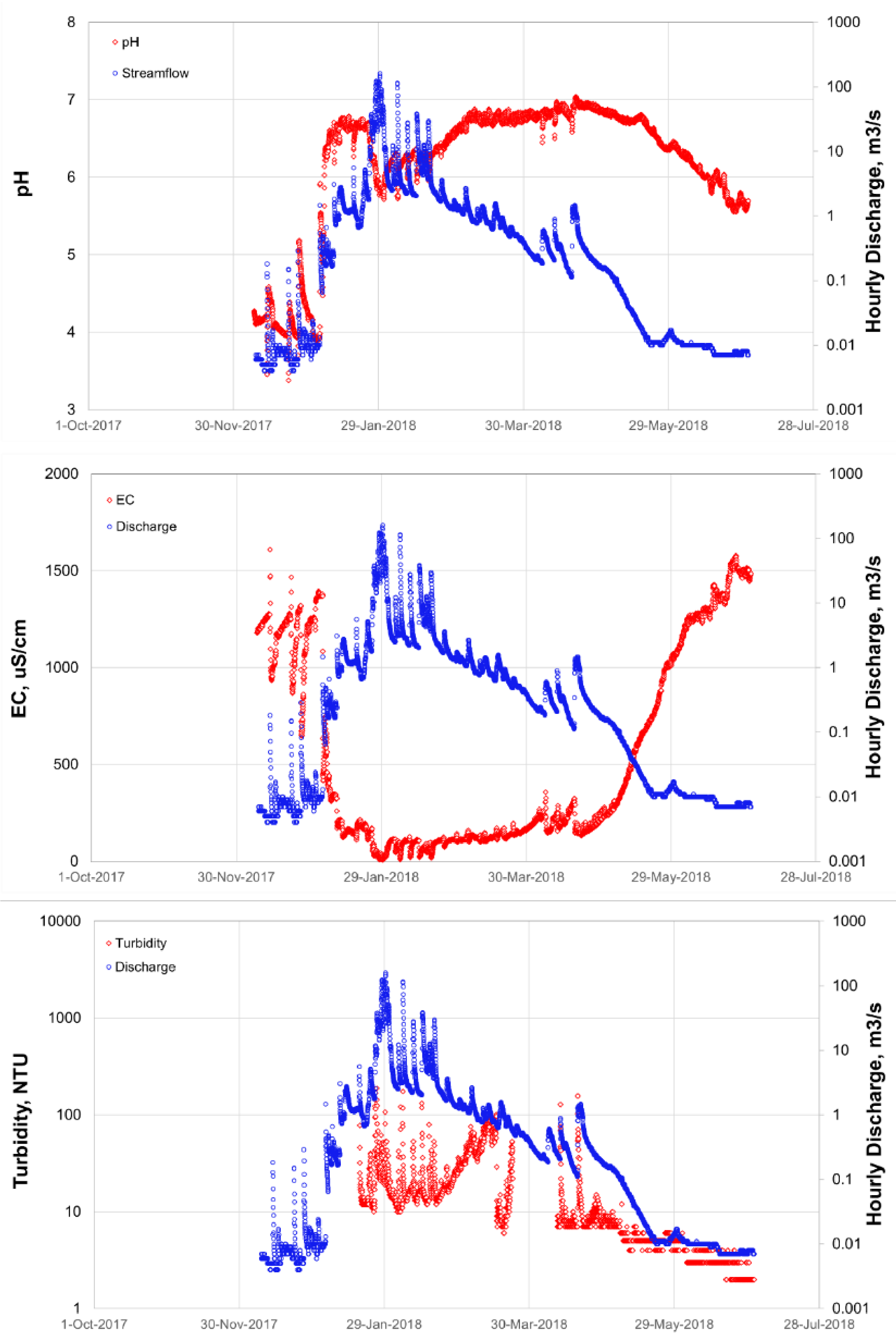


Figure 10-13: Hourly pH, EC and turbidity observations in the EBFR at gauge G81500200, 2017/2018 Water Year

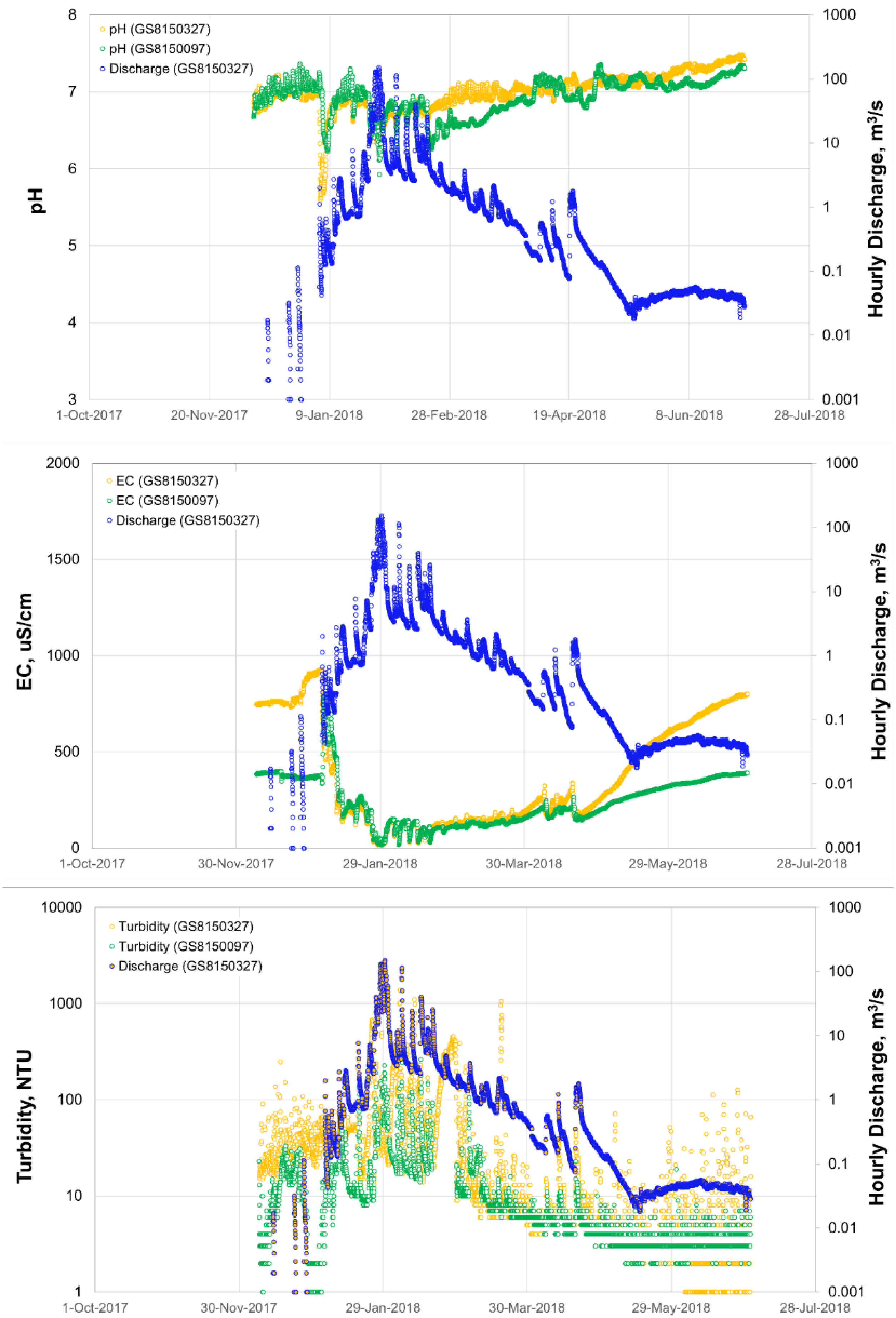


Figure 10-14: Hourly pH, EC and turbidity observations in the EBFR at gauges GS8150327 and GS8150097, 2017/2018 Water Year

LDWQO exceedances

Table 10-9 and Table 10-10 show percentage exceedances (in green) for SO_4, Mg and total metals in the EBFR at gauge GS8150200 (Zone 2) and gauge GS8150327 (Zone 3) since 2010. At gauge GS8150200, only samples collected when flows in the EBFR exceed 0.05 m^3/s are included and only samples collected when flows in the EBFR exceed 0.1 m^3/s are included for gauge GS8150327. This screening approach excludes samples of stagnant water collected when the creek is not flowing. LDWQOs from Hydrobiology are compared to total metal concentrations. This table shows that SO_4 and Mg concentrations rarely exceed the LDWQOs from Hydrobiology (2016) under current conditions, whereas LDWQOs for Al, Cu, Co, Ni and Fe are consistently exceeded.

Table 10-9: LWQR exceedances at gauge GS8150200

Period	SO_4	Mg	Al-t	Cu-t	Co-t	Fe-t	Mn-t	Ni-t	Zn-t
2010/2011 Water Year n = 73	Above LDWQO 0%	Above LDWQO 1%	Above LDWQO 56%	Above LDWQO 84%	Above LDWQO 51%	Above LDWQO 68%	Above LDWQO 7%	Above LDWQO 19%	Above LDWQO 18%
2011/2012 Water Year n = 70	Above LDWQO 0%	Above LDWQO 13%	Above LDWQO 79%	Above LDWQO 92%	Above LDWQO 64%	Above LDWQO 81%	Above LDWQO 31%	Above LDWQO 46%	Above LDWQO 43%
2012/2013 Water Year n = 57	Above LDWQO 0%	Above LDWQO 4%	Above LDWQO 95%	Above LDWQO 63%	Above LDWQO 32%	Above LDWQO 98%	Above LDWQO 16%	Above LDWQO 21%	Above LDWQO 23%
2013/2014 Water Year n = 47	Above LDWQO 0%	Above LDWQO 0%	Above LDWQO 4%	Above LDWQO 79%	Above LDWQO 87%	Above LDWQO 47%	Above LDWQO 85%	Above LDWQO 15%	Above LDWQO 26%
2014/2015 Water Year n = 51	Above LDWQO 0%	Above LDWQO 0%	Above LDWQO 77%	Above LDWQO 78%	Above LDWQO 13%	Above LDWQO 98%	Above LDWQO 2%	Above LDWQO 4%	Above LDWQO 6%
2015/2016 Water Year n = 67	Above LDWQO 0%	Above LDWQO 0%	Above LDWQO 63%	Above LDWQO 88%	Above LDWQO 21%	Above LDWQO 92%	Above LDWQO 8%	Above LDWQO 11%	Above LDWQO 11%
2016/2017 Water Year n = 19	Above LDWQO 0%	Above LDWQO 0%	Above LDWQO 47%	Above LDWQO 50%	Above LDWQO 29%	Above LDWQO 71%	Above LDWQO 18%	Above LDWQO 18%	Above LDWQO 18%

Table 10-10: LDWQO exceedances at gauge GS8150327

Period	SO_4	Mg	Al-t	Cu-t	Co-t	Fe-t	Mn-t	Ni-t	Zn-t
2010/2011 Water Year n = 0	-	-	-	-	-	-	-	-	-
2011/2012 Water Year n = 52	Above LDWQO 0%	-	Above LDWQO 59%	Above LDWQO 81%	Above LDWQO 85%	Above LDWQO 58%	Above LDWQO 10%	Above LDWQO 79%	Above LDWQO 10%
2012/2013 Water Year n = 48	Above LDWQO 0%	Above LDWQO 0%	Above LDWQO 91%	Above LDWQO 94%	Above LDWQO 66%	Above LDWQO 96%	Above LDWQO 7%	Above LDWQO 48%	Above LDWQO 7%
2013/2014 Water Year n = 59	Above LDWQO 0%	Above LDWQO 0%	Above LDWQO 78%	Above LDWQO 92%	Above LDWQO 90%	Above LDWQO 82%	Above LDWQO 22%	Above LDWQO 88%	Above LDWQO 14%
2014/2015 Water Year n = 67	Above LDWQO 0%	Above LDWQO 0%	Above LDWQO 62%	Above LDWQO 86%	Above LDWQO 68%	Above LDWQO 78%	Above LDWQO 2%	Above LDWQO 47%	Above LDWQO 0%
2015/2016 Water Year n = 65	Above LDWQO 0%	Above LDWQO 0%	Above LDWQO 64%	Above LDWQO 98%	Above LDWQO 87%	Above LDWQO 80%	Above LDWQO 2%	Above LDWQO 66%	Above LDWQO 2%
2016/2017 Water Year n = 24	Above LDWQO 0%	Above LDWQO 0%	Above LDWQO 38%	Above LDWQO 92%	Above LDWQO 43%	Above LDWQO 25%	Above LDWQO 10%	Above LDWQO 33%	Above LDWQO 10%

Contaminant loads in EBFR, 2010 to 2018

Observed SO_4 and Cu loads in the EBFR for the seven water years since 2010 are summarised in Table 10-11 and Table 10-12, respectively. Average rainfall and discharge volume in the EBFR for each water year (July 1st to June 30th) are also provided. SO_4 and Cu loads in the EBFR were calculated by "patching" the historic concentration records for gauges GS8150200, GS8150327 and GS8150097. Patching, which is shorthand for the process by which sensible estimates are made for data gaps in a record, requires an examination of the concentration-discharge relationship at a given gauge. This is particularly important for the EBFR because the range of SO_4 and Cu concentrations decreases substantially downstream and the slopes of the concentration-discharge relationships varies between the monitoring stations. Further details on these relationships and the patching of historic concentrations records are provided in RGC (2019).

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

- Annual SO_4 loads in the EBFR at gauge GS81503200 range from 821 to 2086 t/yr. The highest SO_4 load was for the 2010/2011 water year, which was the wettest water year during the calibration period. The average annual SO_4 load in the EBFR at gauge GS8150200 is 1270 t/yr, or about 40% lower than the load for the 2010/2011 water year. Annual SO_4 loads are typically around 800 to 1000 t/yr for water years with rainfall amounts near the long-term average for the site, *i.e.* 1438 mm.
- Annual SO_4 loads in the EBFR at gauge GS8150327 are higher than the loads at gauge GS8150200, suggesting a SO_4 load to the EBFR between these gauges, most likely due to AMD-impacted pH neutral groundwater that discharges from the Old Tailings Dam area. The annual SO_4 loads in the EBFR at gauges GS8150327 and GS8150097 are often within 10 to 20% of one another, suggesting no significant additional SO_4 load to the EBFR between these gauges.
- Loads in the EBFR at gauge GS8150097 were the primary calibration target for the surface water modelling in Section 10.6, as it has the longest record of discharge and water quality and the EBFR is thoroughly mixed at that location. The rating curve for gauge GS8150097 does substantially over-estimate high flows but this over-estimation has few implications for the load calculations provided in this chapter (see RGC, 2019).

- Cu loads in the EBFR (for complete years) range from 1.4 t/yr Cu to 5.7 t/yr Cu, with the average annual Cu load being 2.6 to 2.8 t/yr. Approximately two-thirds of the total Cu load in the EBFR at gauge GS8150097 is particulate Cu, either related to suspended sediments or precipitates. The proportion of particulate Cu at the other gauges is slightly less. In contrast for SO_4 there is no evidence of any further inputs of Cu downstream of gauge GS8150200.

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

Table 10-11: Observed Annual Sulphate loads in the EBFR, 2010 to 207

Water Year	Rainfall, mm/year	Annual Discharge Volume (at GS8150327) Mm^3	Sulphate Loads at GS8150200, t/year SO_4	Sulphate Loads at GS8150327, t/year SO_4	Sulphate Loads at GS8150097, t/year SO_4
2010/2011	2,460	74	2,086	-	3,354
2011/2012	1,492	30	1,100	1,886	1,707
2012/2013	1,432	23	821	1,233	973
2013/2014	1,649	44	1,960	2,992	2,244
2014/2015	1,146	28	914	1,010	1,196
2015/2016	1,291	13	893	1,112	1,074
2016/2017	1,529	39	1,119	1,759	1,648
Average:	**1,571**	**36**	**1,270**	**1,665**	**1,742**

Table 10-12: Observed Annual Copper loads in the EBFR, 2010 to 2017

Water Year	Rainfall	Average Annual Streamflow (at GS8150097)	Copper Loads in EBFR at GS8150200		Copper Loads in EBFR at GS8150327		Copper Loads in EBFR at GS8150097	
			Cu-t	Cu-d	Cu-t	Cu-d	Cu-t	Cu-d
	mm	Mm^3	t/year	t/year	t/year	t/year	t/year	t/year
2010/2011	2,460	74	5.1	-	-	-	7.1	-
2011/2012	1,492	30	2.4	-	2.2	-	2.0	-
2012/2013	1,432	23	1.9	-	1.5	0.5	0.8	0.3
2013/2014	1,649	44	3.7	1.0	5.7	2.6	3.5	2.1
2014/2015	1,146	28	2.4	1.0	1.4	0.6	1.6	0.6
2015/2016	1,291	13	1.9	0.7	2.6	0.7	1.7	0.6
2016/2017	1,529	39	1.7	0.9	2.4	1.7	3.2	1.4
Average:	**1,571**	**36**	**2.7**	**0.9**	**2.6**	**1.2**	**2.8**	**1.0**

Notes:

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

10.5. Simulated Current Conditions

10.5.1. Simulated Groundwater Conditions

Groundwater Model overview

Groundwater conditions are simulated with a transient flow model constructed with the MODFLOW-NWT finite difference code and transient solute transport model developed using the transport code MT3DMS. Together, the numerical flow and transport models are referred to as the “groundwater model” throughout the EIS. The groundwater model is a numerical representation of RGC’s updated conceptual hydrogeological model for the site, which is detailed in RGC (2019).

Groundwater model development was an iterative process that began in 2011 during Stage 1 of the Rum Jungle Rehabilitation Project when the initial conceptual hydrogeological model for the site was developed. A numerical groundwater flow model was later developed (RGC, 2012). A transport model, based on an average steady-state flow field, was incorporated into the groundwater model in 2016 (see RGC, 2016). A fully transient flow and transport model was developed in 2019 for the EIS.

The latest groundwater model is a Class 2 model as defined by the Australian Groundwater Modelling Guidelines (Barrett, 2012), although some components of the model are consistent with a Class 3 model. A comprehensive description of the model calibration process and a discussion of model sensitivity and uncertainty are also provided in RGC (2019). Selected results from RGC (2019) are provided below, including simulated results from the calibrated groundwater model and uncalibrated model predictions made by adapting the “current conditions” model.

Model Domain and Boundary Conditions

Boundaries of the numerical model domain are shown in Figure 10-15. The model domain was defined by local topographic highs and low-lying drainage features which are conceptualised to represent no-flow boundaries. All external boundaries of the model domain represent no-flow boundaries except for the most downgradient (northern) boundary representing the EBFR which is represented by a constant head. This approach implicitly assumes that cross-boundary flows into or out of the groundwater system are negligible. For this reason, net recharge by rainfall and inflows from the flooded Main and Intermediate Pits are the only sources of water to the groundwater system within the model domain, whereas any outflows are accounted for by groundwater discharge and evapotranspiration.

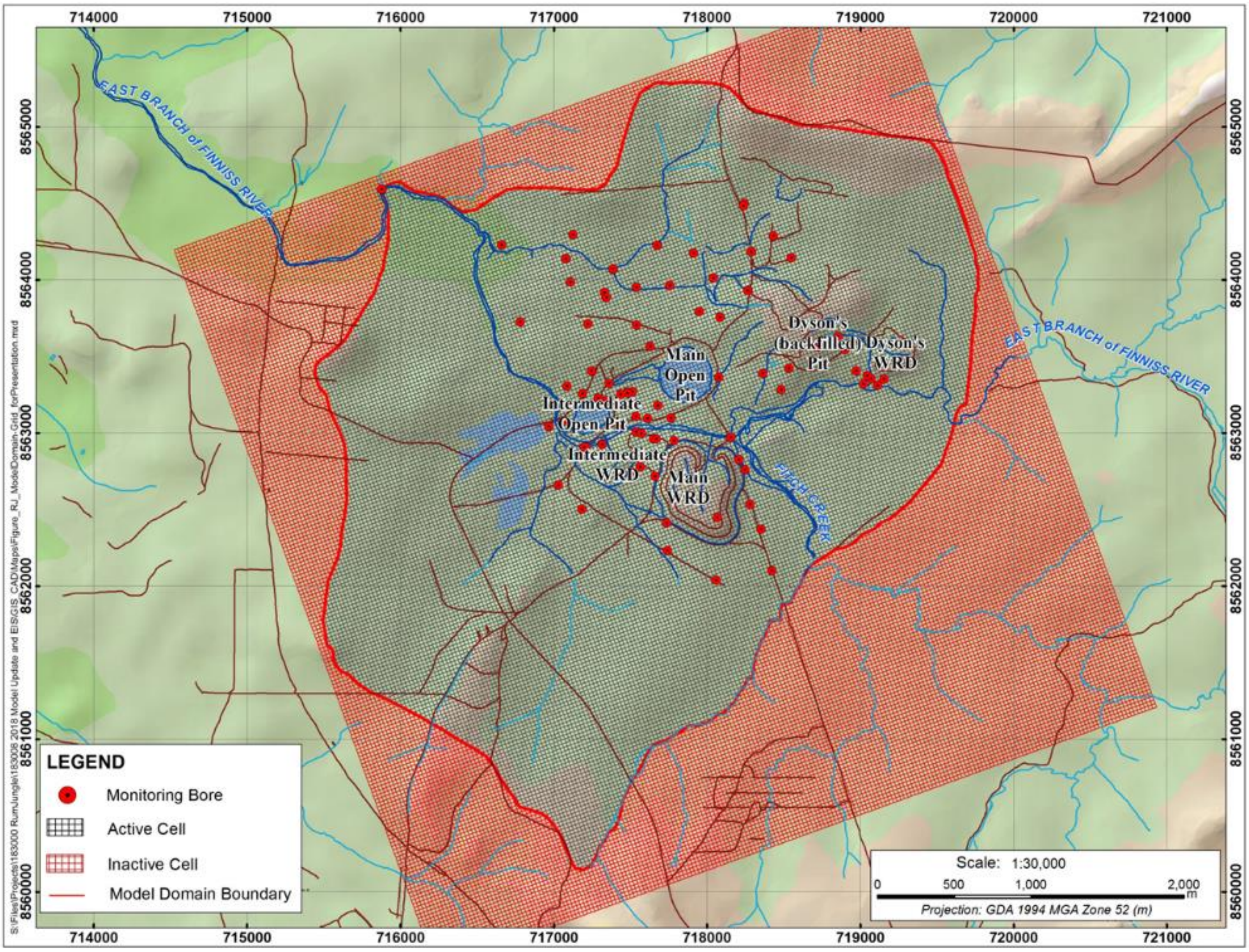


Figure 10-15: Model Domain, Finite Difference Grid, and Boundary Conditions

Simulated groundwater conditions, 2010 to 2018

Simulated flow fields for the 2018 Dry season and Wet season are shown in Figure 10-16. Colour shading represents ground elevations and the EBFR and secondary creeks are shown. Simulated groundwater head equipotential lines are shown with arrows indicating the direction of groundwater flow. Red dots are the monitoring bores used for model calibration (see RGC, 2019). Groundwater is simulated to flow from upland areas to lower elevation areas near the pits and the EBFR. Some mounding near the Main WRD and Dyson's WRD is simulated by the model, as the WRD are assumed to be preferential recharge areas. Mounding is not simulated near or beneath the Intermediate WRD due to the more permeable bedrock (Coomalie Dolostone) that underlies this WRD. The model predicts steeper hydraulic gradients during Wet season than during the Dry season. The flooded pits have a strong influence on the groundwater flow field, as the pits act as a source or sink for groundwater depending on the difference between pit water level and groundwater levels. This interaction tends to dampen groundwater level fluctuations near the pits.

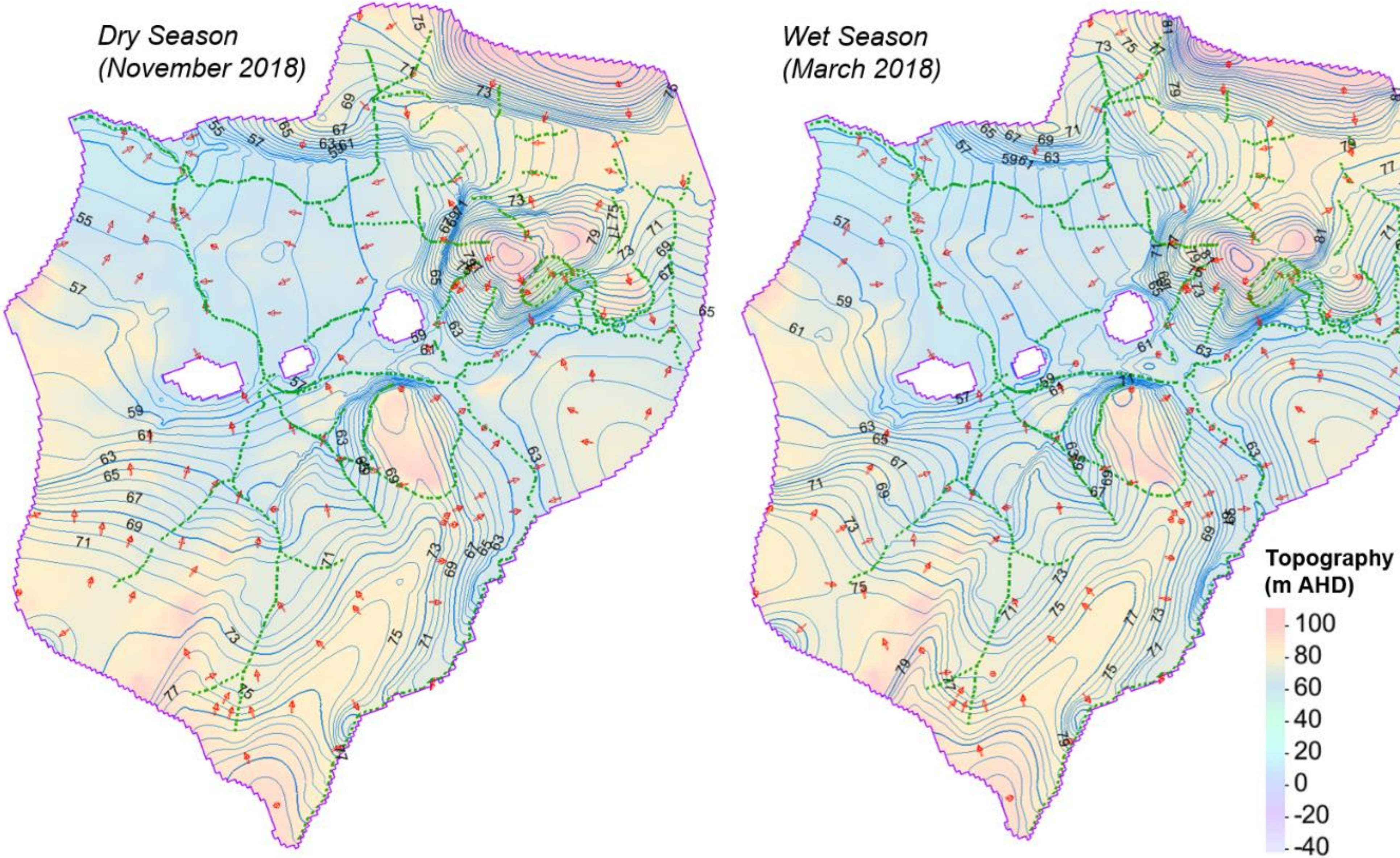


Figure 10-16: Simulated groundwater flow field, Wet and Dry Seasons 2018

Simulated groundwater balance, 2010 to 2018

The simulated average water balance from the calibrated groundwater model is summarised in Figure 10-17. Recharge to undisturbed areas accounts for approximately 90% of inflows to the model domain. Recharge from the WRDs and Intermediate Pit account for most of the remaining inflow, as recharge from Main Pit is relatively minor to the lower permeability bedrock it intersects. The key outflows from the model domain are groundwater discharge to the EBFR and various creeks within the model domain. Evapotranspiration and seasonal groundwater discharge to the flooded pits are the other outflows from the model domain.

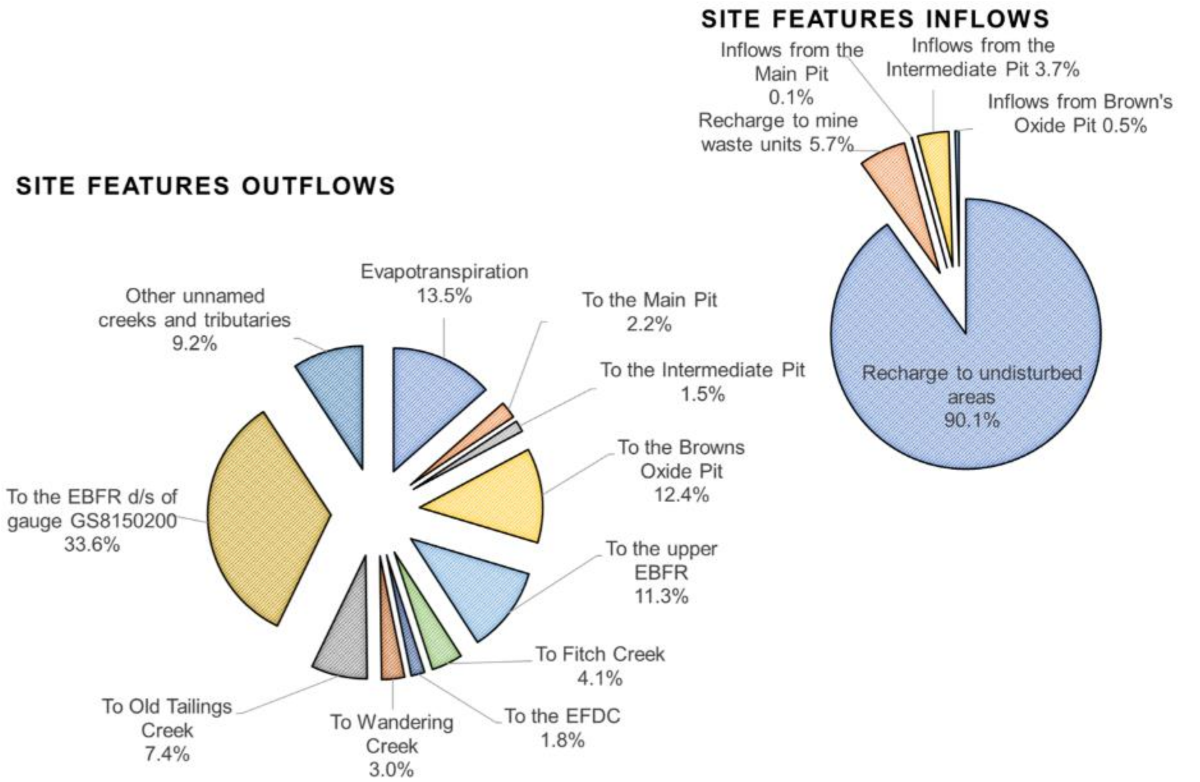


Figure 10-17: Simulated site features inflows and outflows (Average: 2011 to 2018)

Simulated Sulphate and Copper plumes

Simulated SO_4 and Cu plumes for historic conditions (1963 to 1985) and "current conditions" (1985 to 2018) in shallow bedrock (Layer 3) are provided in Figure 10-18 and Figure 10-19, respectively**.** The simulated plumes for 1985 are the initial condition for the "current conditions" model. Current conditions, in this case, refers to the site in its configuration, *i.e.* since rehabilitation in 1985 was completed. Further description of the model runs for 1963 to 1985 are provided in RGC (2019). These simulated initial conditions are critical for the predictive modelling for copper because they approximate the substantial mass of copper in local groundwater that is related to historic AMD sources, *e.g.* liquor losses from the Copper Extraction Pad and/or higher loads from the WRDs before they were covered in 1985.

For current conditions, the groundwater model simulates SO_4 plumes emanating (migrating) from each of the active AMD sources and residual impacted groundwater in the Old Tailings Dam area, the former ore stockpile area and in the Copper Extraction Pad area. SO_4 concentrations are highest near the Main and Intermediate WRDs and near Dyson's (backfilled) Pit. Elevated SO_4 concentrations are simulated in the Old Tailings Dam area due to SO_4 related to historic tailings that were re-located from this area in 1985. The SO_4 plume is simulated to reach the EBFR northeast of Intermediate Pit, where up to 500 mg/L SO_4 is simulated (see Figure 10-19). Simulated SO_4 plumes extend to each of the other creeks onsite and beneath the EFDC towards Intermediate Pit.

Simulated Cu plumes are less spatially extensive than the simulated SO_4 plume because the groundwater model incorporates substantial retardation and attenuation of copper due to adsorption and geochemical reactions in groundwater (see RGC, 2019). The highest Cu concentrations are simulated at the northern toe of Intermediate WRD (near the EFDC) and near Dyson's (backfilled) Pit, both of which are active AMD sources, and in the Copper Extraction Pad area where liquor loss in the 1960s was simulated with the historic model (see RGC, 2019). Elevated Cu is also simulated in the former ore stockpile area due to historic seepage from surface ore stockpiles that were removed during rehabilitation in the 1980s. Elevated Cu concentrations are not simulated north of the central mining area or northwest of Intermediate Pit near the EBFR.

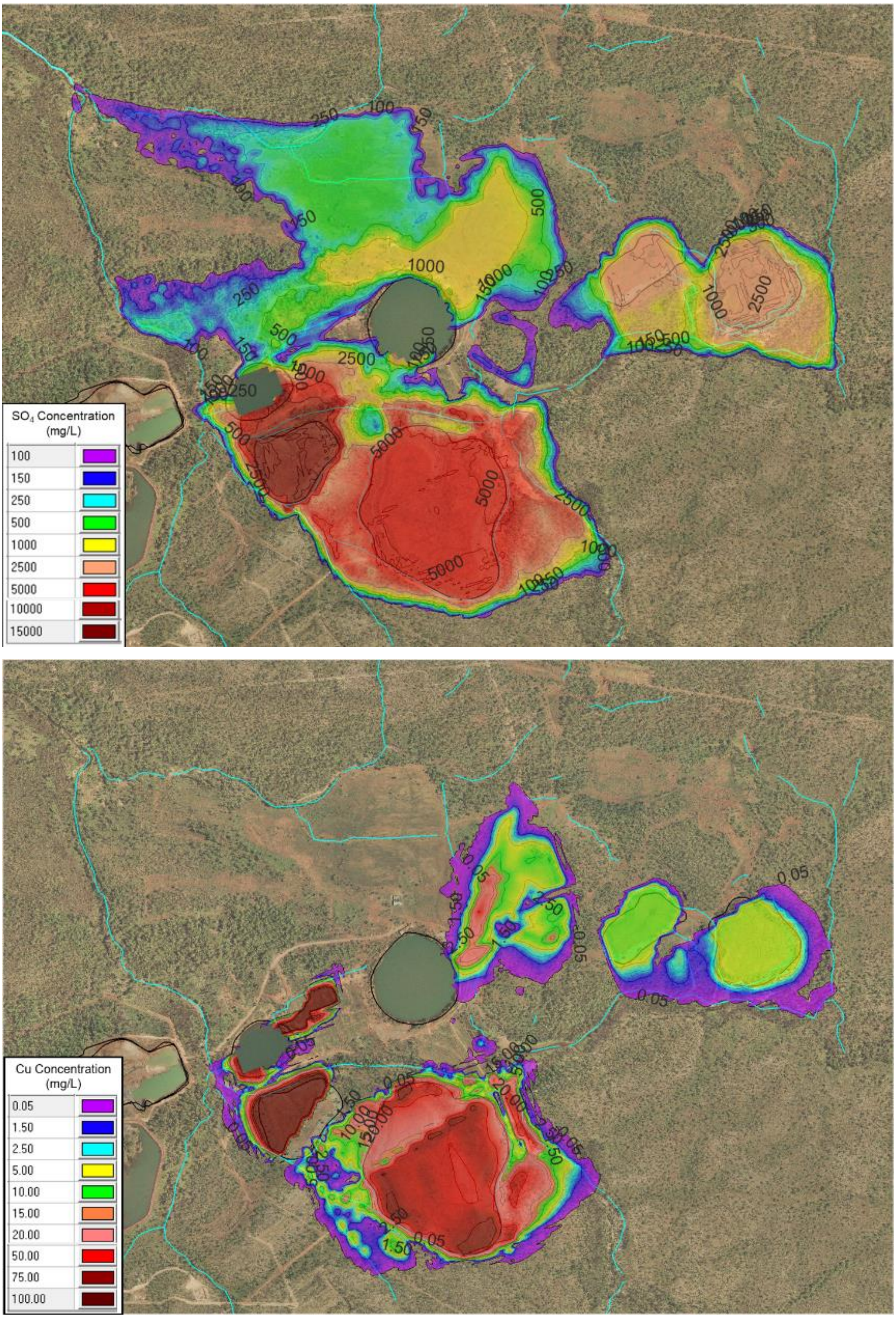


Figure 10-18: (Upper) Simulated Sulphate plume; (Lower) Simulated Copper plume, 1985

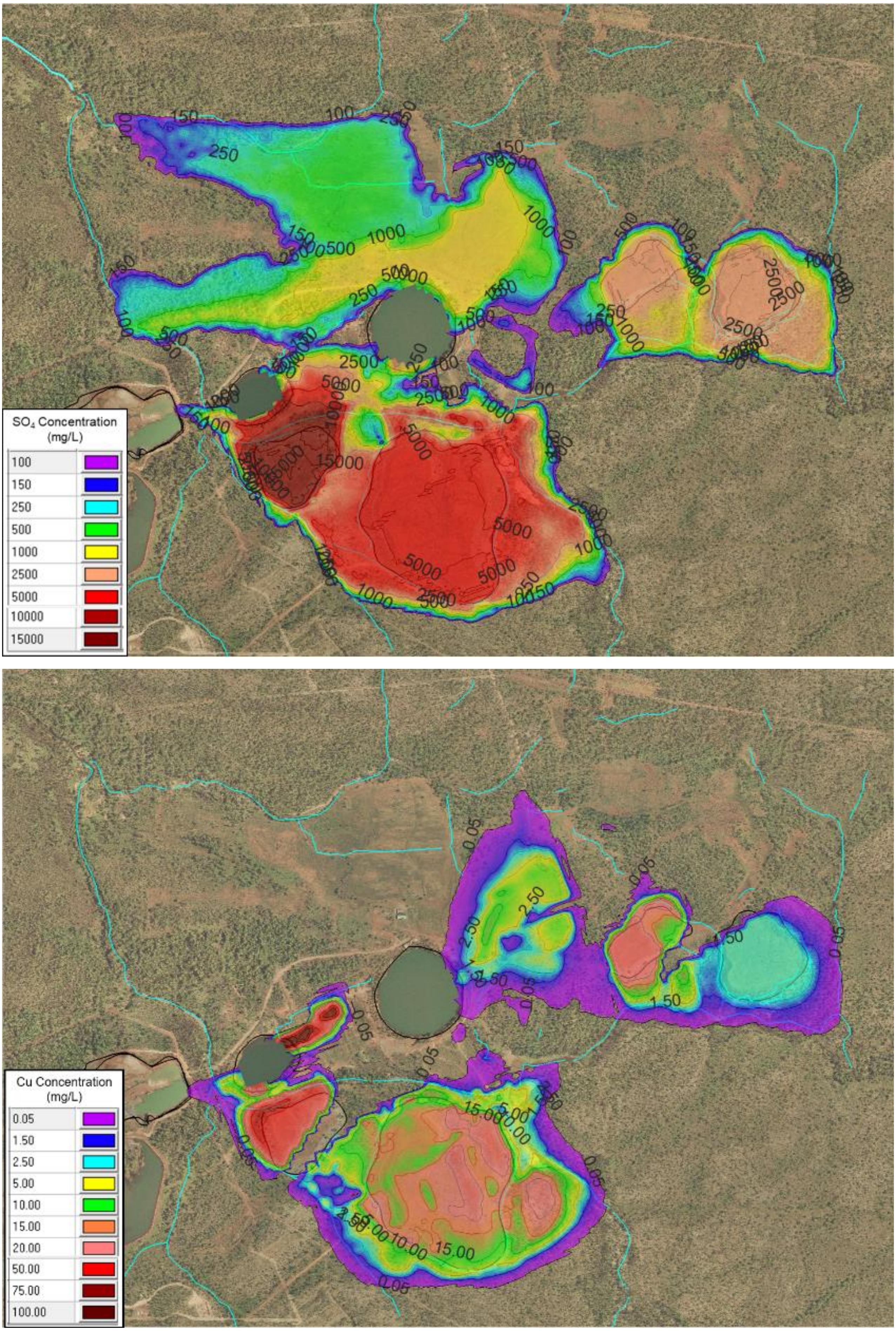


Figure 10-19: (Upper) Simulated Sulphate plume, (Lower) Simulated Copper plume, Current Conditions

Simulated annual Sulphate and Copper loads to EBFR

Simulated SO_4 and Cu loads to the EBFR (by reach) are summarised in Table 10-13 and Table 10-14, respectively. Overall, the results from the modelling indicate that the majority of SO_4 and Cu in the EBFR originates from the three WRDs and Dyson's (backfilled) Pit and/or residual AMD-impacted groundwater near these active AMD sources. The average simulated annual SO_4 load to the EBFR and the pits from 2010 to 2018 ranged from 1067 to 1697 t/yr SO_4, with the average being 1322 t/yr SO_4.

Simulated annual Cu loads range from 2.2 to 3.5 t/yr Cu, averaging at 2.8 t/yr. Nearly 90% of the SO_4 and Cu loads simulated by the model report to the EBFR with most of the remaining loads reporting to Main and Intermediate Pits. In the EBFR most of the SO_4 and Cu loads originate from Dyson's WRD and Dyson's (backfilled) Pit in Reach A, and Main and Intermediate WRDs in Reaches B, C, and E. Minor SO_4 loads report to other creeks and to the EBFR downstream of gauge GS8150200 in Reaches G, H and I.

Importantly, residual AMD-impacted groundwater in the Copper Extraction Pad area and in the former ore stockpile area is not simulated to be a major source of SO_4 or Cu to the EBFR in the "current conditions" model.

Table 10-13: Simulated Sulphate loads to EBFR (by Reach), Current Conditions

Reach Description		2010/2011 Water Year	2011/2012 Water Year	2012/2013 Water Year	2013/2014 Water Year	2014/2015 Water Year	2015/2016 Water Year	2016/2017 Water Year	2017/2018 Water Year	Average (2010 to 2018)	
		t/year	t/year	t/year	t/year	t/year	t/year	t/year	t/year	t/year	%
A	Dyson's Area	294	208	224	252	178	169	223	245	224	19%
B	Main WRD (east)	272	197	192	226	161	152	190	219	201	17%
C	Main WRD (west) and Int. WRD	224	142	136	170	114	108	146	193	154	13%
D	Middlebrook Creek	0	0	0	0	0	0	0	0	0	0%
E	EFDC near Main and Int. WRDs	605	469	447	531	417	418	480	501	484	41%
F	Former stockpile area	39	16	17	31	11	14	27	38	24	2%
G	EBFR downstream of GS8150200	70	64	43	64	52	54	63	57	58	5%
H	EBFR in Old Tailings Dam area	21	18	17	20	23	22	23	21	21	2%
I	EBFR near GS8150327	10	10	14	15	14	15	13	14	13	1%
	Simulated Load to EBFR:	**1537**	**1126**	**1090**	**1308**	**970**	**951**	**1166**	**1288**	**1179**	**100%**
-	To Main Pit	78	53	61	67	46	48	59	71	61	43%
-	To Int. Pit	48	66	88	68	53	59	63	71	64	45%
-	To Browns Pit	8	2	18	13	9	8	9	9	9	7%
-	To Model Flooding Drains	22	3	1	12	0	0	6	19	8	6%
	Simulated Load to Pits:	**157**	**124**	**168**	**160**	**109**	**115**	**136**	**170**	**142**	**100%**
	TOTAL:	**1,694**	**1,250**	**1,258**	**1,468**	**1,078**	**1,067**	**1,302**	**1,458**	**1,322**	**-**

Table 10-14: Simulated Copper loads to EBFR (By Reach), Current Conditions

Reach Description		2010/2011 Water Year	2011/2012 Water Year	2012/2013 Water Year	2013/2014 Water Year	2014/2015 Water Year	2015/2016 Water Year	2016/2017 Water Year	2017/2018 Water Year	Average (2010 to 2018)	
		t/year	t/year	t/year	t/year	t/year	t/year	t/year	t/year	t/year	%
A	Dyson's Area	0.5	0.3	0.4	0.5	0.3	0.3	0.4	0.5	0.4	17%
B	Main WRD (east)	0.5	0.3	0.3	0.4	0.3	0.3	0.3	0.4	0.4	15%
C	Main WRD (west) and Int. WRD	0.5	0.3	0.3	0.3	0.2	0.2	0.3	0.4	0.3	13%
D	Middlebrook Creek	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
E	EFDC near Main and Int. WRDs	1.6	1.2	1.2	1.4	1.1	1.1	1.3	1.3	1.3	54%
F	Former stockpile area	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
G	EBFR downstream of GS8150200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
H	EBFR in Old Tailings Dam area	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
I	EBFR near GS8150327	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
	Simulated Load to EBFR:	**3.1**	**2.1**	**2.2**	**2.6**	**1.9**	**1.9**	**2.3**	**2.6**	**2.3**	**100%**
-	To Main Pit	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	14%
-	To Int. Pit	0.4	0.4	0.4	0.4	0.3	0.3	0.4	0.4	0.4	85%
-	To Browns Pit	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
-	To Model Flooding Drains	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
	Simulated Load to Pits:	**0.5**	**0.4**	**0.5**	**0.5**	**0.3**	**0.4**	**0.5**	**0.5**	**0.5**	**100%**
	TOTAL:	**3.5**	**2.6**	**2.7**	**3.1**	**2.2**	**2.3**	**2.8**	**3.1**	**2.8**	**-**

10.5.2. Simulated Current Conditions (Surface Water)

Overview – Water and Load Balance Model

A site-wide water and load balance model (WLBM) was developed using the Goldsim software package (https://www.goldsim.com) to support decision-making and design work undertaken for the EIS. Modelling objectives were to:

- Validate the simulated SO_4 and Cu loads from the "current conditions" groundwater model to the EBFR from 2010 to 2018.
- Simulate groundwater and pit water flows to Intermediate Pit and a WTP to minimise potential spillage (overtopping) to the EBFR during the Construction phase of rehabilitation.
- Predict daily SO_4 and Cu concentrations in the EBFR to illustrate the timing and degree of future improvement in EBFR water quality once rehabilitation is complete.

The flow-related modelling objectives were achieved, in part, by using the Australian Water Balance Model (AWBM) to simulate daily streamflows in the EBFR and catchment yield components, including runoff from the model domain. The water management strategy for the construction period was also represented in Goldsim to simulate how groundwater and pit water flows will be managed based on the rate of waste re-location and pit water levels specified by the design team (SLR).

Objectives related to water quality were achieved by using outputs from the groundwater model (see Section 10.4) in the WLBM and accounting for additional background loads of SO_4 and Cu from upstream and from shallow flows (interflow) from the WRDs that are not simulated by the groundwater model. Further details on WLBM development are provided in RGC (2019).

Simulated water balance

Figure 10-20 illustrates the movement and storage of water within the boundaries of the model domain and the linkages between AMD sources, groundwater and the EBFR.

Simulated Streamflow in EBFR

Simulated and observed streamflows in the EBFR at gauges GS8150200, GS8150327 and GS8150097 from 2010 to 2018 are plotted in Figure 10-21. For further clarity, the same simulations are plotted in Figure 10-22 for the last three water years of the model calibration period. These figures show that the AWBM adequately simulates the magnitude and timing of flows in the EBFR under most conditions but that peak flows (particularly at gauge GS8150097) tend to be under-estimated. Flows up to 70 m^3/s are simulated to occur in January, February, and March at gauge GS8150097, after which flows are simulated to recede until the river is predicted to be dry from about July onwards. These same trends are repeated upstream at gauges GS8150200 and GS8150327.

Within the site, a portion of EBFR flows are diverted through Main and Intermediate Pits to ensure the pits are topped up and flushed annually. Flows through the pits are not routinely monitored so the split in flows between the EFDC and the pits cannot be directly specified. Instead, the system of culverts was represented in the WLBM using the original designs (see Cameron McNamara Consultants, 1985) to simulate these flows. The AWBM simulates peak flows routed through Main and Intermediate Pits and non-peak flows diverted through the EFDC (see Figure 10-23).

Simulated results show flows being routed to the pits for about 32% of the simulation period, predominantly between December and May when flows in the EFDC are generally greater than 70 L/s. Re-routed flows to the pits tend to be larger than those passing through the EFDC, and as such, 56% of the average annual volume within the EBFR at the inlet to the EFDC passes through the pits. This split flow pattern is a functional important element of the site as it ensures annual flushing of the pits with good quality water. However, it does not affect the simulations from the WLBM (provided there is complete mixing in the pits), as only combined flows and loads transported in the EBFR downstream of site are simulated.

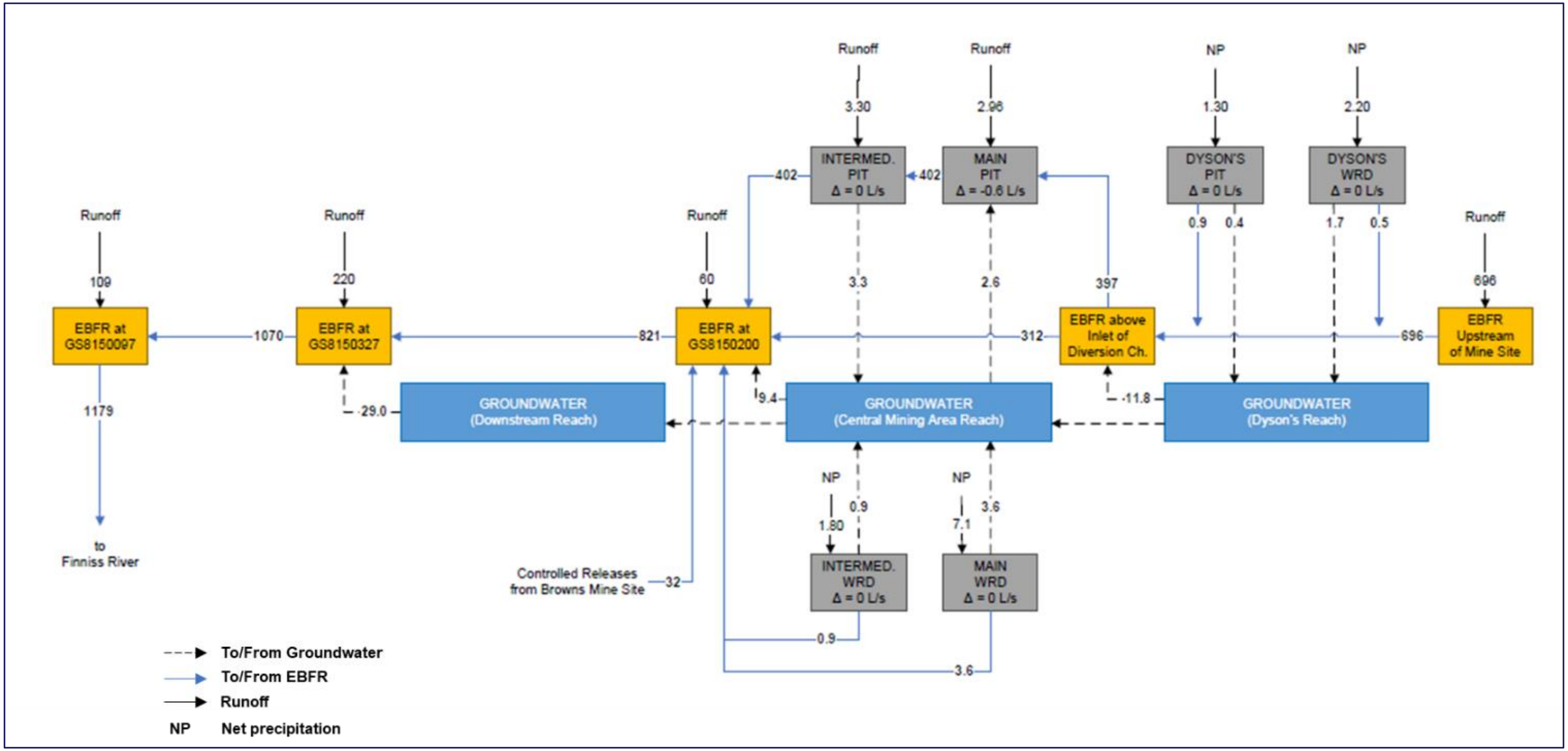


Figure 10-20: Simulated Average Annual Water Balance, 2010 to 2017. Flows expressed in L/s

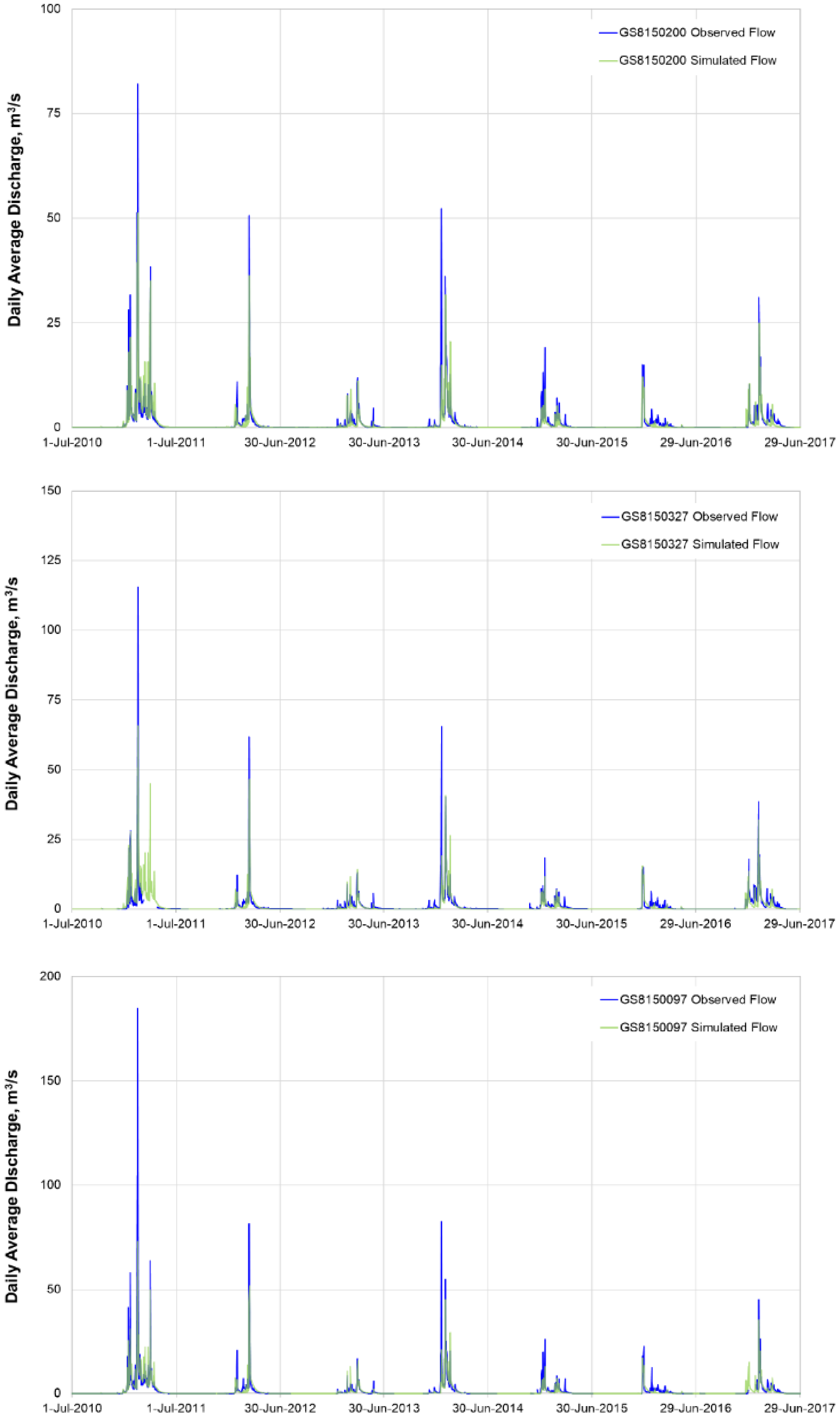


Figure 10-21: Simulated and observed streamflows in EBFR at GS8150200, GS8150327 and GS8150097. July 2010 to July 2017

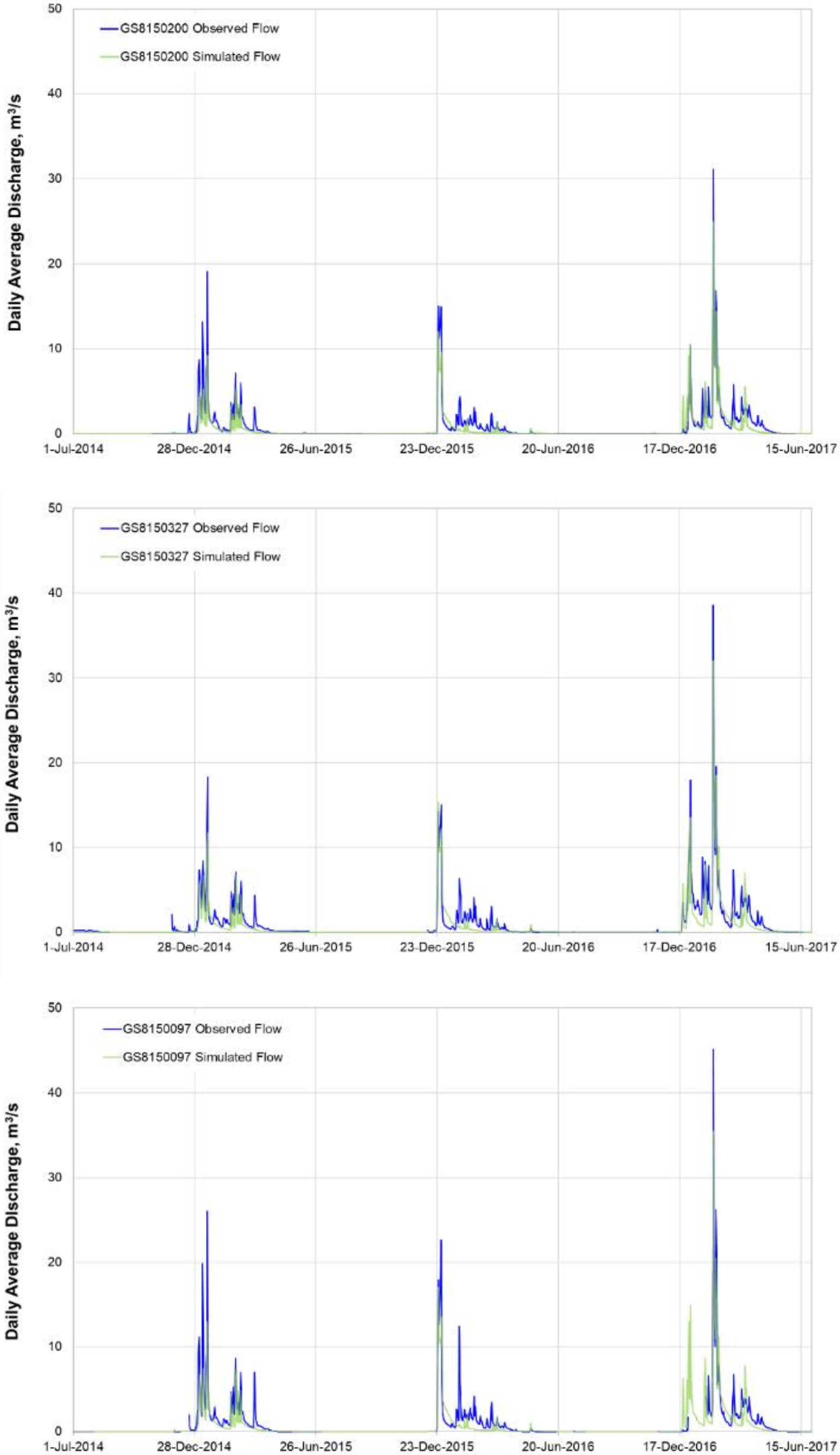


Figure 10-22: Simulated and observed streamflows in EBFR at GS8150200, GS8150327, and GS8150097. July 2014 to July 2017

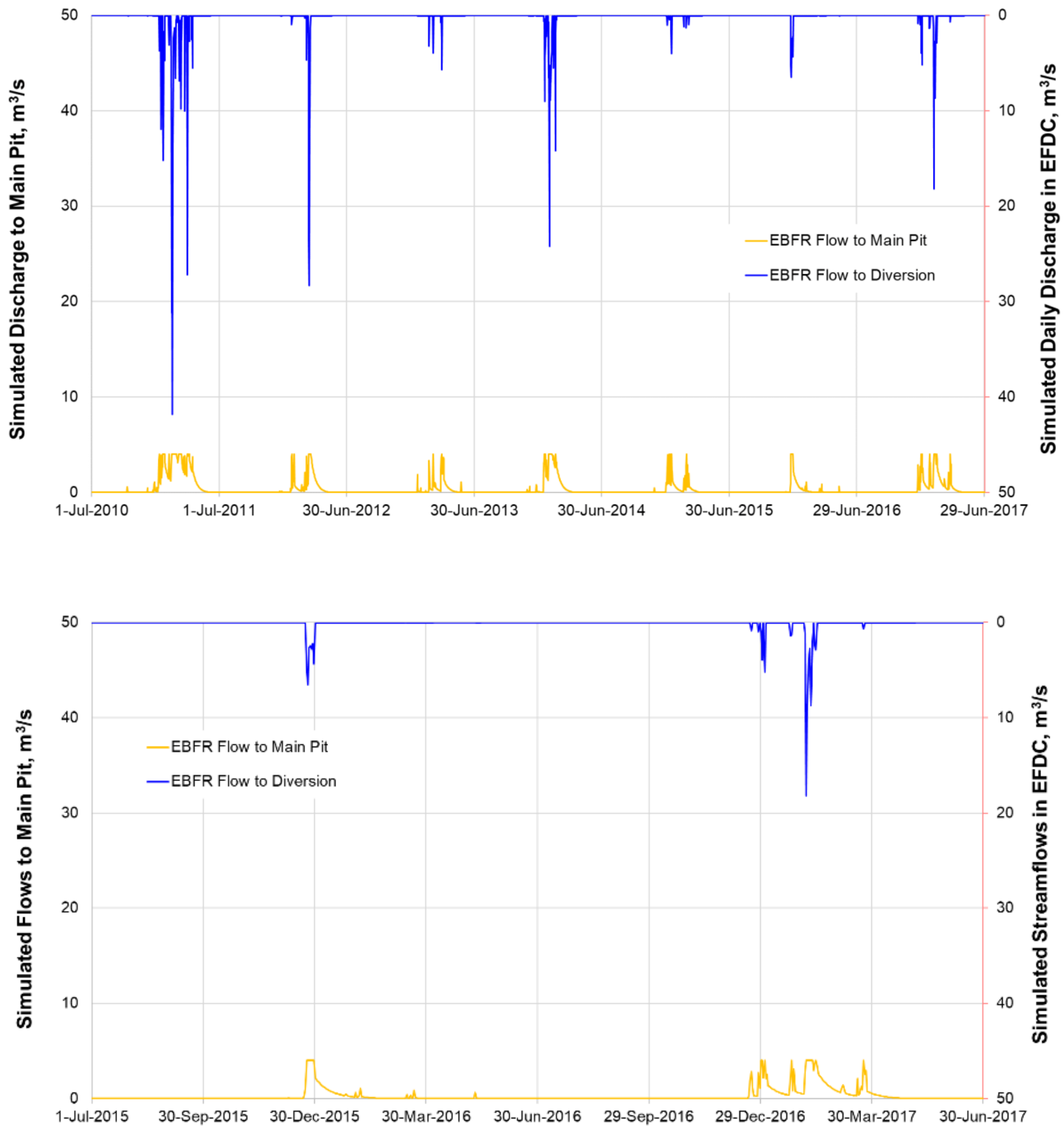


Figure 10-23: Simulated Flows to the Main Pit and EFDC. July 2010 to July 2017 (top) and July 1st, 2015, to July 1st, 2017 (bottom)

Simulated Sulphate and Copper loads in EBFR

SO_4 and Cu loads (outputs) from the groundwater model were incorporated into the WLBM to simulate total SO_4 and Cu loads in the EBFR. Simulated loads in the EBFR represent the sum of (i) simulated loads from the groundwater model, (i) natural loads to the EBFR from the upstream catchment and (iii) additional loads attributed to interflow from the historic WRDs. Interflow is shallow, fast-moving seepage that may carry a substantial load to the EBFR but is not simulated by the groundwater model. Further details on how the interflow component of load was represented in the WLBM are provided in RGC (2019).

Simulated SO_4 and Cu loads in the EBFR from the WLBM are summarised in Table 10-15 and Table 10-16, respectively. Observed SO_4 and Cu-t loads and Relative Percent Difference (RPD) values are provided for reference. The average RPD values for annual SO_4 loads range from 2 to 27%, with lower RPD values for gauges GS8150327 and GS8150097.

RPD values for Cu are generally higher than RPD values for SO_4 and the WLBM tends to over-estimate Cu loads in the EBFR. This is particularly evident for high rainfall years when the load from interflow is simulated to be much higher (as it is a fixed percentage of rainfall) than observed. This finding suggests that the governing assumption breaks down when the amount of infiltration exceeds a certain threshold. Conceptually this is not unreasonable because there is likely a finite reservoir of solutes that have been produced and stored within the rock matrix during intervening dryer periods. Once this is leached out, no more metal will be available for leaching by further infiltration. For more typical years, *e.g.* 2014/2015 Water Year, RPD values are lower, suggesting a better fit between the simulated and observed Cu loads.

Overall, the simulated SO_4 and Cu loads are close enough to observed loads to allow predictions to be made of SO_4 and Cu concentrations in the EBFR and, more importantly, to support decision-making as part of the EIS review process.

Table 10-15: Comparison of observed and simulated SO_4 loads in the EBFR, 2010 to 2017

Gauge	Load	Units	2010/2011 Water Year	2011/2012 Water Year	2012/2013 Water Year	2013/2014 Water Year	2014/2015 Water Year	2015/2016 Water Year	2016/2017 Water Year	Average (2010 to 2017)
GS8150200	Observed	t/year SO_4	2,086	1,100	821	1,960	914	893	1,119	**1,270**
	Simulated	t/year SO_4	2,992	1,550	1,271	1,860	1,155	1,145	1,655	**1,661**
	RPD	%	36%	34%	43%	5%	23%	25%	39%	**27%**
GS8150327	Observed	t/year SO_4	-	1,886	1,233	2,992	1,010	1,112	1,759	**1,665**
	Simulated	t/year SO_4	3,149	1,662	1,365	1,987	1,256	1,256	1,785	**1,780**
	RPD	%	-	13%	10%	40%	22%	12%	1%	**7%**
GS8150097	Observed	t/year SO_4	3,354	1,707	973	2,244	1,196	1,074	1,648	**1,742**
	Simulated	t/year SO_4	3,155	1,664	1,366	1,989	1,257	1,257	1,787	**1,782**
	RPD	%	6%	3%	34%	12%	5%	16%	8%	**2%**

Table 10-16: Comparison of observed and simulated Copper loads in the EBFR, 2010 to 2017

Gauge	Load	Units	2010/2011 Water Year	2011/2012 Water Year	2012/2013 Water Year	2013/2014 Water Year	2014/2015 Water Year	2015/2016 Water Year	2016/2017 Water Year	Average (2010 to 2017)
GS8150200	Observed	t/year Cu-t	5.1	2.4	1.9	3.7	2.4	1.9	1.7	**2.7**
	Simulated	t/year Cu-t	4.1	2.3	2.1	2.8	1.9	1.9	2.5	**2.5**
	RPD	%	22%	2%	10%	28%	24%	1%	40%	**8%**
	Observed	t/year Cu-d	-	-	-	1.1	1.1	0.8	1.4	**1.1**
	Simulated	t/year Cu-d	-	-	-	-	-	-	-	-
	RPD	%	-	-	-	-	-	-	-	-
GS8150327	Observed	t/year Cu-d	-	-	0.5	2.6	0.6	0.7	1.7	**1.2**
	Simulated	t/year Cu-d	2.9	1.0	0.6	1.4	0.6	0.5	1.3	**1.2**
	RPD	%	-	-	24%	57%	6%	22%	27%	**1%**
	Observed	t/year Cu-t	-	2.2	1.5	5.7	1.4	2.6	2.4	**2.6**
	Simulated	t/year Cu-t	4.7	2.1	1.3	3.9	1.0	1.4	3.5	**2.6**
	RPD	%	-	3%	13%	37%	33%	60%	39%	**2%**
GS8150097	Observed	t/year Cu-d	-	-	0.3	2.1	0.6	0.6	1.4	**1.0**
	Simulated	t/year Cu-d	3.1	1.1	0.7	1.5	0.6	0.6	1.4	**1.3**
	RPD	%	-	-	64%	33%	0%	12%	1%	**24%**
	Observed	t/year Cu-t	7.1	2.0	0.8	3.5	1.6	1.7	3.2	**2.8**
	Simulated	t/year Cu-t	4.7	2.1	1.3	3.9	1.0	1.4	3.5	**2.6**
	RPD	%	40%	5%	49%	11%	44%	22%	8%	**10%**

Simulated Sulphate and Copper concentrations in EBFR

SO_4 and Cu concentrations were simulated by importing the simulated monthly SO_4 and Cu loads from the groundwater model into the WLBM. Monthly average loads were assigned to each day of a month unless streamflows in the EBFR decreased below 0.05 m^3/s, which necessitated storing the load and releasing it when streamflows increased. Loads from interflow were also added and simulated Cu loads were slightly decreased in proportion to the load attributed to interflow (see RGC, 2019).

Simulated SO_4 and Cu concentrations in the EBFR at gauges GS8150200, GS8150327 and GS8150097 are shown in Figure 10-24**,** Figure 10-25**,** and Figure 10-26, respectively. Simulated SO_4 and Cu concentrations are represented by a dashed line (by convention), whereas observed concentrations appear as circles. An additional, more quantitative description of the goodness of fit between simulated and observed concentrations is provided in RGC (2019), with additional details also provided on the methods used to derive the concentrations.

Simulated SO_4 concentrations in the EBFR at gauge GS8150200 are highest during the early Wet season and at the end of the Wet season when surface flows in the EBFR are receding. During the Wet season, SO_4 concentrations are at their lowest due to substantial dilution in the creek. For most years, the magnitude and trends in SO_4 concentrations are simulated reasonably well (see RGC, 2019, for details on this) by the WLBM. The WLBM also simulates Cu concentrations in the EBFR at gauge GS8150200 reasonably well, as the magnitude of Cu concentrations during the Wet season is consistent with observations, and the changes at the beginning and end of the Wet season are accounted for. These results suggest the magnitude and daily trends in daily SO_4 and Cu concentrations in the EBFR can be simulated with a reasonable degree of confidence, without the need to over-parameterise the groundwater model or the WLBM.

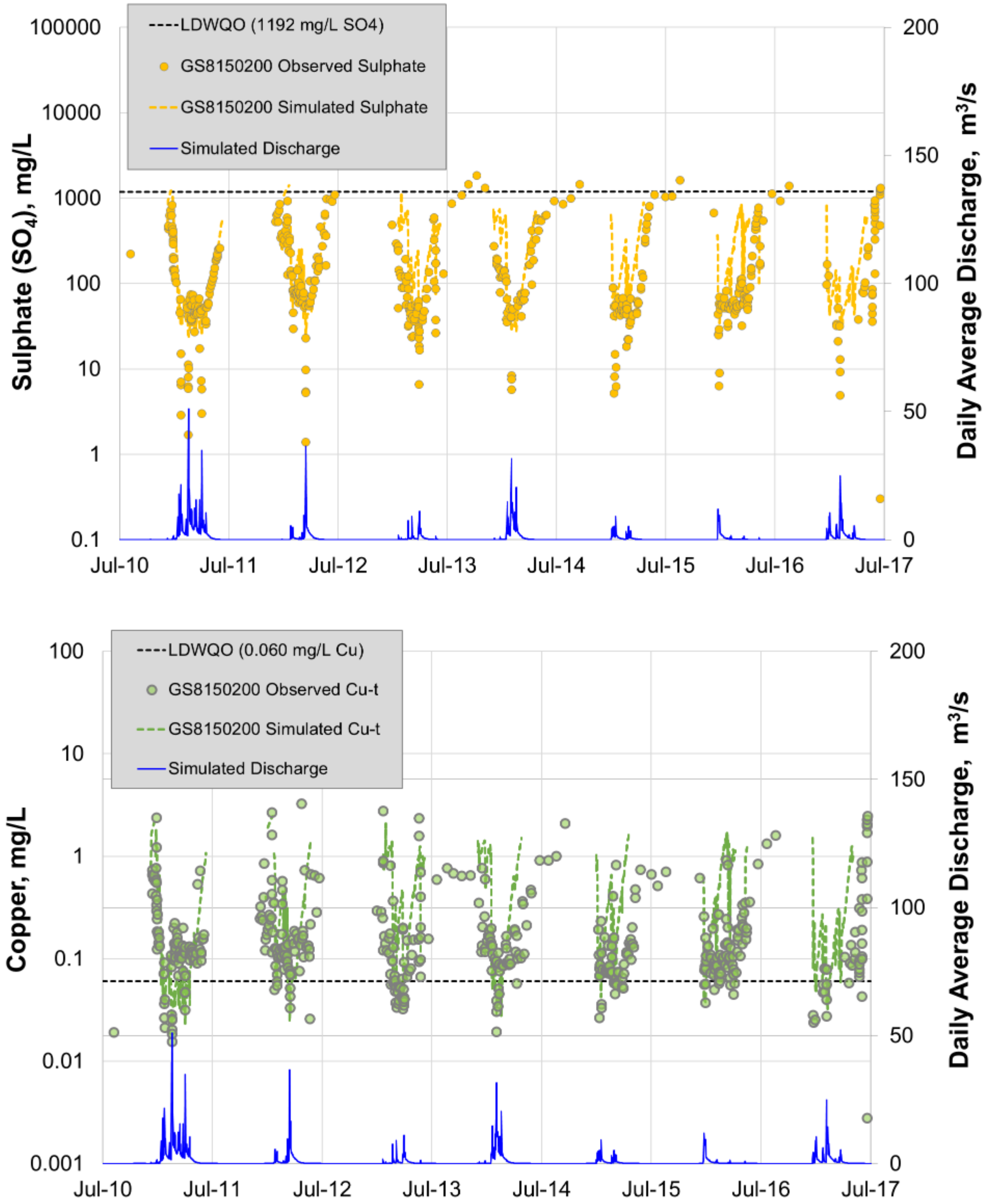
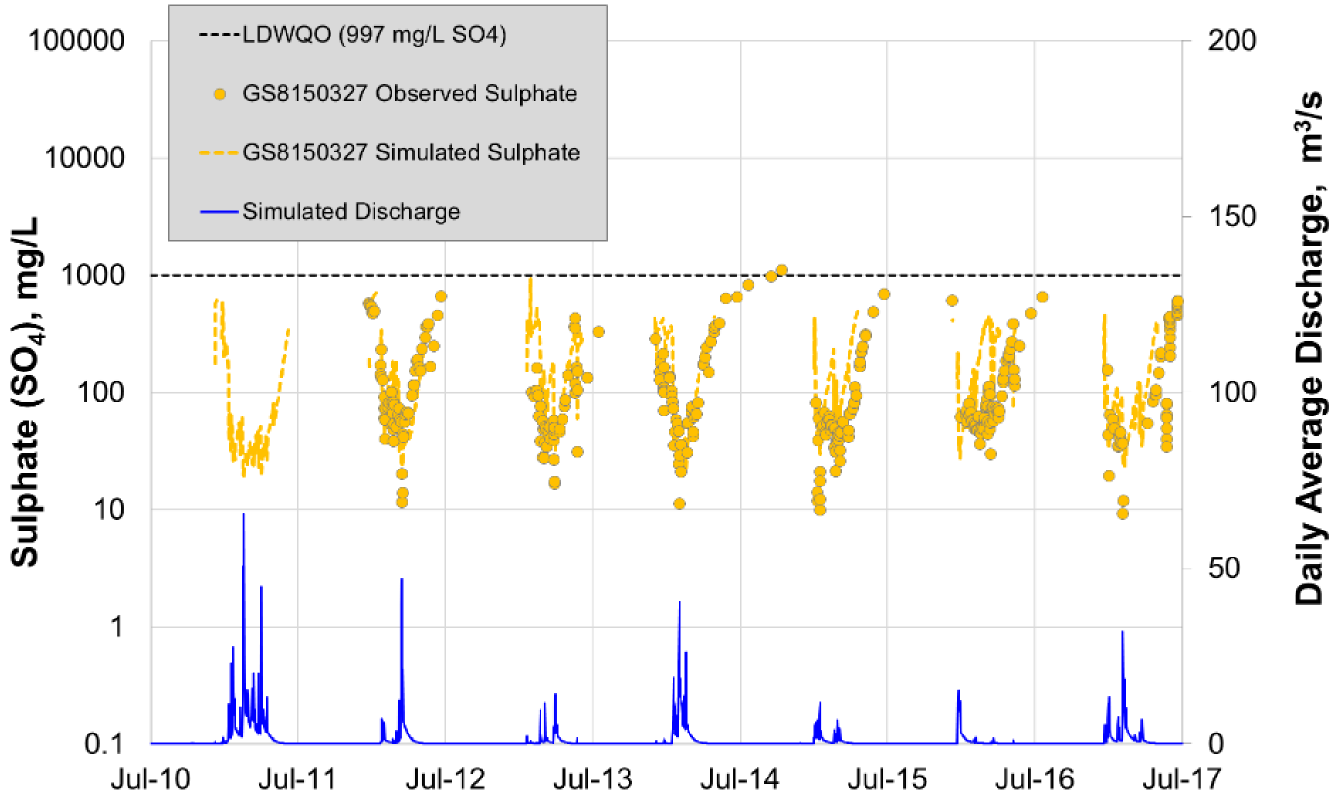


Figure 10-24: Simulated and observed Copper and Sulphate concentrations in the EBFR at gauge GS8150200, 2010 to 2017



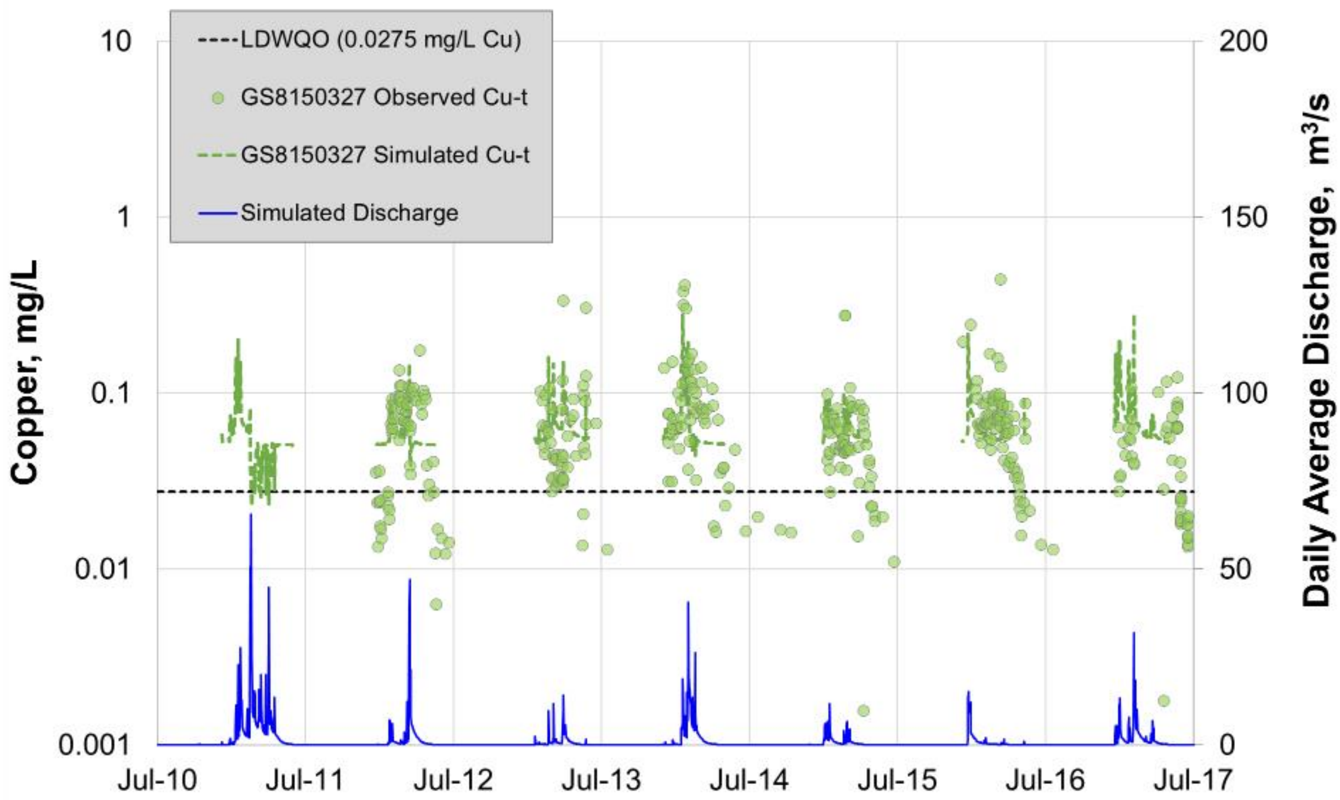
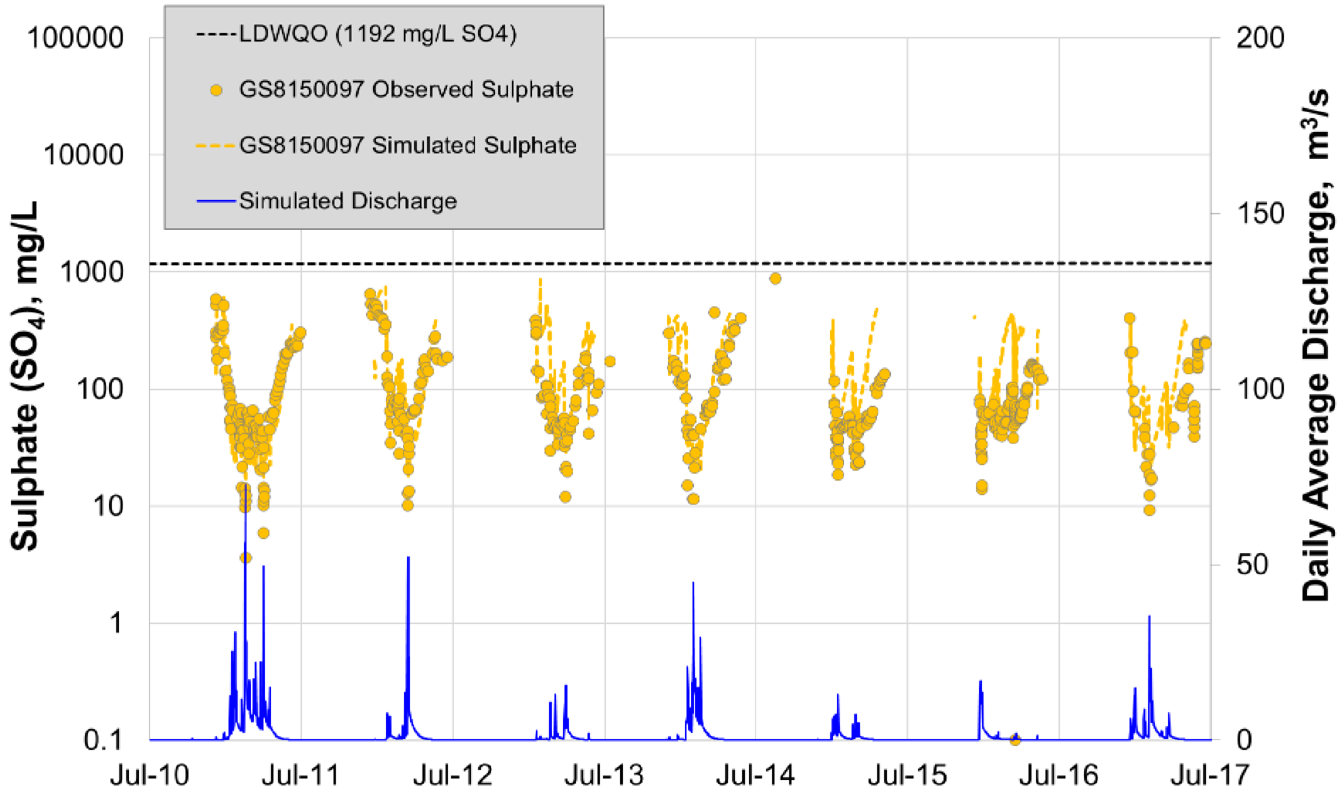


Figure 10-25: Simulated and observed Copper and Sulphate concentrations in the EBFR at gauge GS8150327, 2010 to 2017



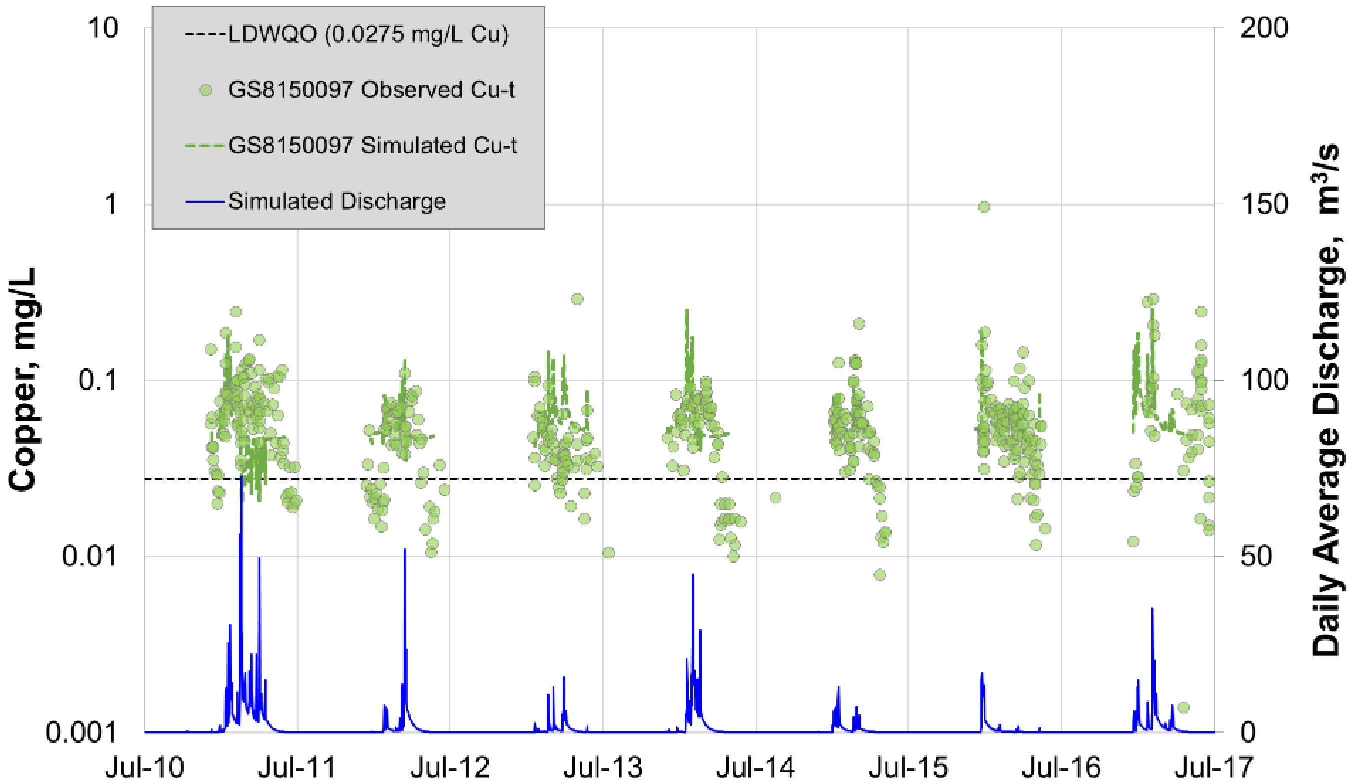


Figure 10-26: Simulated and observed Copper and Sulphate concentrations in the EBFR at gauge GS8150097, 2010 to 2017

10.6. Predicted Water Quality Improvements for Rehabilitation

10.6.1. Predictive Groundwater Modelling

Groundwater Model adaptations

Groundwater conditions during the Construction phase of rehabilitation were predicted by adjusting the calibrated groundwater model. Key adaptations were to:

- Represent the effect of thirteen groundwater recovery bores (SIS bores) that are intended to reduce loads to the EBFR during the Construction phase of rehabilitation and reduce the extent of impacted groundwater (plumes) that may discharge to the EBFR post-rehabilitation (see Figure 10-27). The bores would be constructed in the Year 1 Dry season and are assumed to operate throughout the Construction phase of rehabilitation and for five years after construction earthworks are completed. Seepage may also be collected from (i) the existing ditch along the western toe of Main WRD (*via* a sump near the head of the EFDC) and/or (ii) an interceptor trench along the northern “toe” of Intermediate WRD.
- Represent the effect of three groundwater recovery bores in the Copper Extraction Pad area and one recovery bore in the former ore stockpile area that are intended to improve local groundwater quality in these areas.
- Progressively reduce the extents of the WRD footprints and the footprint of Dyson’s (backfilled) Pit each year as material is hauled to either the WSF or Main Pit. This was done by assuming any changes in the residual footprint areas at the end of a Dry season are represented in the subsequent Wet season, based on footprint areas provided by SLR (see Figure 10-28).
- Maintain a fixed pit water level (58 m AHD) in Main Pit during pit backfilling in Years 1 to 4, *i.e.* three Wet seasons, to allow the conveyor proposed by SLR to operate safely and efficiently during a range of rainfall (runoff) conditions (see *Water Management Plan* for further details).
- Maintain a fixed pit water level for Intermediate Pit approximately 8 m (49 m AHD) below the invert elevation of the outlet to provide adequate live storage to prevent spillage from Intermediate Pit during backfilling for most rainfall events (see *Water Management Plan* for further details).
- Assume seepage to groundwater from the new WSF at a rate of 21 mm/yr through the horizontal top and 17 mm/yr for the side-slopes, as *per* infiltration rates for the “Cover #3 Low NP” cover alternative from O’Kane Consultants (2013). This rate represents infiltration through the closure cover proposed for the WSF and does not consider water introduced during the construction period, either by rainfall dust suppression or to compact waste rock. Seepage from the WSF to groundwater was assumed to start in Year 6 when the WSF is complete. Seepage to groundwater is assigned source concentrations of 10,000 mg/L SO_4 and 0.2 mg/L Cu as *per* RGC and Jones (2019).
- Assume seepage from backfill materials in Main Pit to groundwater downgradient in Year 5 and onwards. The seepage rate is proportional to a constant head boundary that is assumed to maintain at least 2 m of water over the sand backfill in Main Pit. Seepage from backfill materials is assigned 2,000 mg/L SO_4 and 0.2 mg/L Cu, based on batch testing results provided in RGC and Jones (2019).
- Cease operating the recovery bores after the Year 10 Wet season.

Further details on water management planning and the rationale for the assumed pit water levels is provided in the *Water Management Plan* and later in this chapter.

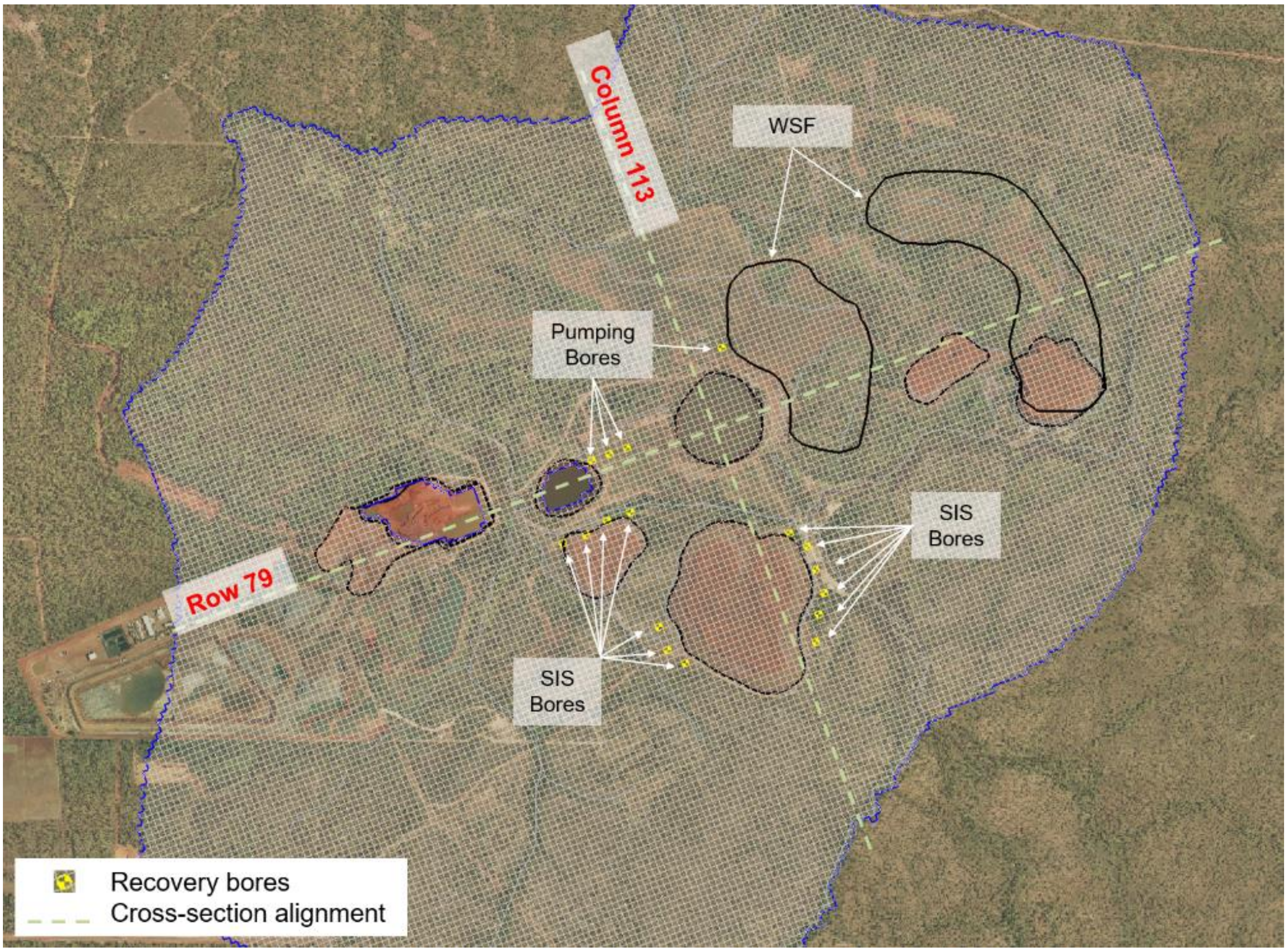


Figure 10-27: Recovery bore locations and cross-section alignments. Cross-section alignments for Figures 10-40 to 10-43 are shown

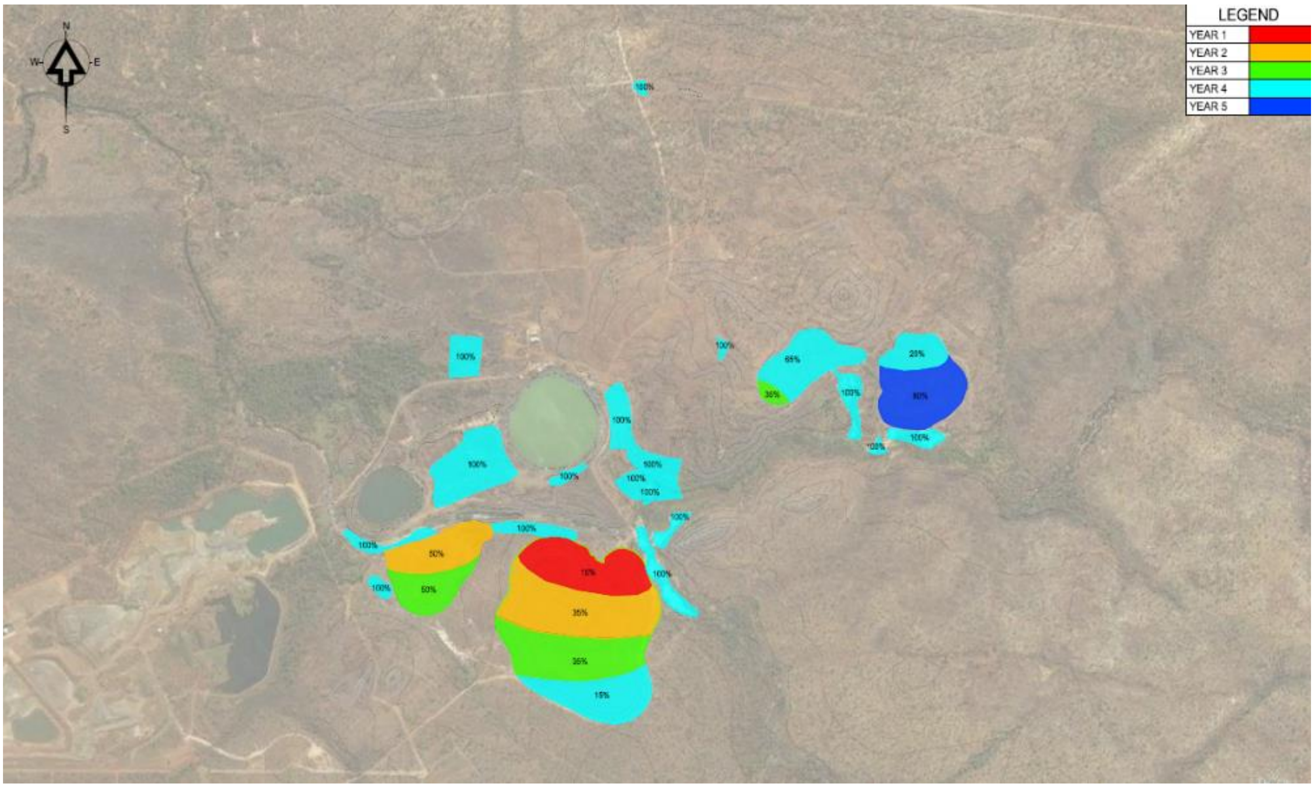


Figure 10-28: Waste re-location sequence and residual WRD footprints

Predicted groundwater conditions – Construction phase

Simulated SO_4 and Cu plumes for Years 1 to 10 are shown in Figure 10-29 and Figure 10-30, respectively. Predicted loads to the EBFR and the pits during the construction period are summarised in Table 10-17 and Table 10-18. Key observations from these figures and tables are summarised below:

- The SIS bores and the recovery bores in the Copper Extraction Pad area and former ore stockpile area are simulated to extract a combined 10 L/s during the Dry season and 20 L/s during the Wet season, or about 1 to 2 L/s *per* bore. These flows are the maximum able to be sustained by pump extraction based on the calibrated hydraulic properties for bedrock, *i.e.* Rum Jungle Complex near the Main WRD and Whites Formation near the Intermediate WRD.
- The SIS bores are predicted to recover more than 1000 t/yr SO_4 in Years 1, 2, and 3. Annual loads are then predicted to decrease as the extent of the SO_4 plumes is reduced by pumping, particularly after the Main and Intermediate WRDs have been re-located. The SIS bores recover 6 to 8 t/yr Cu in Years 1 to 8 and slightly less in Years 9 and 10. The average annual Cu load recovered during the construction period is 6.6 t/yr. This load is approximately twice the observed Cu load in the EBFR for current conditions, as the Cu load recovered in the Copper Extraction Pad area is predicted to be substantial.
- A substantial reduction during the construction period in the extent of the AMD-impacted groundwater is predicted by the model due to operating the SIS and recovery bores in the Copper Extraction Pad area and former ore stockpile area. The extent of the simulated SO_4 and Cu plumes is reduced to a greater extent after the active AMD sources onsite (the WRDs and shallow backfill materials in Dyson's (backfilled) Pit) have been removed. This is particularly evident for SO_4 because it is assumed to be transported conservatively in groundwater. Cu plumes are slower to reduce in strength and extent because the SIS relies on Cu-impacted groundwater near and within the WRD footprints reaching the SIS bores near the EBFR. The rate of reduction of Cu loads in the system will be much slower than for SO_4, since, as discussed previously, it is dependent on the rate of desorption/dissolution of Cu from the rock matrix.
- There are no SIS bores proposed to be installed in the Dyson's Area because the Cu load to the EBFR is considered small enough that LDWQOs could be achieved during construction without recovering this load. Hence groundwater quality in Dyson's Area is not predicted to start to improve until waste rock from Dyson's WRD and shallow backfill materials from Dyson's Pit are re-located and groundwater in this area begins to be diluted and eventually flushed by rainfall without an AMD source present.
- In Year 5, a SO_4 plume is predicted to start emanating from the backfilled Main Pit and SO_4 plumes emanating from the new WSF footprints are predicted to develop. The predicted SO_4 plume from the Eastern WSF footprint migrates north and then west towards Old Tailings Creek. The SO_4 plume from the Western WSF footprint is simulated to move west until it reaches Main Pit. A Cu plume is also predicted to develop from the Main Pit backfill but is characterised by concentrations that are too small to differentiate from residual impacted groundwater in the Copper Extraction Pad area. A low-strength Cu plume from the WSF is restricted in extent and difficult to discern at the regional scale of the groundwater model.
- In Year 9, the groundwater model predicts that SO_4 and Cu loads to the EBFR will be reduced to 66 t/yr and 0.24 t/yr, respectively. These loads are both at least an order-of-magnitude lower than the simulated SO_4 and Cu loads for current conditions, suggesting SO_4 and Cu concentrations in the EBFR will likely be much lower than LDWQOs while the SIS is operating. Also, the loads intercepted approach a lower bound by Year 10, suggest the low loading could persist once the SIS ceases to operate, implying the SIS is only needed as a transition until the residual metal plumes are adequately flushed.
- In Year 10, the groundwater model predicts residual Cu plumes near the northern toe of Intermediate WRD (where it meets the EFDC) and near the northeast corner of Main WRD. These residual plumes account for most of the post-rehabilitation Cu load to the EBFR and could affect whether LDWQOs for Zone 2 are achieved post-rehabilitation. More detailed modelling could be done during the detailed design phase of the project to help determine if these residual plumes may be problematic or if the current predictions of the groundwater model are over-estimating the extent and strength of the Cu plumes in these areas (see RGC, 2019).

Table 10-17: Predicted Sulphate loads during construction period

Reach	Description	Current Conditions	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Average (Years 5 to 10)	
		t/year	t/year	t/year	t/year	t/year	t/year	t/year	t/year	t/year	t/year	t/year	t/year	%
A	Dyson's Area	224	118	146	147	150	124	59	37	32	27	25	50	56%
B	Main WRD (east)	201	21	4	1	1	0	0	0	0	0	0	0	0%
C	Main WRD (west) and Int. WRD	154	22	13	9	6	3	3	2	2	1	1	2	2%
D	Middlebrook Creek	0	0	0	0	0	0	0	0	0	0	0	0	0%
E	EFDC near Main and Int. WRDs	484	9	10	8	6	5	5	4	4	3	3	4	5%
F	Former stockpile area	24	9	6	5	5	4	7	7	7	7	7	6	7%
G	EBFR downstream of GS8150200	58	2	0	0	0	5	13	13	13	13	13	12	13%
H	EBFR in Old Tailings Dam area	21	5	2	1	1	2	7	8	8	8	8	7	8%
I	EBFR near GS8150327	13	5	2	1	1	2	6	8	9	9	10	7	8%
	Simulated Load to EBFR:	**1,179**	**192**	**183**	**172**	**169**	**146**	**100**	**80**	**75**	**69**	**66**	**89**	**100%**
-	To Main Pit	61	42	47	46	48	37	37	26	25	25	25	29	86%
-	To Int. Pit	64	235	276	225	195	3	4	3	3	3	3	3	9%
-	To Browns Pit	9	0	0	0	0	1	2	2	2	2	2	2	5%
-	To Model Flooding Drains	8	1	1	1	0	0	0	0	0	0	0	0	0%
	Simulated Load to Pits:	**142**	**277**	**324**	**271**	**243**	**40**	**43**	**31**	**30**	**30**	**29**	**34**	**100%**
-	Load to SIS and recovery bores	-	1112	1398	1004	703	446	381	325	295	282	266	332	-

Table 10-18: Predicted Copper loads during construction period

Reach	Description	Current Conditions	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Average (Years 5 to 10)	
		t/year	t/year	t/year	t/year	t/year	t/year	t/year	t/year	t/year	t/year	t/year	t/year	%
A	Dyson's Area	0.40	0.24	0.29	0.29	0.31	0.28	0.25	0.22	0.21	0.20	0.19	0.23	84%
B	Main WRD (east)	0.36	0.04	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	3%
C	Main WRD (west) and Int. WRD	0.30	0.06	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	9%
D	Middlebrook Creek	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
E	EFDC near Main and Int. WRDs	1.26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4%
F	Former stockpile area	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1%
G	EBFR downstream of GS8150200	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
H	EBFR in Old Tailings Dam area	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
I	EBFR near GS8150327	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
	Simulated Load to EBFR:	**2.33**	**0.35**	**0.36**	**0.35**	**0.36**	**0.33**	**0.30**	**0.26**	**0.25**	**0.24**	**0.23**	**0.27**	**100%**
-	To Main Pit	0.06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	12%
-	To Int. Pit	0.38	0.7	1.2	1.2	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.02	86%
-	To Browns Pit	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	2%
-	To Model Flooding Drains	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0%
	Simulated Load to Pits:	**0.45**	**0.7**	**1.3**	**1.3**	**1.3**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.02**	**100%**
-	Load to SIS and recovery bores	-	4.8	7.8	6.9	6.5	7.9	7.4	6.7	6.3	5.8	5.4	6.6	-

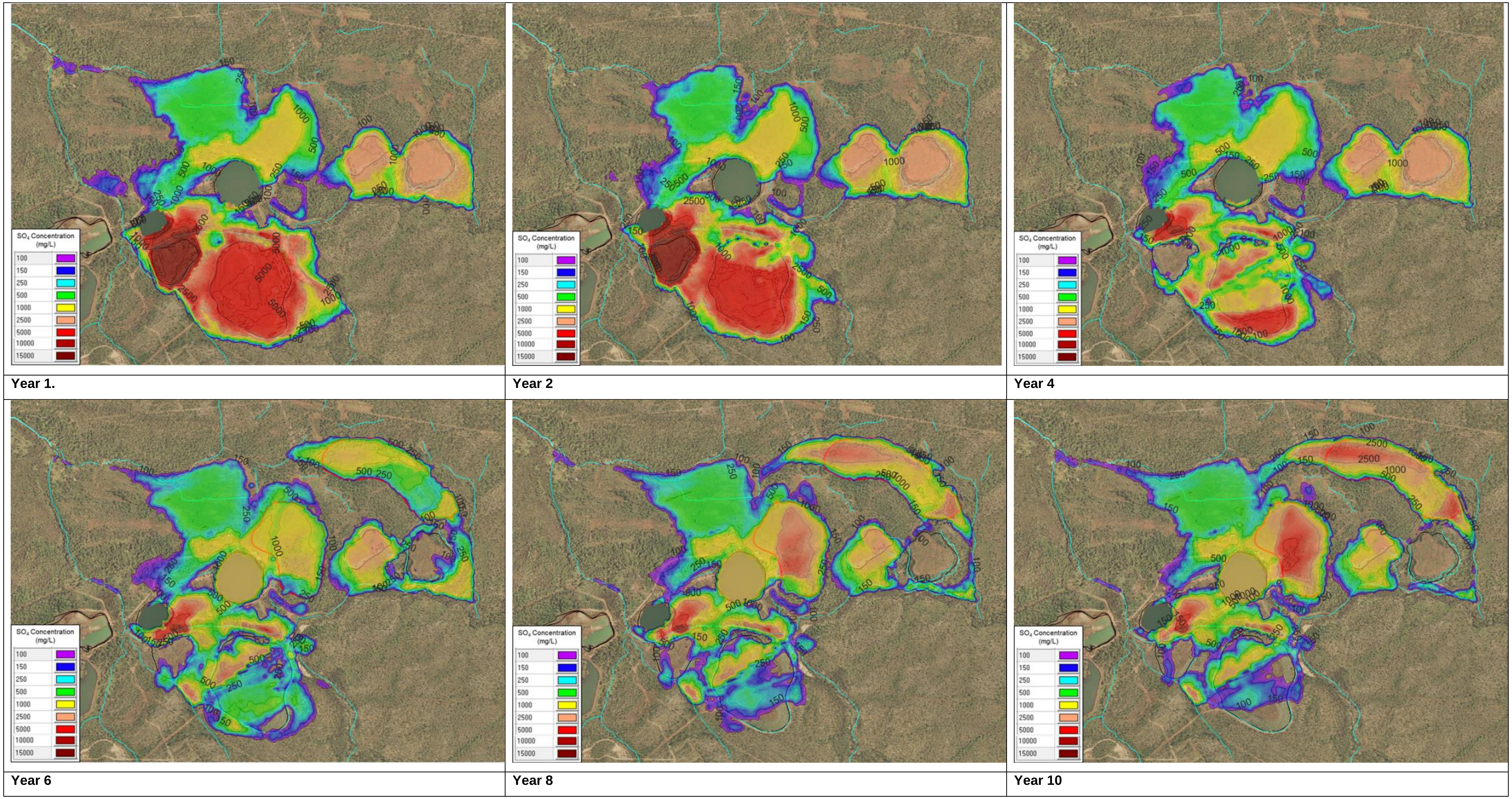
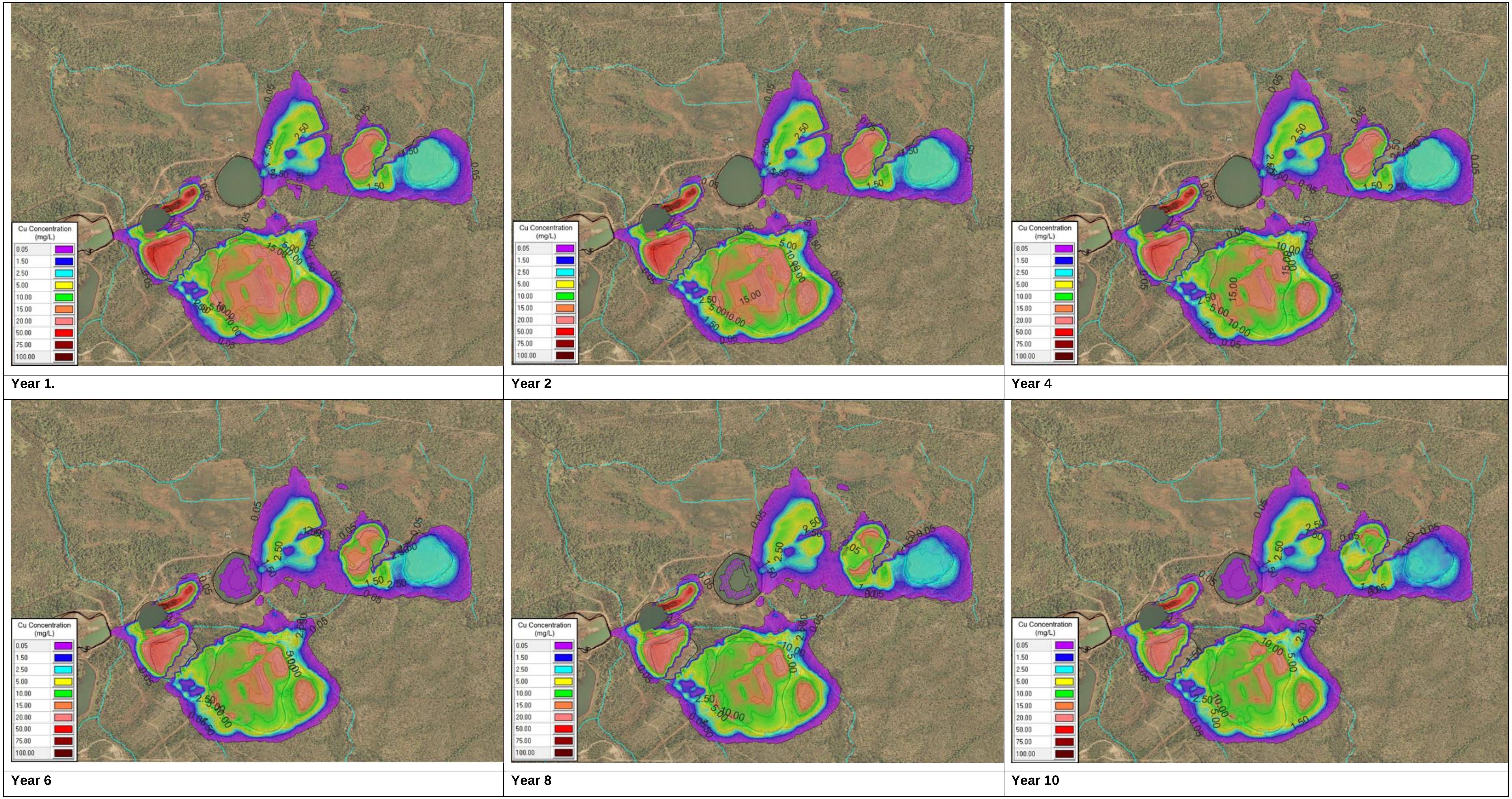


Figure 10-29: Predicted Sulphate plumes, construction period



Year 1. | **Year 2** | **Year 4**

Year 6 | **Year 8** | **Year 10**

Figure 10-30: Predicted Copper plumes, construction period

Water management during construction

It is currently proposed that waste rock will be deposited in Main Pit by a conveyor system that will extend onto the surface of the pit lake *via* a system of articulated pontoons. Waste rock will be discharged at the surface of the pit lake and dropped through the water column to the bottom of the pit. Agricultural lime will be mixed with waste rock before it is placed and hydrated lime could be added directly to pit water to ensure the entire pore volume is initially neutralised. Before waste rock is added, a bridging layer of sand will be deposited over the tailings present in the pit to minimise the possibility of waste rock from penetrating the tailings and displacing this material upwards.

Rock will continue to be placed until it is approximately 1.5 m below the predicted minimum post-groundwater level. The system of articulated pontoons will allow this configuration to be achieved by moving the discharge point of the conveyor around the pit lake in a systematic manner, allowing for an even distribution of waste rock. The deposited waste rock will ultimately be capped with a layer of clean material (rock and sand) to physically separate it from the overlying water column.

The Main Pit will be backfilled during Years 1 to 4. Water management during construction will entail managing the pit water displaced during backfilling and the groundwater flows from the SIS and the recovery bores in the Copper Extraction Pad area and former ore stockpile area. The recovery bores will operate from Year 1 to 10 and recovered groundwater will be delivered to a WTP.

The Intermediate Pit will be de-watered during backfilling to provide “live storage” if required for displaced pit water and groundwater flows from the SIS and other recovery bores. Flows from the SIS bores, Main Pit and Intermediate Pit will report to a water treatment system. Treated water from the water treatment system will be discharged to the EBFR. Discharge of treated water to the EBFR during the Dry season may be necessary. However, this could be greatly limited if water demands during the construction period for dust suppression, irrigation associated with revegetation or waste rock compaction during WSF construction, that have not been included in the current Water Balance Model (WBM) are substantial during the Dry season.

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

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

These objectives will be achieved using the following strategy:

- The inlet culvert to Main Pit will be blocked at the outset of the rehabilitation phase to direct the full flow of the EBFR down the existing diversion channel, thereby substantially reducing the effective catchment areas of Main and Intermediate Pits.
- All excess flows generated on the incremental catchments of the open pits, plus groundwater from recovery bores, are assumed to report to a WTP. The hydraulic capacity of the WTP will be sized to prevent spillage of untreated water from Intermediate Pit to the EBFR, except during extremely wet years. For the purpose of the EIS, rainfall conditions that occurred during the 2010/2011 water year were adopted as the design event for selecting a suitable capacity. This water year was the wettest year of the 129-year SILO rainfall record (DES, 2019) and included Tropical Cyclone Carlos.
- Storage will be required to regulate the inflows to the water treatment system. The groundwater system will effectively act as the storage for the SIS, allowing for the temporary interruption of bore extractions during upset conditions at the WTP or during extreme flooding events. Additional storage (400,000 m^3) will be provided by maintaining minimum operating levels in Main Pit and Intermediate Pit at 58 m AHD and 49 m AHD, respectively (see Table 10-19). These levels are roughly 2 m and 8 m below the spill elevations of the respective pit’s outlet culvert. With the pit lakes drawn down to these target levels, Main Pit would provide a live storage of about 160,000 m^3 while Intermediate Pit would provide a larger storage of 240,000 m^3.
- The Intermediate Pit will be initially de-watered by pumping pit water directly to the EBFR during the Wet season. Once the initial dewatering is completed, subsequent de-watering flows will be directed to the water treatment system. The lake level in Main Pit will be maintained within a tight range to facilitate operation of the conveyor. To minimise interruptions of the pit backfilling operations, flows from Main Pit may also be directed to Intermediate Pit, meaning the pit backfilling operation will effectively become independent of the operation of the water treatment system.
- Some spillage may occur to the EBFR during extreme rainfall events such as Tropical Cyclone Carlos in February 2011, which generated the single largest daily discharge ever recorded on the EBFR at gauge GS8150097. During Tropical Cyclone Carlos, the WLBM (see RGC, 2019) simulated the complete filling of the live storage in the system resulting in a small spill of water from Intermediate Pit, *i.e.* about 60 L/s for two days.

- During an extreme rainfall event such as Tropical Cyclone Carlos, the operation of the SIS and the conveyor system could be suspended to manage the Intermediate Pit level to avoid over-topping (spillage) to the EBFR. Overall, however, it seems unlikely that there will be any spillage from the pits to the EBFR unless an event comparable to Tropical Cyclone Carlos occurs while Main Pit is being backfilled. Further details on how to reduce the likelihood of spillage, including the construction of diversion ditches around Main Pit and operating rules to exploit live storage of Main Pit, are provided in RGC (2019).

Flows ranging from 10 to 100 L/s of treated water to the EBFR during the Dry season are predicted while the pit is being backfilled. Averaged values are presented in Chapter 11 – Hydrological Processes. Water demands for dust suppression and waste rock compaction during WSF construction, amongst other water demands, were not accounted for in the WLBM due to timing and intensity of these demands not yet being modelled. Each of these demands could be substantial during the Dry season and estimated to be at least half of the total WTP production so it is conceivable that there may be much less than 10 to 100 L/s of discharge, if any at all. Additional demands such as vehicle washing, nursery production and fire water will also reduce flow to EBFR. Flows are then simulated to decrease so further reducing the likelihood of Dry season discharge.

Table 10-19: Model setup for simulating Construction phase

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

Inferred EBFR water quality during construction

Cu loads are predicted to be reduced by 75% by Year 2 due to operating the SIS/recovery bores near the WRDs, and by an order of magnitude by Year 10 following removal of the WRDs. SO_4 and Cu concentrations in the EBFR during construction were not simulated with the WLBM. Their concentrations are, however, expected to be substantially reduced during the Wet season due to the major reduction in loads to the EBFR by operation of the SIS, implying concentrations could be much lower than observed from 2010 to 2018. Further details on discharge volumes are provided in Chapter 11 – Hydrological Processes.

It has been assumed for the operation of the WBM that controlled discharge will be authorised year-round. The Proponent will limit Dry season discharge to the extent practical and achievable. Dry season discharge to the EBFR during the construction period will be restricted to treated water from the WTP. LDWQOs will apply to the EBFR throughout the year, regardless of what the composition of water in the EBFR is, *i.e.* river flows, treated water or a mixture of both, meaning the LDWQOs will be design criteria for the water treatment system unless other criteria are specified in a WDL.

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

Predicted groundwater conditions – Post-rehabilitation (Base Case)

Post-rehabilitation groundwater conditions were predicted by running the groundwater model for 30 years, assuming saline drainage from Main Pit backfill and the new WSF is discharged to groundwater and residual impacted groundwater from the old WRD footprints and other sources continues to discharge to the EBFR. The initial conditions used for the post-rehabilitation model runs are predicted groundwater conditions in Year 11, *i.e.* after 10 years of operating the SIS and recovery bores in the Copper Extraction Pad area and former ore stockpile area.

Post-rehabilitation loads in groundwater have been simulated by assuming monthly recharge rates for a typical (average) rainfall year. No attempt was made to account for inter-annual changes in rainfall and/or changes in rainfall regime that may occur as a result of climate change. Cu loads could, therefore, decrease more rapidly than predicted if recharge rates were higher, or it could take longer if there is less recharge by rainfall. More critical, however, is how effectively the extent of AMD-impacted groundwater can be reduced during the construction period by operation of the SIS.

Predicted post-rehabilitation SO_4 and Cu plumes for 30 years, *i.e.* Year 40, after the start of the construction period, are provided in Figure 10-31. Cross-sections showing predicted SO_4 and Cu concentrations in groundwater are provided in Figure 10-32, Figure 10-33, Figure 10-34, and Figure 10-35. See Figure 10-27 for the locations of these sections. Simulated SO_4 and Cu concentrations in 1985 and for current conditions are also shown for comparison in these cross-sections. Monthly simulated and predicted SO_4 and Cu loads for current conditions, the construction period, and 30-years post-rehabilitation are shown in Figure 10-36 and Figure 10-37. Predicted SO_4 and Cu loads for these years are summarised in Table 10-20 and Table 10-21. Predicted loads are much lower than the loads for the current conditions, which are provided in the tables for reference.

Other key findings are summarised below:

- The groundwater model predicts high SO_4 concentrations in groundwater near the two WSF footprints. The plume emanating from the WSF footprint nearest Main Pit is predicted to report to it, mainly from Layers 1 to 4 in the model, *i.e.* < 50 m bgs. Most of the SO_4 load therefore reports to the portion of the pit that is backfilled but it is plausible that the plume reaches the shallow pit lake. The SO_4 plume from the Eastern WSF footprint migrates along the northern mine site boundary to Old Tailings Creek and there is a small plume migrating east to an unnamed drainage. A less concentrated SO_4 plume is also simulated downgradient of the backfilled Main Pit. This plume is predicted to occur for the 30 year simulation period but backfill materials in Main Pit are eventually assumed to stop producing impacted seepage and this plume will likely be flushed from groundwater (see RGC, 2019).

- Post-rehabilitation, the groundwater model predicts 1.3 t/yr Cu to the EBFR in Year 15, *i.e.* 5 years after the SIS ceases to operate. The model predicts the new plume will stabilise in space and loading within a few years after rehabilitation, *i.e.* well before Year 40. 1.0 t/yr Cu (75%) is predicted in the EBFR and 0.3 t/yr Cu (25%) reports to Intermediate Pit in Year 15. These loads come from residual AMD-impacted groundwater near the footprints of the former Main and Intermediate WRDs and are predicted to gradually decrease over time as this groundwater is flushed by rainfall infiltration. The predicted Cu load (0.6 t/yr) to the EBFR in Year 40 is about 40% lower than the predicted load in Year 15 and 75% less than the simulated Cu load for current conditions (see Table 10-21).

Table 10-20: Predicted post-rehabilitation Sulphate loads

Reach	Description	Current Conditions (2010 to 2018)		Year 15	Year 20	Year 30	Year 40	
		t/year	%	t/year	t/year	t/year	t/year	%
A	Dyson's Area	224	19%	23	22	18	18	14%
B	Main WRD (east)	201	17%	9	11	10	10	8%
C	Main WRD (west) and Int. WRD	154	13%	5	6	6	5	4%
D	Middlebrook Creek	0	0%	0	0	0	0	0%
E	EFDC near Main and Int. WRDs	484	41%	12	9	7	6	4%
F	Former stockpile area	24	2%	20	20	18	18	15%
G	EBFR downstream of GS8150200	58	5%	27	27	28	29	23%
H	EBFR in Old Tailings Dam area	21	2%	20	21	23	24	19%
I	EBFR near GS8150327	13	1%	16	17	18	17	14%
	Simulated Load to EBFR:	**1179**	**100%**	**134**	**132**	**126**	**126**	**100%**
-	To Main Pit	61	43%	46	46	47	50	43%
-	To Int. Pit	64	45%	44	48	53	54	46%
-	To Browns Pit	9	7%	10	11	12	13	11%
-	To Model Flooding Drains	8	6%	0	1	0	0	0%
	Simulated Load to Pits:	**142**	**100%**	**100**	**106**	**112**	**118**	**100%**
	TOTAL:	**1322**	**-**	**235**	**239**	**239**	**244**	**-**

Table 10-21: Predicted post-rehabilitation Copper loads

Reach	Description	Current Conditions (2010 to 2018)		Year 15	Year 20	Year 30	Year 40	
		t/year	%	t/year	t/year	t/year	t/year	%
A	Dyson's Area	0.4	17%	0.2	0.2	0.1	0.1	17%
B	Main WRD (east)	0.4	15%	0.2	0.2	0.2	0.2	27%
C	Main WRD (west) and Int. WRD	0.3	13%	0.1	0.1	0.1	0.1	10%
D	Middlebrook Creek	0.0	0.0%	0.0	0.0	0.0	0.0	0%
E	EFDC near Main and Int. WRDs	1.3	54%	0.5	0.4	0.4	0.3	45%
F	Former stockpile area	0.0	0.2%	0.0	0.0	0.0	0.0	0%
G	EBFR downstream of GS8150200	0.0	0.1%	0.0	0.0	0.0	0.0	0%
H	EBFR in Old Tailings Dam area	0.0	0.0%	0.0	0.0	0.0	0.0	0%
I	EBFR near GS8150327	0.0	0.0%	0.0	0.0	0.0	0.0	0%
	Simulated Load to EBFR:	**2.3**	**100%**	**1.0**	**0.9**	**0.8**	**0.6**	**100%**
-	To Main Pit	0.1	14%	0.0	0.0	0.0	0.0	1%
-	To Int. Pit	0.4	85%	0.3	0.3	0.3	0.3	99%
-	To Browns Pit	0.0	0.2%	0.0	0.0	0.0	0.0	0%
-	To Model Flooding Drains	0.0	0.4%	0.0	0.0	0.0	0.0	0%
	Simulated Load to Pits:	**0.5**	**100%**	**0.3**	**0.3**	**0.3**	**0.3**	**100%**
	TOTAL:	**2.8**	**-**	**1.3**	**1.2**	**1.1**	**0.9**	**-**

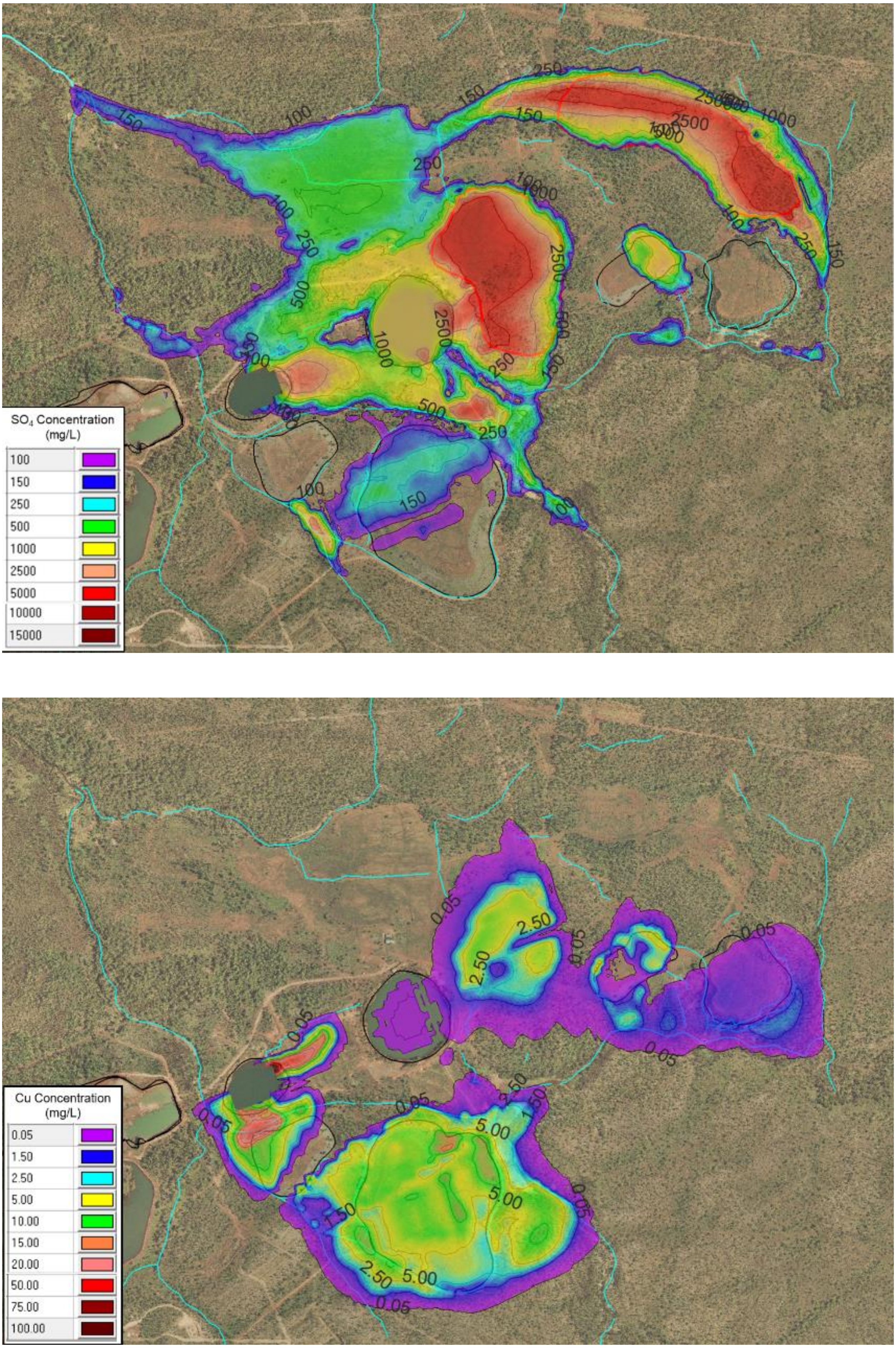
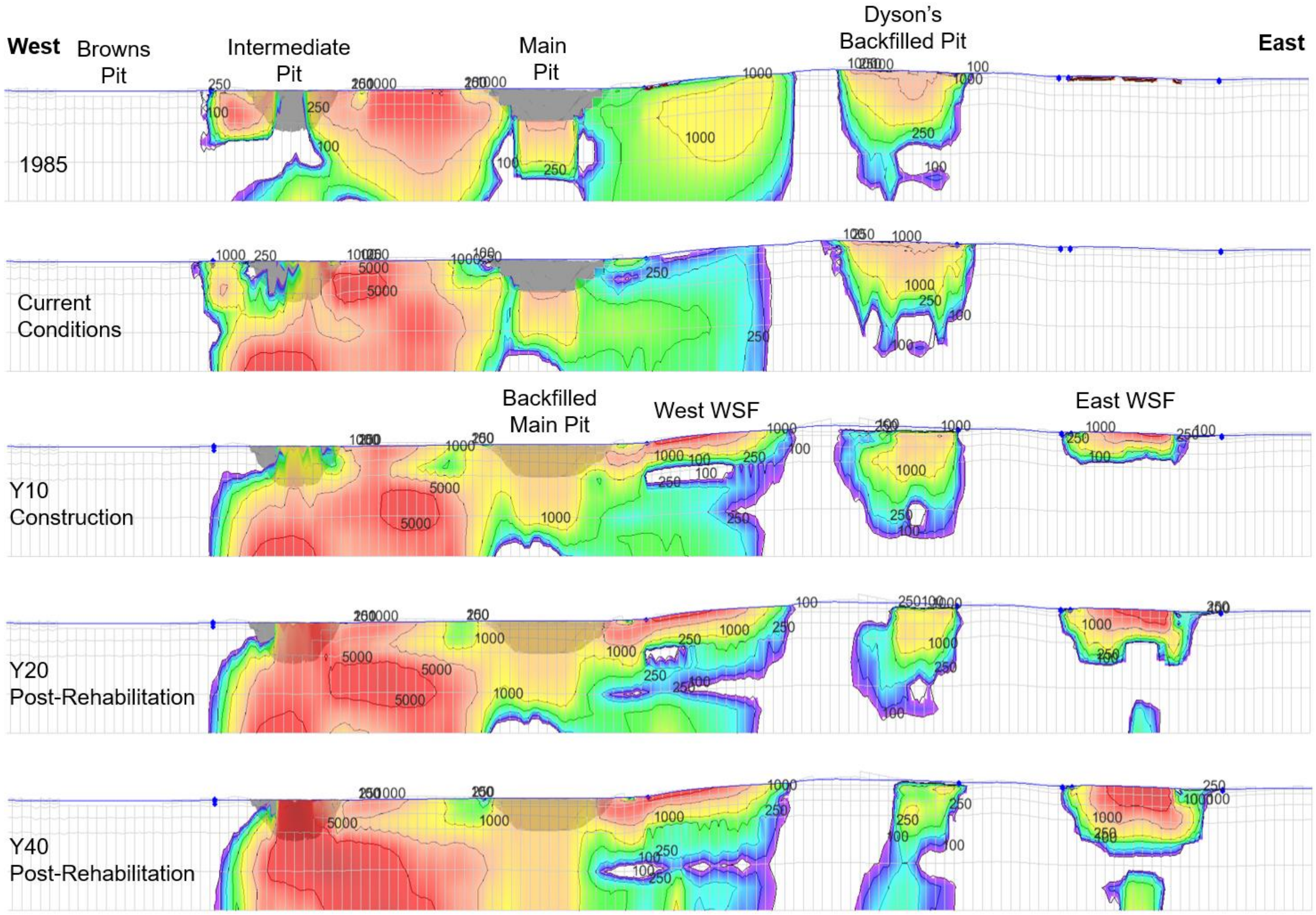


Figure 10-31: (Upper) Simulated Sulphate plume, (Lower) Simulated Copper plume, Year 40



Notes: Vertical exaggeration x 2. Results for Row 79.

Figure 10-32: Cross-section (Row 79) with simulated Sulphate plume

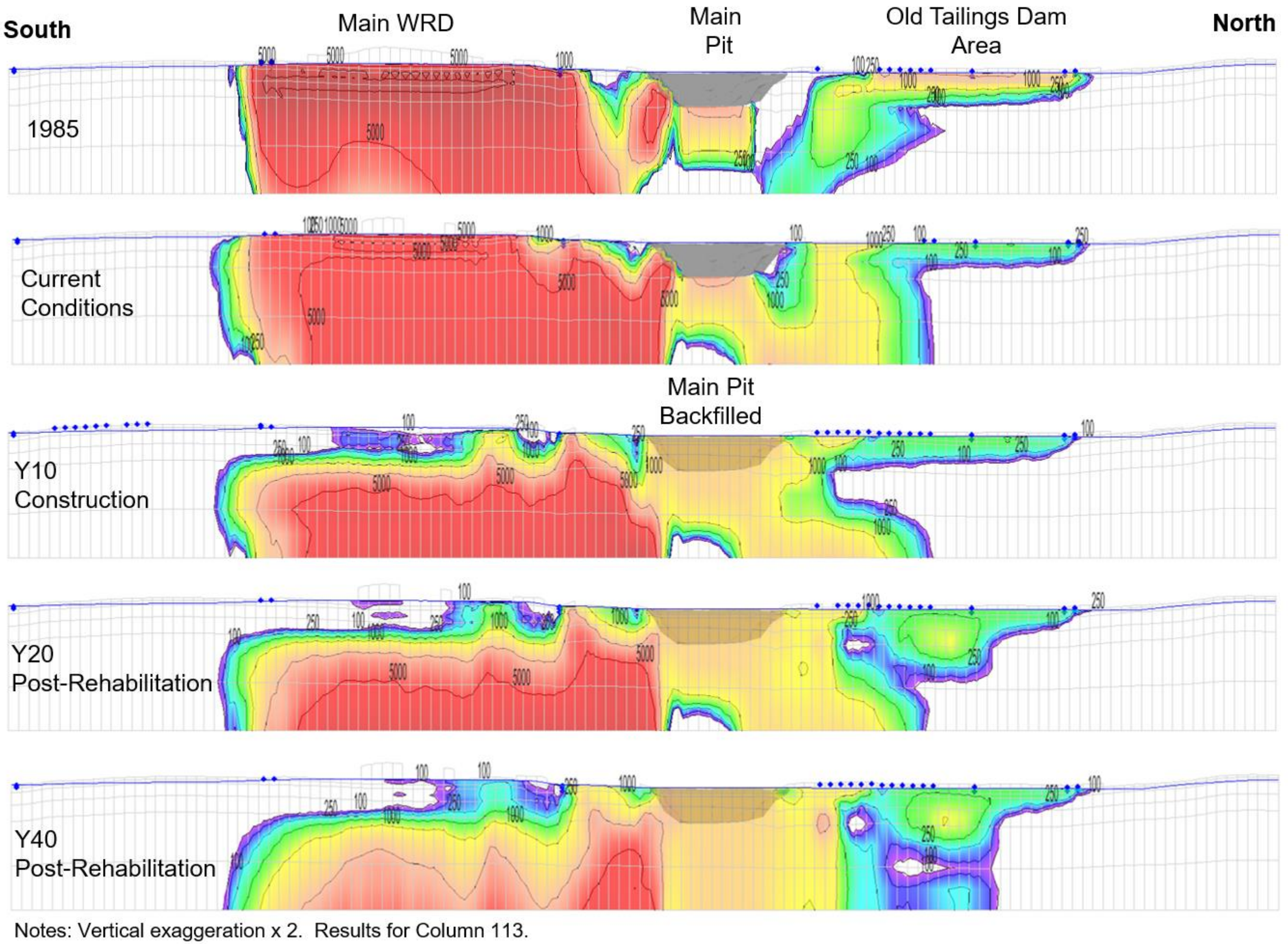


Figure 10-33: Cross-section (Column 113) with simulated Sulphate plume

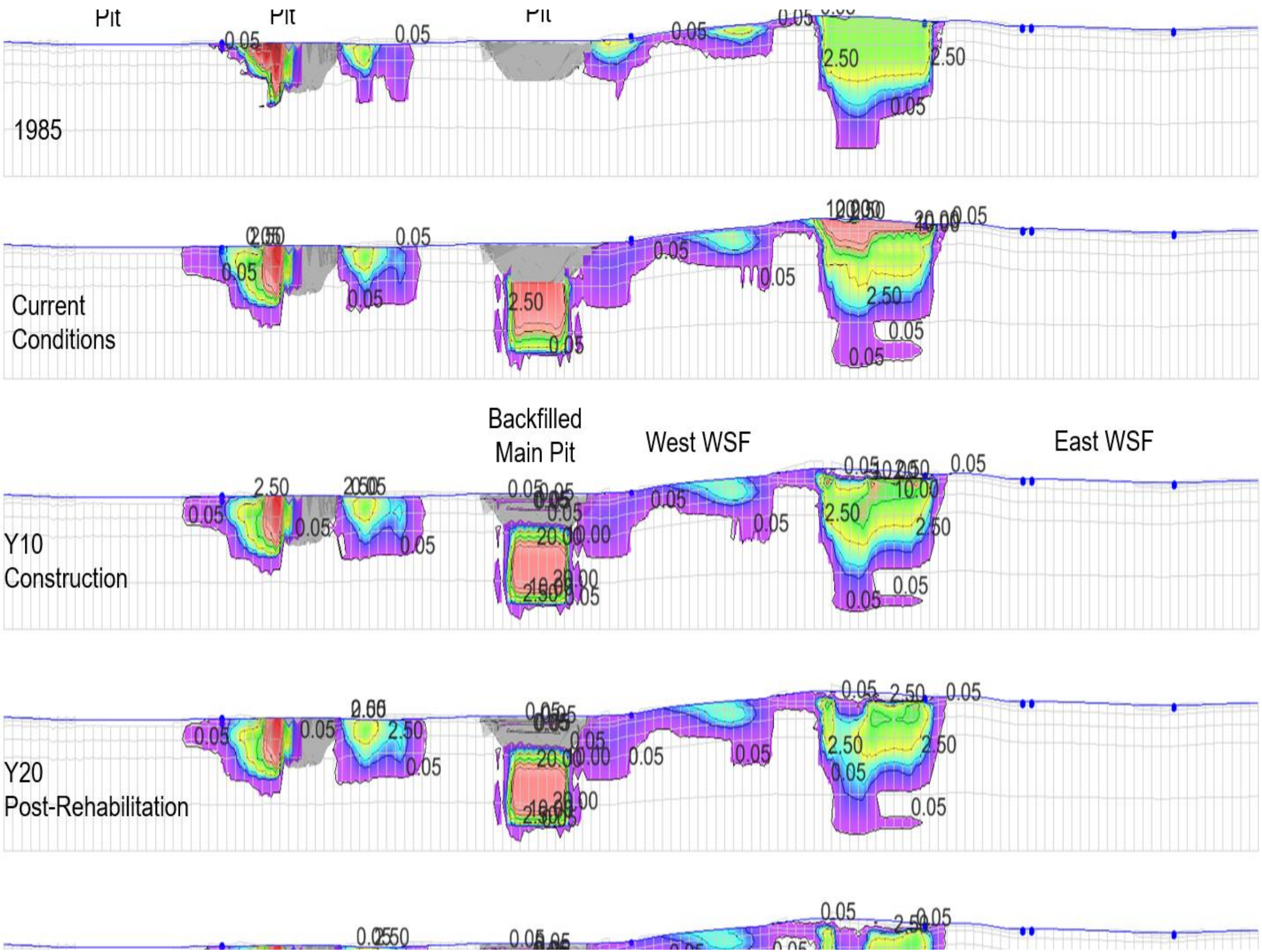
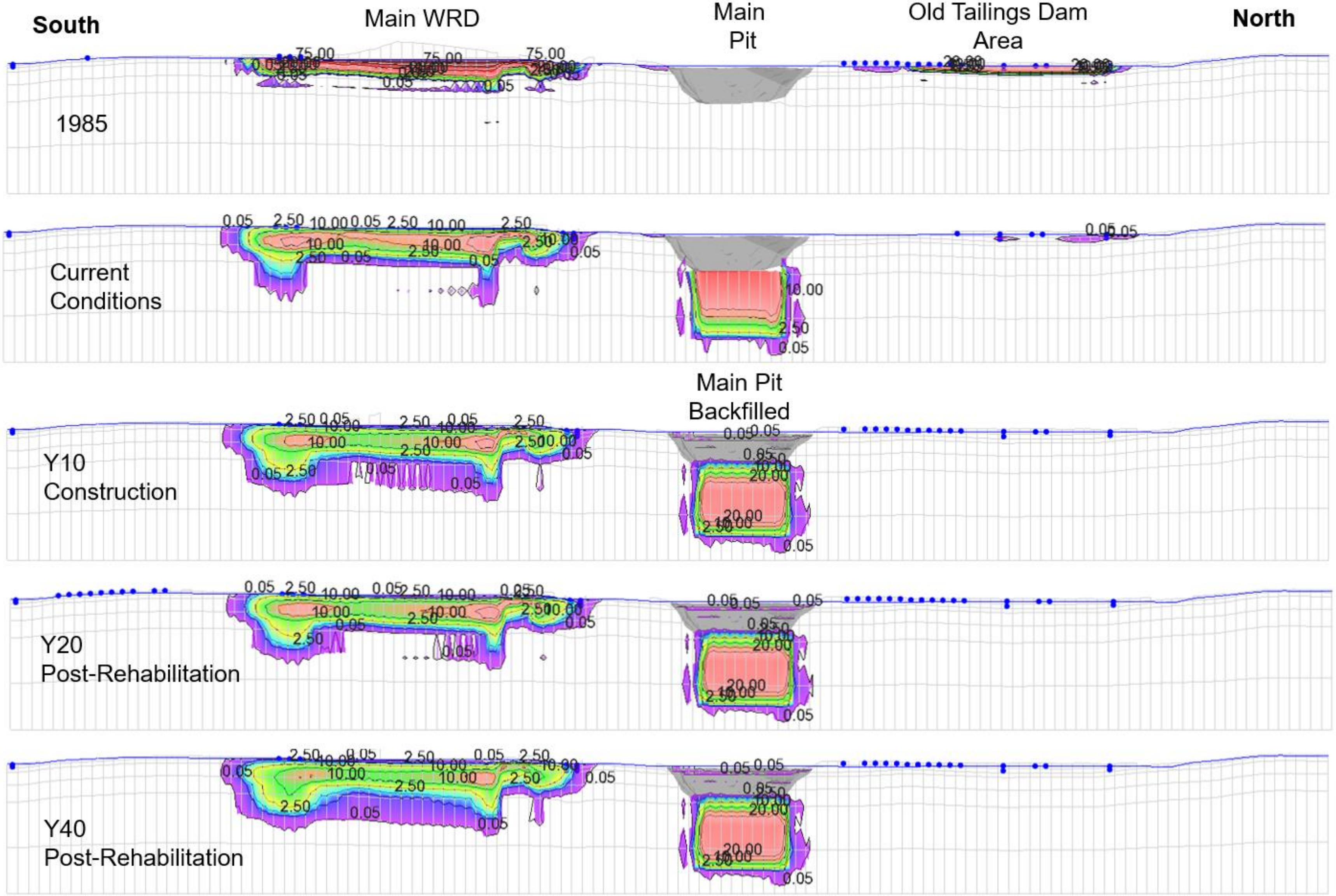


Figure 10-34: Cross-section (Row 79) with simulated Copper plume



Notes: Vertical exaggeration x 2. Results for Column 113.

Figure 10-35: Cross-section (Row 113) with simulated Copper plume

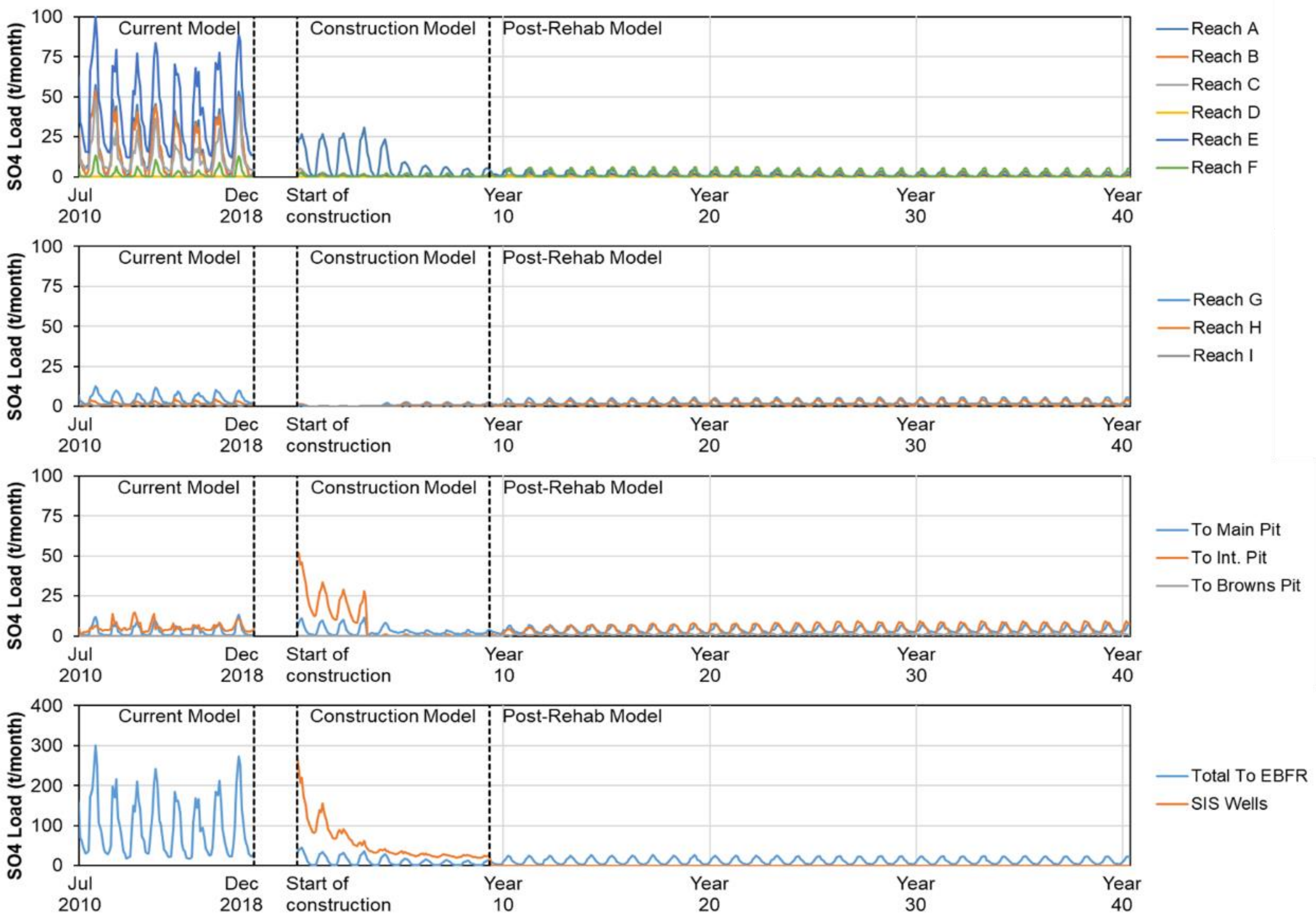


Figure 10-36: Simulated and predicted Sulphate loads, Base Case scenario

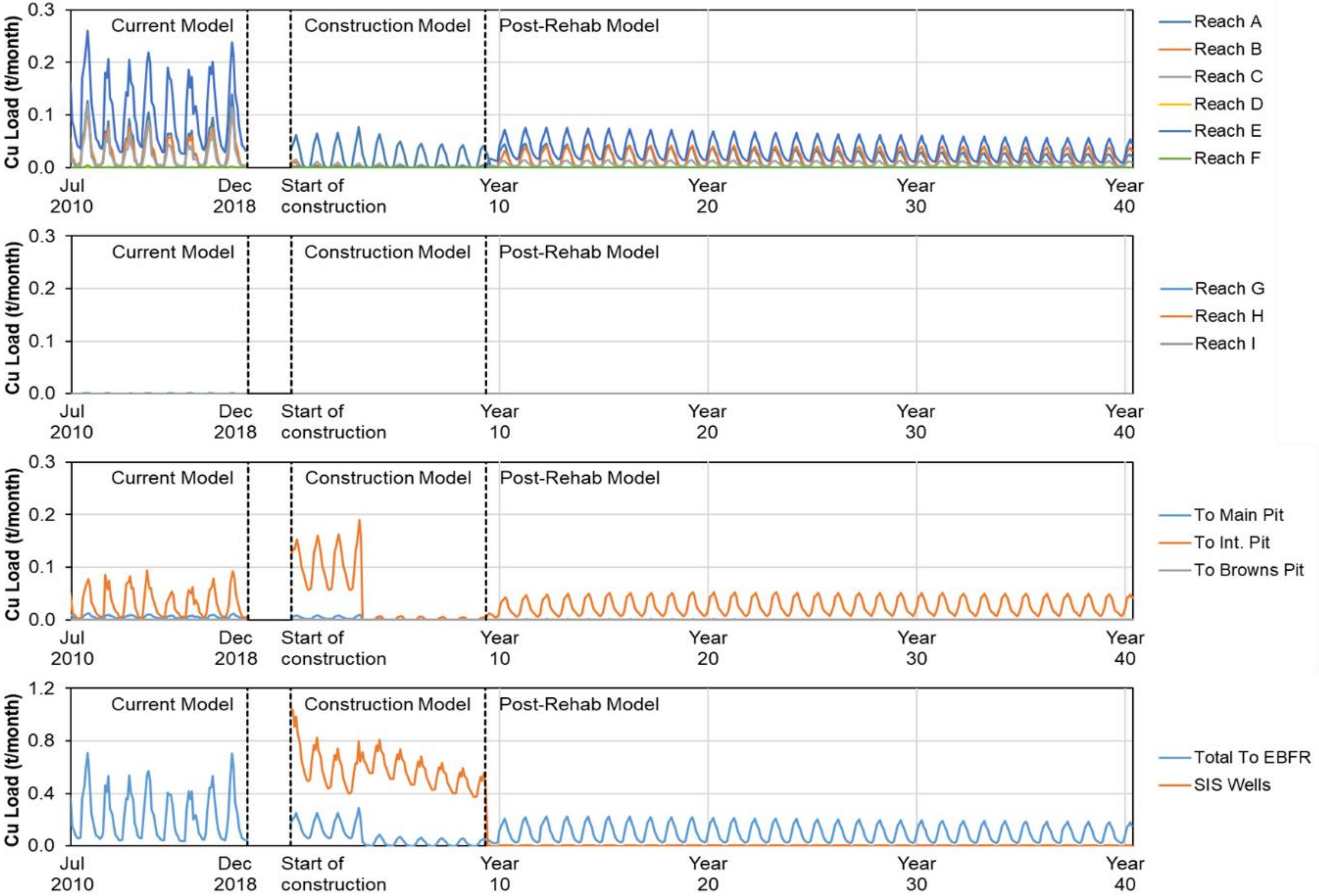


Figure 10-37: Simulated and predicted Copper loads, Base Case scenario

10.6.2. Predictive Surface Water Quality Modelling

WLBM adjustments

The WLBM was not substantially modified to predict SO_4 and Cu concentrations in the EBFR post-rehabilitation. Instead, SO_4 and Cu concentrations were derived by using predicted loads from the groundwater model for Year 40 in the WLBM and eliminating load contributions to the EBFR by interflow (seepage from the WRDs). The model was then run assuming the same rainfall pattern observed from 2010 to 2017 and using predicted SO_4 and Cu loads from the groundwater model. This allows direct comparison of the simulated loads and concentrations for current conditions to the long-term predicted loads in Year 40. Further details are provided in RGC (2019).

Predicted loads in EBFR

Predicted post-rehabilitation SO_4 and Cu loads in the EBFR are summarised in Table 10-22. The predicted SO_4 and Cu loads in the EBFR represent the Year 40 loads to the EFDC and EBFR from the groundwater model plus loads from upstream of the mine site assuming the rainfall that occurred during each water year of the calibration period (2010 to 2018). This was done to illustrate how loads and concentrations in the EBFR could vary in response to varying streamflow discharge, *i.e.* dilution.

Cu loads to Intermediate Pit are excluded because any Cu that reaches Intermediate Pit is assumed to precipitate within the pit (owing to the higher pH in that water body) and remain there in the form of a precipitated solid. The Intermediate Pit therefore serves as a buffer, in some regards, as it receives and attenuates approximately one-third of the Cu load predicted to be delivered to it by the groundwater model. This assumes the post-rehabilitation configuration of Intermediate Pit is as it is currently and the water quality is not substantially degraded when the EBFR is directed through it.

Table 10-22: Summary of predicted Sulphate and Copper loads, Year 40 (Base Case)

Assumed Rainfall,	Current Conditions (GS8150097)		Predicted - Year 40 (GS8150097)		Predicted Load Reduction	
mm	SO_4 Load, t/year	Cu-t Load, t/year	SO_4 Load, t/year	Cu-t Load, t/year	SO_4 Load	Cu-t Load
2,392	3,354	7.1	333	0.9	90%	88%
1,475	1,707	2.0	217	0.6	87%	72%
1,573	973	0.8	201	0.4	79%	50%
1,622	2,244	3.5	220	0.7	90%	81%
964	1,196	1.6	221	0.4	82%	73%
1,290	1,074	1.7	228	0.5	79%	71%
1,528	1,648	3.2	287	0.9	83%	72%
Average:	**1,742**	**2.8**	**244**	**0.6**	**84%**	**72%**

Predicted Sulphate and Copper concentrations in EBFR, Base Case

Predicted SO_4 and Cu concentrations in the EBFR at gauge GS8150200, GS8150327 and GS8150097 are shown in Figure 10-38. Predictions for other gauges are provided in RGC (2019). Table 10-23 summarises predicted Cu concentrations in Year 40 in the EBFR at gauges GS8150200, GS8150327 and GS8150097. Observed Cu concentrations in the EBFR from 2010 to 2018 are provided for comparison. SO_4 and Cu concentrations in the EBFR are predicted in the WLBM by importing the predicted post-rehabilitation loads in the EBFR for Year 40 (30 years post-rehabilitation) and assuming the same streamflow discharge that was simulated for the 2010 to 2018 calibration period. Further details on these predictions are provided in RGC (2019).

SO_4 concentrations in the EBFR are predicted to be much lower than for current conditions due to substantial decrease in SO_4 in groundwater due to operating the SIS recovery bores and the long-term flushing of SO_4 from the former impacted areas that is predicted by the groundwater model. Future Cu concentrations in the EBFR at gauge GS8150200 are predicted to be much lower than Cu concentrations for current conditions but may still exceed the Zone 2 LDWQO at certain times of the year. This is mainly related to the residual plume of AMD-impacted groundwater from the Intermediate WRD that remains downgradient of the remediated footprint and continues to discharge to the EFDC post-rehabilitation.

In the EBFR at gauges GS8150327 and GS8150097, Cu concentrations are predicted to be much lower than currently observed and exceed LDWQO much less frequently than at gauge GS8150200. Further characterisation of the residual plume downgradient from the footprint of the former Intermediate WRD and how it will be affected by pumping with the SIS would be needed to confirm the predictions from the groundwater model and determine whether the recovery bores will have to be operated for a longer period of time to control the residual Cu plume in this area of the site (see RGC, 2019 for recommendations to address this).

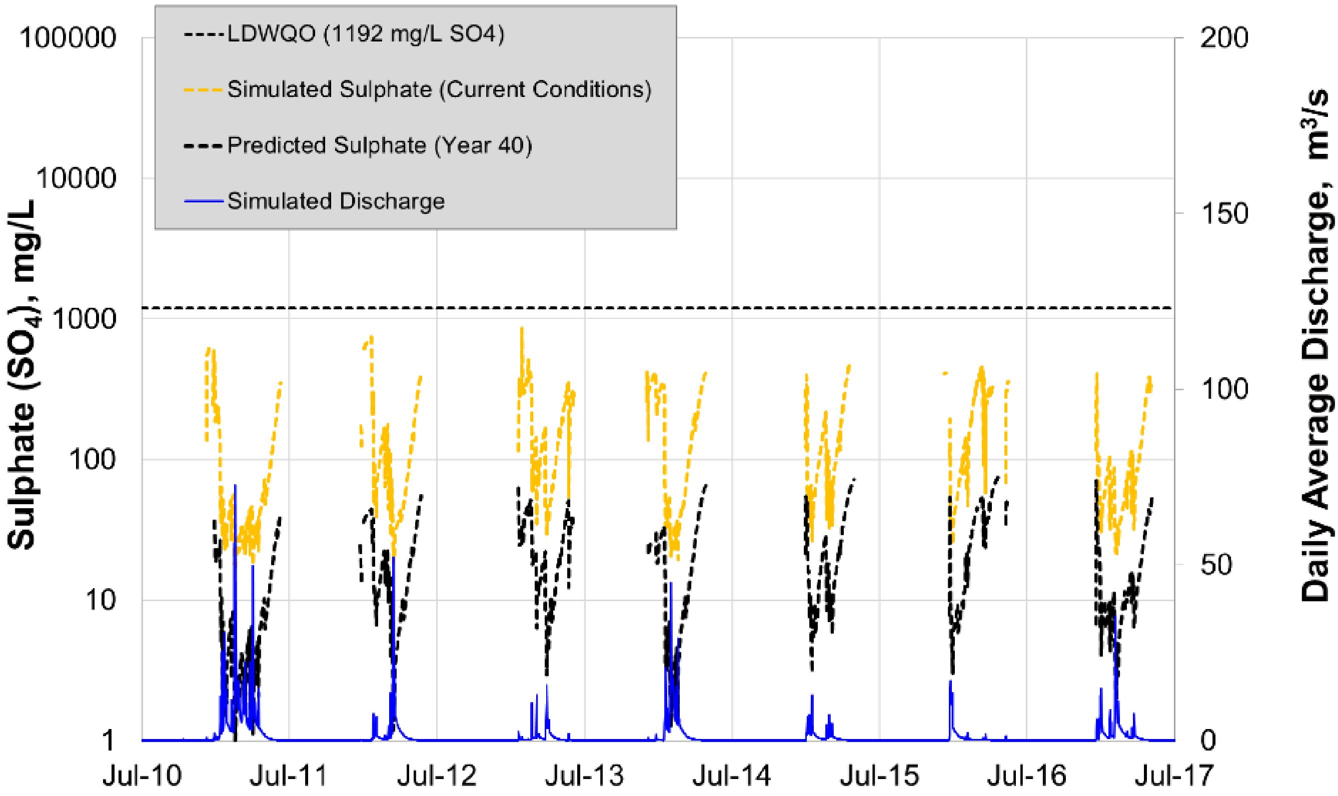
Table 10-23: Summary of predicted Copper concentrations and exceedances, Year 40 (Base Case)

Assumed rainfall:	2392 mm	1475 mm	1573 mm	1622 mm	964 mm	1290 mm	1528 mm
Predicted Concentrations at Station GS8150200, Year 40							
n	165	151	138	104	120	119	140
Min, mg/L	0.002	0.003	0.009	0.003	0.007	0.005	0.005
Max, mg/L	0.290	0.697	1.1	0.708	0.750	0.740	0.705
Median, mg/L	0.018	0.100	0.126	0.045	0.109	0.217	0.048
Mean, mg/L	0.053	0.188	0.179	0.151	0.188	0.268	0.096
No. of exceedances	27%	63%	73%	46%	66%	74%	39%
Water Year:	2010/2011 Water Year	2011/2012 Water Year	2012/2013 Water Year	2013/2014 Water Year	2014/2015 Water Year	2015/2016 Water Year	2016/2017 Water Year
No. of exceedances (current conditions)	84%	92%	63%	87%	78%	88%	50%
Median, mg/L	0.116	0.128	0.093	0.114	0.078	0.097	0.068
Predicted Concentrations at GS8150327, Year 40							
n	-	43	35	48	41	45	19
Min, mg/L	-	0.002	0.004	0.005	0.006	0.007	0.008
Max, mg/L	-	0.054	0.103	0.125	0.050	0.089	0.036
Median, mg/L	-	0.024	0.016	0.024	0.016	0.021	0.017
Mean, mg/L	-	0.021	0.021	0.031	0.018	0.026	0.018
No. of exceedances	-	30%	17%	38%	7%	24%	16%
Water Year:	2010/2011 Water Year	2011/2012 Water Year	2012/2013 Water Year	2013/2014 Water Year	2014/2015 Water Year	2015/2016 Water Year	2016/2017 Water Year
No. of exceedances (current conditions)	-	81%	94%	92%	85%	98%	92%
Median, mg/L	-	0.074	0.047	0.076	0.0490	0.070	0.055
Predicted Concentrations at GS8150097, Year 40							
n	73	38	35	46	39	47	24
Min, mg/L	0.006	0.003	0.005	0.003	0.004	0.004	0.004
Max, mg/L	0.042	0.026	0.038	0.028	0.045	0.070	0.061
Median, mg/L	0.020	0.015	0.012	0.018	0.015	0.017	0.014
Mean, mg/L	0.021	0.015	0.013	0.016	0.016	0.018	0.019
No. of exceedances	23%	0%	3%	2%	8%	13%	17%
Water Year:	2010/2011 Water Year	2011/2012 Water Year	2012/2013 Water Year	2013/2014 Water Year	2014/2015 Water Year	2015/2016 Water Year	2016/2017 Water Year
No. of exceedances (current conditions)	99%	49%	84%	89%	95%	96%	88%
Median, mg/L	0.073	0.052	0.039	0.037	0.054	0.055	0.050

Notes:

LDWQO (Zone 2) = 0.061 mg/L Cu-t

LDWQO (Zone 3) = 0.028 mg/L Cu-t



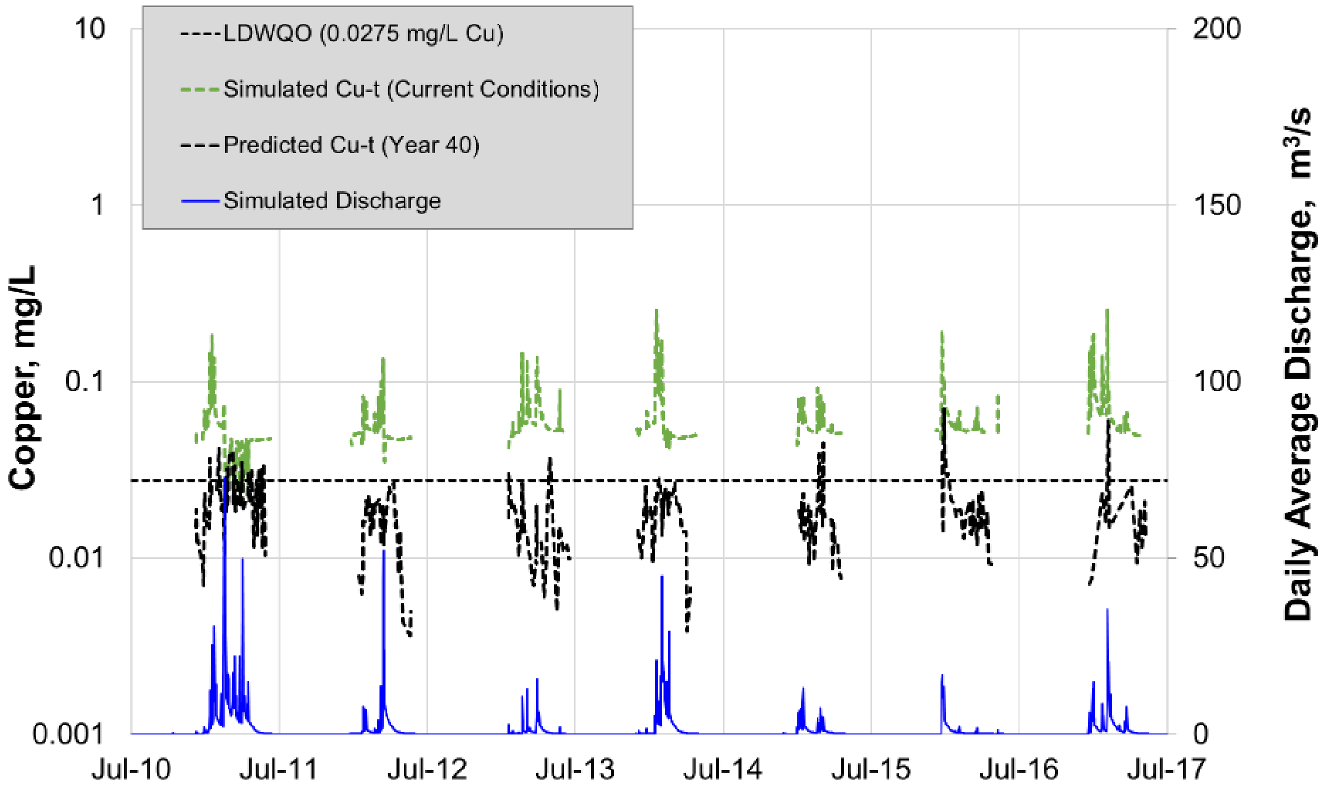


Figure 10-38: Predicted post-rehabilitation SO_4 and Cu concentrations in the EBFR at GS8150097

10.7. Potential Impacts and Risks

A comprehensive list of risks, potential negative impacts and proposed mitigation measures associated with the Proposal is provided in the Risk Register (GHD, 2019f – see Appendix) and is not repeated here. Instead, potential events assigned a High or Extreme risk rating are reviewed and discussed to demonstrate how the most crucial risks and uncertainties are being addressed.

10.7.1. Construction Phase

Risks and potential impacts related to groundwater and surface water quality during the Construction phase are provided below.

Potential Impacts and Risks

None of the potential events during the Construction phase were assigned an Extreme risk rating. Most of the potential events assigned a High risk rating were risks related to the management of leachate and/or runoff characterised by elevated metals or other solutes related to AMD or related to road construction, water crossings, land clearing or the release of hazardous liquids, *e.g.* hydrocarbons. One of the five pertains to spillage from Intermediate Pit while the Main Pit is being backfilled (see also Chapter 11 – Hydrological Processes) and there is an identified risk to the vine thicket (a Groundwater Dependent Ecosystem, GDE) north of Intermediate Pit should the cone of depression that develops around the de-watered Intermediate Pit extend to this area. This is discussed further in Chapter 11 – Hydrological Processes.

Mitigation and Management

Risks related to poor quality leachate and/or runoff will be managed by the implementation of an Erosion and Sediment Control Plan (ESCP) and *Water Management Plan* during construction. The ESCP will be developed according to Australian Standards and will be implemented according to the conditions of a WDL to ensure turbidity and TSS levels in the EBFR are acceptable. Sludge management and disposal procedures and the management of any water storage facilities will be outlined in the *Water Management Plan* and will be governed by a WDL.

Water management planning will require detailed consideration and will be a critical aspect of the Stage 3 design work. Currently, the only dedicated water management facility proposed (aside from the WTP and the groundwater SIS) is the Intermediate Pit, which will be partly de-watered to provide live storage during pit backfilling. There are, for instance, no water retaining dams or other facilities aside from the small sediment trap storage ponds that are likely needed to collect runoff from the working faces. Therefore, the only “failure” that could occur would be if Intermediate Pit were to over-top during an extreme rainfall event of similar magnitude as Tropical Cyclone Carlos. This is an unlikely scenario, however, and only a relatively small volume (up to about 10,000 m^3) would be lost to the EBFR. This water will most likely be of poor quality though so there are potential consequences to EBFR water quality.

The risk of over-topping could be mitigated by refining the *Water Management Plan* to reduce the likelihood of spillage from Intermediate Pit while Main Pit is being backfilled, although there are implications should Intermediate Pit be further de-watered, including a larger water treatment requirement and a greater risk to the vine thicket due to additional drawdown of groundwater levels in this area. In the unlikely event such a spill does occur in a very high rainfall event it is unlikely to have any long-term impact on the EBFR compared with the severity of current AMD impacts, noting the substantial dilution that would also be occurring at that time. Such a release would be considered an uncontrolled discharge event in a WDL and reported as such.

Monitoring and Reporting

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

- Groundwater monitoring to assess remediation performance, including pumping rate monitoring for the SIS and recovery bores, water level monitoring and monthly and quarterly water quality sampling.
- Weekly sampling of the EBFR from Dyson’s Area to gauge GS5150200 to assess water quality improvements during the Wet season and monthly monitoring at gauge GS8150327 during the Wet season.
- Continuous monitoring of pH, EC and turbidity levels at gauges GS8150200, GS8150327 and GS8150097, as currently undertaken.
- Monthly monitoring at gauge GS8150327 during the Dry season when only treated water flows will be present in the EBFR.

- Monitoring inflows to the water treatment system during pit backfilling, including flows of displaced pit water and the quality of groundwater pumped from recovery bores.
- Treated water monitoring (flows and daily composite for water quality) where controlled discharge to the EBFR is authorised.

The groundwater monitoring locations to be used for performance assessment and frequencies of sampling are to be decided once additional hydrogeological field investigations have been completed during Stage 3. These investigations will likely involve the installation of additional WSF monitoring bores and recovery bores along the suggested alignments where future seepage recovery will be undertaken in order to complete pump tests. Additional monitoring bores between Main Pit and the former ore stockpile area and near the proposed footprint(s) of the new WSF will be installed. Further details on recommended work to be completed in Stage 3 are provided in RGC (2019).

Water quality monitoring commitments during pit backfilling and monitoring of treated water will be defined during the process of applying for a WDL. An Annual Monitoring Report that reviews and interprets flow and water quality monitoring data will be prepared as a requirement for the WDL. The Monitoring Report should include a performance assessment for the SIS and recovery bores onsite and detail any changes in routine monitoring for the subsequent year and recommendations for additional recovery bores, if necessary.

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

Statement of Residual Impact

Failure of existing or planned water storage facilities is the only residual risk with a Medium rating. The residual risk of spillage is acceptable given that any uncontrolled discharge would report to the EBFR, which is already severely-impacted by AMD. As EBFR water quality is predicted to significantly improve during the Construction phase any potential for greater adverse effects than the current condition on aquatic ecosystems are expected to be limited. Also, any risks to the EBFR due to a temporary breakdown of the water treatment system could be mitigated by stopping waste rock deposition into the pit and temporarily shutting down the SIS and recovery bores until the WTP is repaired.

The residual risk of spillage (over-topping) could also be further mitigated by including additional measures in the Stage 3 *Water Management Plan* to reduce the likelihood of spillage from Intermediate Pit, including raising the spill elevation of Intermediate Pit and/or constructing upstream diversions near Main Pit to reduce catchment runoff to the pit during extreme rainfall periods.

10.7.2. Post-Rehabilitation Phase

Potential Impacts and Risks

The following potential events were assigned an Extreme risk rating:

- Contaminant loads in the EBFR are not sufficiently reduced due to continued loads from residual impacted groundwater.

The following potential events were assigned a High risk rating:

- Seepage from WSF characterised by higher acidity and metals than predicted.
- Leachate from historic WRD footprints characterised by persistent elevated acidity and metals.
- Uncertainty in contaminant transport rates in groundwater results in longer timeframes for improvement and/or higher contaminant loads in the EBFR.
- Failure of the WSF, due to insufficient neutralant (*i.e.* Lime), damage to closure cover and/or poor design, construction and material selection *etc*.

Mitigation and Management

Each of the potential events listed above pertains to ineffective performance of key rehabilitation measures, including:

- Poor or ineffective performance of the SIS resulting in higher residual AMD-impacted groundwater loading to EBFR than predicted.
- Insufficient lime amendment of PAF materials in the WSF to prevent future AMD generation.
- Poor selection of sulphide-bearing materials to be re-located to the flooded Main Pit.

- Failure of the closure cover placed on the WSF to reduce rainfall infiltration and oxygen ingress.

Most of the risks related to the performance of the WSF can be mitigated by designing the WSF to appropriate best management standards and ensuring proper QA/QC during construction as detailed in Chapter 7 – Rehabilitation Strategy and Chapter 9 – Terrestrial Environmental Quality. Nevertheless, it is possible that the management strategies that are implemented do not perform as intended. The possibility of lower than anticipated performance was addressed in RGC (2019) with the development of a Credible Worst Case (CWC) scenario that assumed higher soluble Cu concentrations in backfill in the Main Pit and in the waste rock in the WSF, higher long-term infiltration rates to groundwater, and a higher K for backfill materials in Main Pit to increase the predicted load downgradient. The CWC model run predicts higher SO_4 and Cu concentrations in groundwater but no appreciable difference in SO_4 or Cu concentrations in the EBFR (see RGC, 2019, for further details).

The predictions for Cu for the CWC are not substantially different than the predictions for the base case scenario and are generally within the uncertainty of the model. However, it is evident from the CWC that SO_4 and Cu loads to groundwater would be higher and that groundwater quality downgradient of the WSF would be degraded to a greater extent than predicted for the base case. The environmental implications of elevated SO_4 and some metals in groundwater are rather inconsequential however and it is highly unlikely that groundwater quality would degrade to the degree currently observed near Main WRD or Intermediate WRD.

It should, however, be acknowledged that some predictive runs reported in RGC (2019) for the base case scenario indicate that LDWQOs may not be achieved at all times post-rehabilitation until residual AMD-impacted groundwater is flushed from the site. Because achieving LDWQOs is a key rehabilitation objective, the Extreme risk of not sufficiently reducing loads in the EBFR due to the continued discharge of residual AMD-impacted groundwater is valid and can only be mitigated by ensuring effective remediation of these plumes by the SIS during Stage 3 work.

Monitoring and Reporting

Post-rehabilitation monitoring and reporting will likely be comparable to Construction phase commitments for a multi-year transition period during which monitoring frequencies will decrease based on annual recommendations in a Monitoring Report for the WDL. However, monitoring and reporting will eventually focus on monitored natural attenuation and whether the predicted changes in groundwater quality are occurring.

Statement of Residual Impact

Each of the potential events listed above was assigned a Medium risk rating for residual impact. The likelihood of a less significant improvement in EBFR water quality related to the uncertainty in contaminant transport rate predictions cannot be resolved entirely until the intensive performance monitoring that is planned during the 10 year (combined) Construction and Post-Construction Stabilisation and Monitoring phases of rehabilitation are underway, which will determine whether additional recovery bores and treatment of the footprints of the former WRDs are needed to reduce the extent of residual impacted groundwater. This risk can, however, be reduced during the Stage 3 detailed design phase *via* pump testing of additional groundwater recovery bores in the Copper Extraction Pad area and near the Main and Intermediate WRDs and related performance monitoring (see RGC, 2019, for further details).

Potential residual impacts related to the poor performance of the WSF, leading to greater acidity and metal content in seepage, could cause higher-than-predicted acidity, SO_4 and metal concentration in groundwater downgradient of the WSF. Long-term, groundwater impacted by seepage from the WSF is predicted to report to the upper EBFR in Dyson's Area, to Old Tailings Creek and the flooded Main Pit. Hence loads in the EBFR would be higher than predicted if the WSF does not function as designed. This scenario implies many of the best management strategies that are proposed would have failed to achieve the best possible outcome, including:

- Lime amendment to neutralise existing acidity in PAF waste rock and heap leach materials removed from shallow portions of Dyson's (backfilled) Pit.
- The purposeful placement and compaction of waste rock in the WSF and the placement of a closure cover to reduce rainfall infiltration and oxygen ingress.
- Increased setback between the new WSF and the EBFR and other drainages.

In addition to these design measures, the Proponent has committed to operating an SIS and a water treatment system to achieve LDWQOs for the EBFR during construction and reduce the extent and severity of residual AMD-impacted groundwater to a degree needed to achieve LDWQOs once the Construction phase of rehabilitation is complete. Thus, it seems most likely that there will be significant net benefit to the site and that a substantial improvement in groundwater and surface water quality will be realised during the Construction phase of rehabilitation and post-rehabilitation. Any residual risks related to groundwater and surface water quality are deemed to be low.

10.8. References

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10.9. References included in Appendix

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11. Hydrological Processes

Figures

Tables

11.1. Environmental Values

This Chapter focusses on surface water hydrology and non-environmental beneficial users. Environmental values relating to surface water are detailed in Chapter 12 – Aquatic Ecosystems and Chapter 10 – Inland Water Environmental Quality details groundwater flows.

11.1.1. Overview

The project area exists within the Finniss River catchment. In this chapter, that watercourse is referred to as the Finniss River (main or trunk) until a confluence where it branches into the East and West Branches. As shown in Figure 11-1, the majority of the project footprint is within the catchment of the East Branch. The exceptions are Mt Fitch and Mt Burton which are adjacent to the West Branch, and the low permeability material borrow area which is adjacent to Meneling Creek (which flows into the West Branch).

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

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

- The West Branch (and, indeed, the main Finniss River) is a large, permanent watercourse. It typically has steep banks (3 to 5 m high) that are terraced, a relatively extensive floodplain and is characterised by sandy, heavily-vegetated levees. There are billabongs associated with the watercourse and floodplains, and downstream it flows through the Finniss River Coastal Floodplain SoCS which supports several listed threatened species.
- The East Branch is a semi-permanent stream within a distinct channel that dries to a number of pools in the mid to late Dry season depending on the amount of rainfall in the preceding Wet season. The bed is typically broad with low, earthy banks 1 to 3 m high with many sandy to rocky mid-stream shoals. Although riparian vegetation on the East Branch shows obvious signs of degradation, it currently supports a reasonable density and diversity of riparian species. The East Branch riparian corridor typically merges rapidly with surrounding Eucalypt woodland areas; there is little to no surrounding floodplain areas.

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

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

In light of the knowledge gleaned by a technical panel during Stage 1 of the Rum Jungle Rehabilitation Project, a zone breakdown of the Finniss River system was developed to allow for the different environmental values and WQOs in different parts of the river system, based on natural geomorphological characteristics, major tributary junctions and the declared SoCS in the lower Finniss River. The zones are described in Table 11-1. Those most relevant to the EIS are shown in Figure 11-1.

Table 11-1: Finniss River zones

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

The drainage lines are mapped in Figure 11-1 below. This figure also shows the Main and Intermediate Pit Lakes within the Rum Jungle site. The smaller Intermediate Pit has a mined volume of 1,087,000 m^3 and the Main Pit has a mined volume of 3,530,000 m^3 as described in Verhoevan (1988). Chapter 6 – Existing Environmental Condition describes the current physical and chemical condition of these water-filled voids. The pertinent point from this description is the presence of backfilled tailings within the Main Pit and the existence of a diversion channel of the East Branch to the south of the Pits (East Finniss Diversion Channel – EFDC). It is a key component of the Stage 3 works to safely re-divert as much flow as possible back through the East Branch original alignment. This alignment is mapped in Figure 11-2.

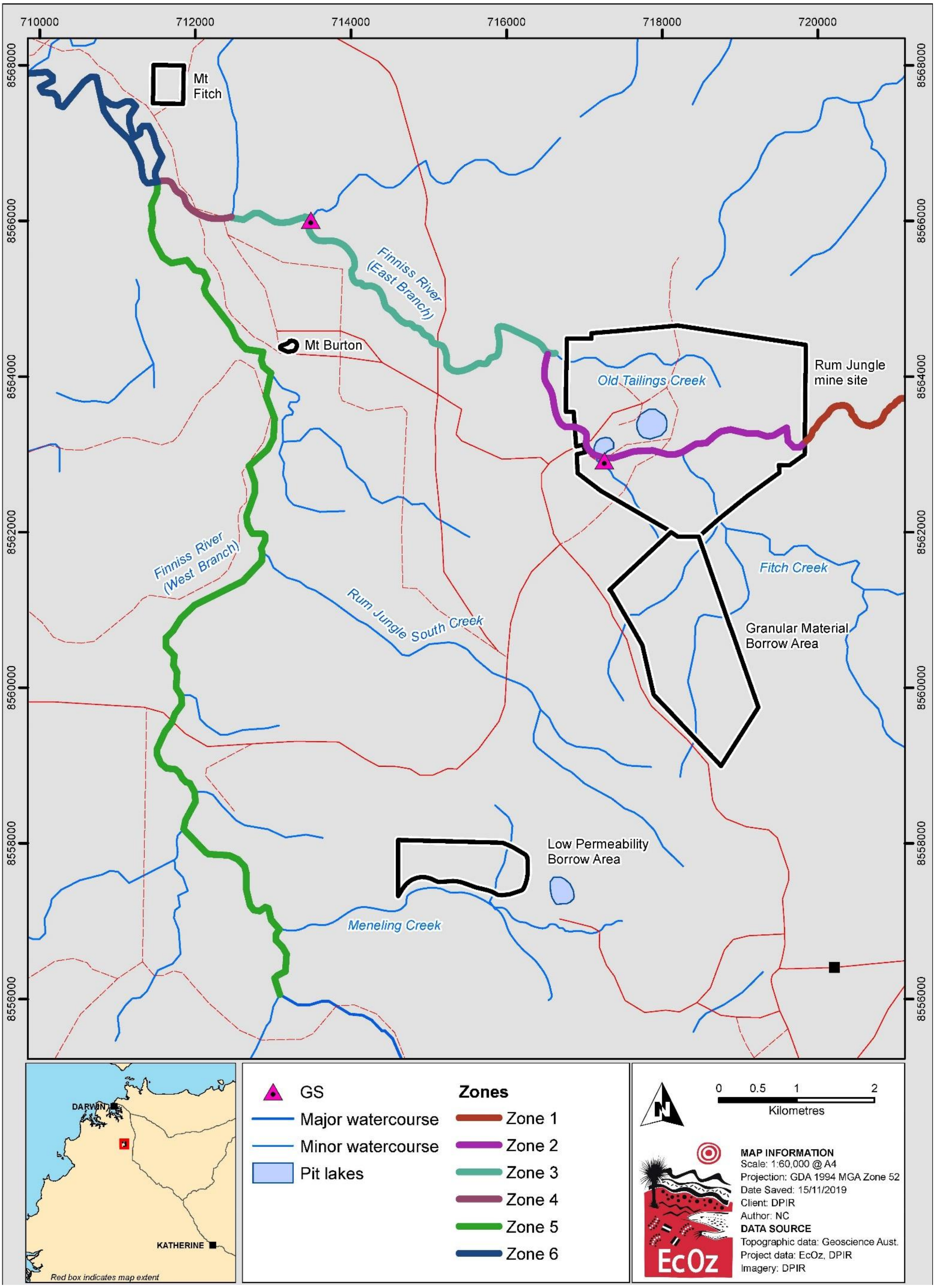

Figure 11-1: Surface water features and river zones within the project footprint

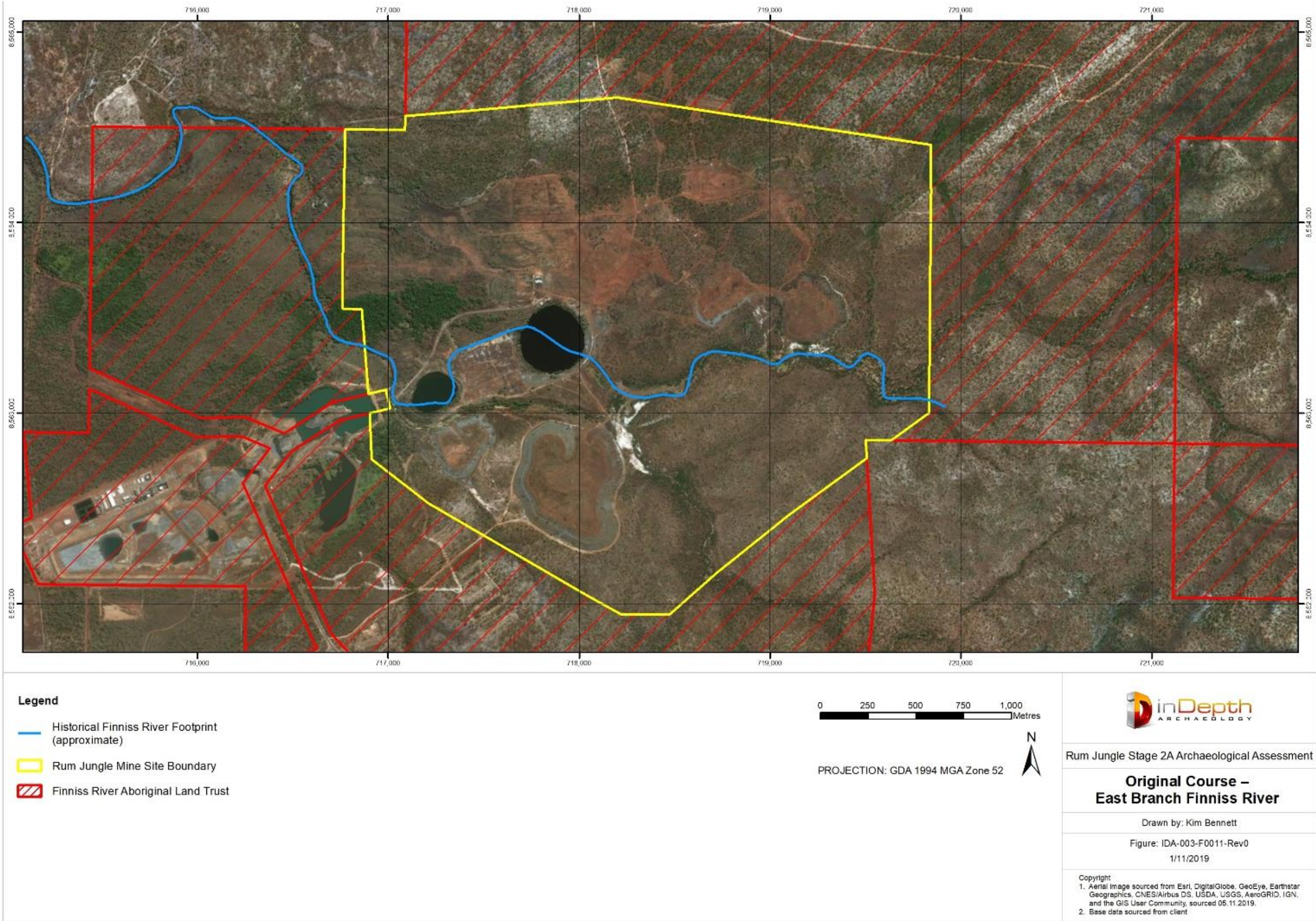

Figure 11-2: Original course of the East Branch

11.1.2. Current Surface Water Flows

Rum Jungle Mine site

Robertson GeoConsultants (2011) describe the historical and existing hydrology on the site. The mine site is located along the EBFR about 8.5 km upstream of its confluence with the West Branch. Surface water enters the mine site *via* the upper East Branch and Fitch Creek. Before mining, these creeks met near the north-east corner of the Main WRD and subsequently flowed eastward *via* the natural course of the East Branch. The original course of the East Branch ran through the Main and Intermediate ore bodies, so flow was diverted to the EFDC during mining operations.

Today, flows from the upper East Branch and Fitch Creek are split between the EFDC and the Main Pit near the former Acid Dam; the majority of flow passes through the EFDC. Water from the Main Pit flows to the Intermediate Pit *via* a channel that roughly follows the original course of the EBFR. Outflow from the Intermediate Pit to the EFDC occurs near the western boundary of the mine site, with the combined flows from the open pits and EFDC continuing in a north-easterly direction via the natural course of the EBFR.

Flows in the East Branch downstream of the former mine site are currently monitored at gauge GS8150200 (near the road bridge) and then again 5.6 km downstream at gauge GS8150097. Gauge GS8150200 drains an area of 53 km^2 that includes the pits and WRDs, but does not capture flows from the former tailings dam area (which drains *via* Old Tailings Creek). Gauge GS8150097 captures the additional flows from Old Tailings Creek and several small tributaries that do not drain the Rum Jungle site. Gauge GS8150097 has long been considered the principal compliance point for surface water monitoring at the Rum Jungle Mine site and so flows at this location have been recorded almost continuously since the 1960s (Davy, 1975). Gauge GS8150200 was established in 1991 to collect flow (and water quality data) during the 1993 to 1998 monitoring period and has been used ever since (see Lawton and Overall, 2002).

Flows in the East Branch vary predictably in response to intra-annual variability in rainfall and typically vary by several orders-of-magnitude over the course of a single year. First flows at gauge GS8150200 are usually observed in early December in response to high-intensity rainfall events that often occur in the early Wet season (Taylor *et al.*, 2003). First flows at gauge GS8150097 usually occur 3 to 4 weeks after they are recorded at gauge GS8150200 due to 'wetting up' of the dry river bed between the gauges (Lawton and Overall, 2002). Sustained flows at both gauges typically occur by mid-January and continue until the end of May with peak flows usually occurring in February or March. No appreciable flow is observed at gauges GS8150200 and GS8150097 from June to November due to minimal rainfall but small, often localised storm events do cause small flows that may not be recorded at the gauges.

From 1969 to 2001, annual flow volumes at gauge GS8150097 ranged from 7 to 10 billion litres (L) for relatively dry years (annual rainfall < 1000 mm), up to 65 billion L in 2000/2001 (the wettest year of this period). These annual flow volumes correspond to Wet season flows of 400 to 600 L/s for relatively dry years to 4,000 L/s for wetter years. Mean annual flows at gauge GS8150097 are higher than at gauge GS8150200 due to inflows from several creeks (including Old Tailings Creek) and the discharge of groundwater from dolomite beds to the EBFR downstream of gauge GS8150200 (Davy, 1975; Lawton and Overall, 2002).

Borrow areas

The low permeability material borrow area has only a first order drainage depression transecting it north to south, possibly created by an old track as it supports no riparian vegetation. This borrow area is adjacent to Meneling Creek.

The granular material borrow area contains two, low order ephemeral creeks that are, in the lower reaches, bordered by riparian vegetation; these flow into Fitch Creek.

Mt Fitch and Mt Burton

Mt Fitch contains an artificial waterbody (a water-filled pit from historic mining) and a north-south drainage line which runs into the main Finniss River. Mt Burton is adjacent to a spring-fed creek and is near to the West Branch.

11.1.3. Beneficial Uses

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

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

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

11.2. Potential Impacts and Risks

The *Risk Register* (GHD, 2019f – see Appendix) identifies three potential impacts that project activities detailed in Chapter 2 – Proposal Description could have on the hydrological process values detailed above. The severity of these impacts have been assessed according to the spatial and/or temporal scale of the 'maximum credible consequence'. For hydrological processes, that consequence is a change in hydrological regime that has a net detriment to other users or the environment, <u>cognisant of the existing condition of the ecosystem</u>. As noted above and in Chapter 10 – Inland Water Environmental Quality and Chapter 12 – Aquatic Ecosystems, some of the hydrological processes are already compromised because of historic watercourse diversion activities at the Rum Jungle Mine and Browns Oxide Mine sites. In other words, many of the watercourses within the project footprint – especially the East Branch – are highly disturbed ecosystems. One of the primary goals of the project is to remedy this as much as possible; nevertheless, as detailed below, there remains the possibility that certain project activities could temporarily have the opposite effect.

One of these potential impacts was rated as being of Low inherent risk to hydrological processes and therefore does not require specific mitigation measures. That potential impact is the change in regional groundwater regime if the neighbouring Browns Oxide Pit is dewatered in preparation for mine production. This potential impact is not addressed any further in this EIS. Risks relating to exceptional rainfall events are addressed in Chapter 15 – Human Health and Safety.

The two remaining potential impacts that project activities could have on hydrological processes had an inherent risk rating of Medium. These impacts are restricted to the mine site and are discussed below.

11.2.1. Impacts due to Altered Flow Regimes

The vast majority of the annual flow volume in the section of the EBFR that bisects the former mine site is during the Wet season. That section of the river has standing water for most of the year as flow ceases fairly early on in the Dry season.

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

The majority of the catchment reports, at present, through site *via* the EBFR diversion channel south of the Main and Intermediate Pits (see Figure 11-3). This catchment will not be modified by Main Pit backfilling activities and diversion of flows will continue to pass *via* the existing diversion channel. No water balance is presented here for this catchment as there is no planned change to the flow regime with surface water flows continuing to report to the diversion channel and pass offsite *via* this channel. This water will not be captured or altered in any way from its current state. The only change to the surface water flow regime during backfilling will be in the small catchment that reports to the Main and Intermediate Pits. This is described in detail below. This catchment is however included in the site-wide Water and Load Balance as described in Robertson GeoConsultants (2019) (see Appendix).

Figure 11-3 and Figure 11-4 show the significant upstream catchment that reports to the existing diversion channel and the three smaller local catchments – Browns Oxide area, the existing WRD area and the Main/Intermediate Pit direct catchment. The catchment areas are estimated at 4,020 ha (Upstream), 389 ha (Browns), 83 ha (WRDs) and 47 ha (Pits). Therefore the vast majority of surface water that passes through site will be diverted *via* the existing Diversion Channel unimpeded and untreated as it does now (see Figure 11-5).

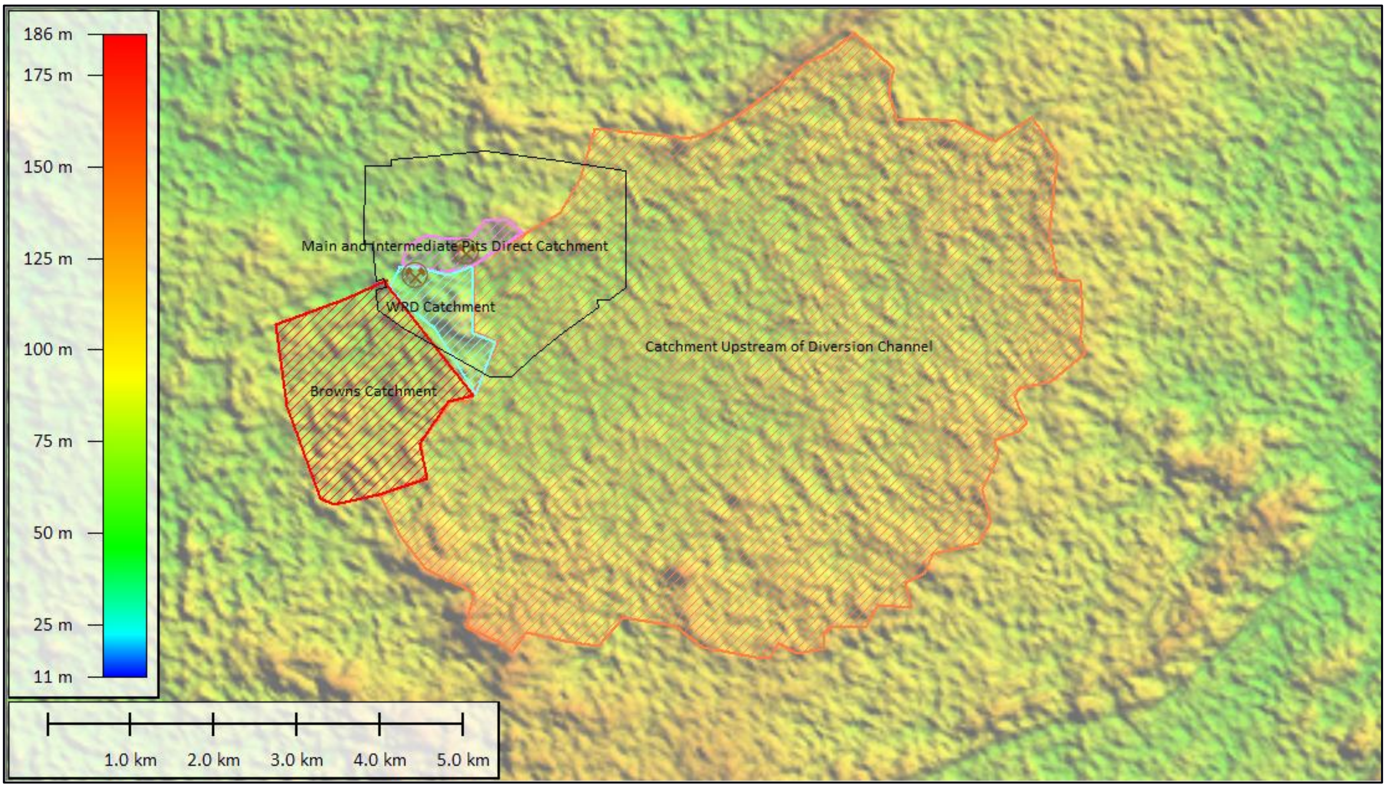

Figure 11-3: Local Catchments Overlaying Aster Global Digital Elevation Model v2

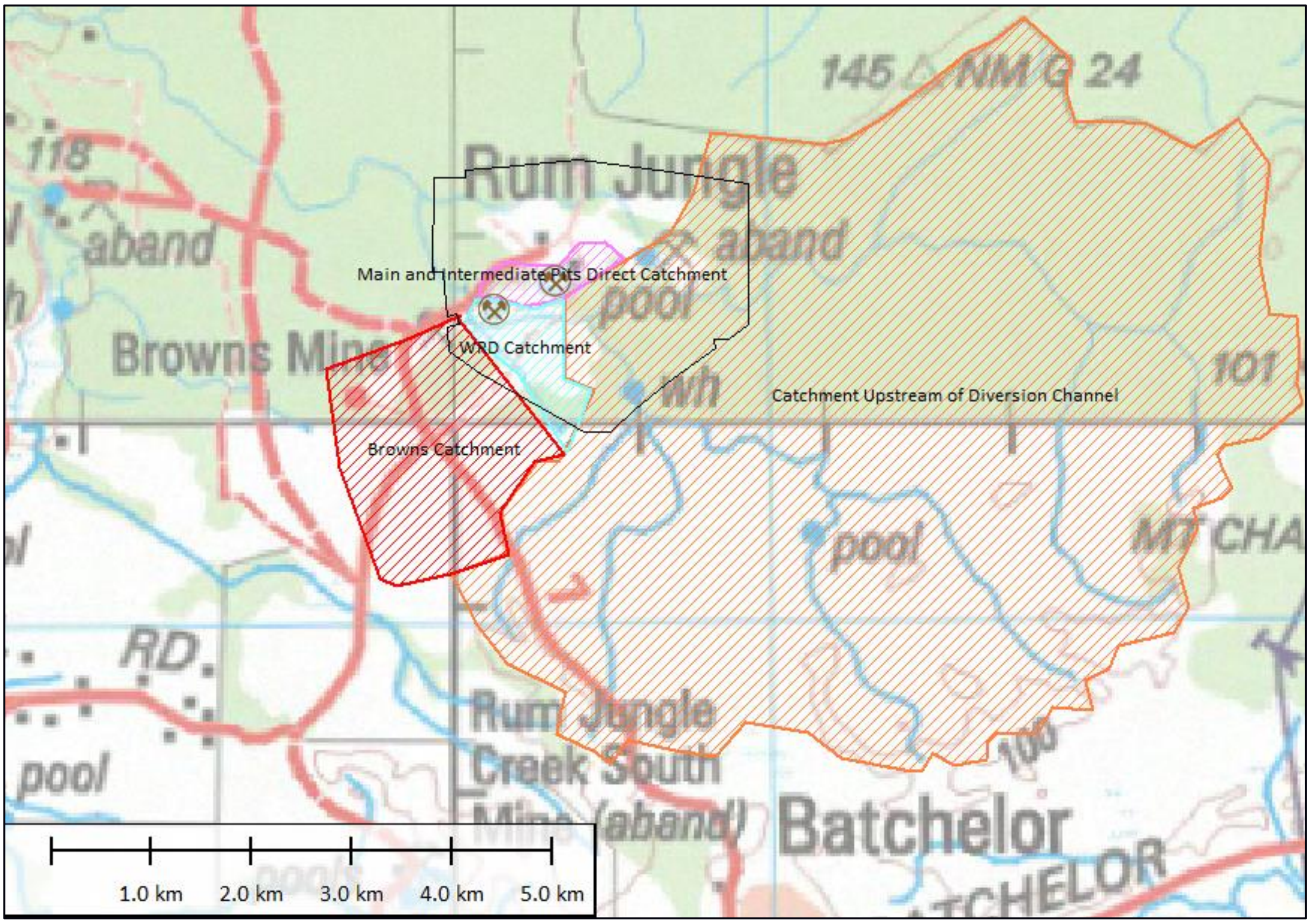

Figure 11-4: Local Catchments Overlaying NT Topographic Maps 1:250,000

A water balance (Goldsim) was developed by Robertson GeoConsultants to assist in development of a water management strategy for Main Pit backfilling and to understand water treatment requirements. In order to safely manage surface waters within the site pits and to backfill Main Pit in the most efficient manner possible, it is proposed that managed surface water discharge from site would be required during the Cease to Flow period (Dry season). The flow rate of this discharge is estimated at a maximum of 10-100 L/s (totalling approximately 0.2 GL) for the Dry season period from the SIS and Copper Extraction Pad recovery bore (see Figure 11-7). This is the maximum volume of water predicted to exit the WTP during the Dry season and it is important to note that a significant proportion of this volume would be consumed in onsite earthworks processes for dust suppression and WSF construction (estimated at . The volume of Dry season treated water is equivalent to the pumped groundwater for treatment from the existing WRDs. This is proposed for the three Wet season Main Pit backfilling operation. Although it would be helpful to also discharge to the EBFR during the Dry season for the post-backfill period of six years, this additional period of time may be considered to pose an unacceptable risk to the downstream ephemeral systems. An efficient alternative storage arrangement for the post-backfilling period can be found in the Intermediate Pit.

It is proposed to discharge from the WTP to a point downstream of Browns Oxide Pit as shown in Figure 11-5. This figure also shows the schematic arrangement of infrastructure required for the groundwater SIS bores, pipe layout, WTP location, Pit dewatering pipe laout in relation to the surface water flow path during construction (*via* the existing diversion channel). The catchment reporting to the existing blue EBFR diveriosn channel during pit backfilling is unchanged from current conditions as described above.

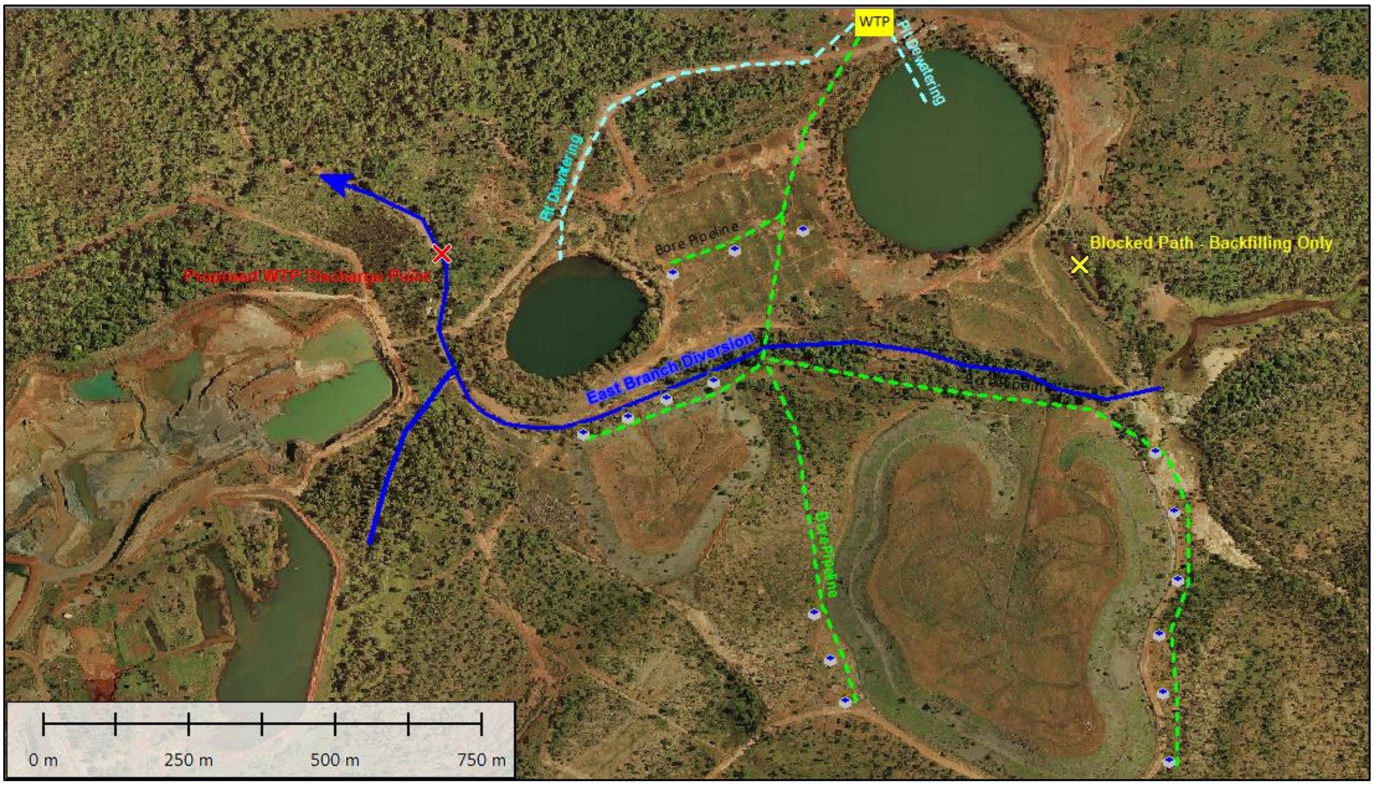

Figure 11-5: Water Management Layout

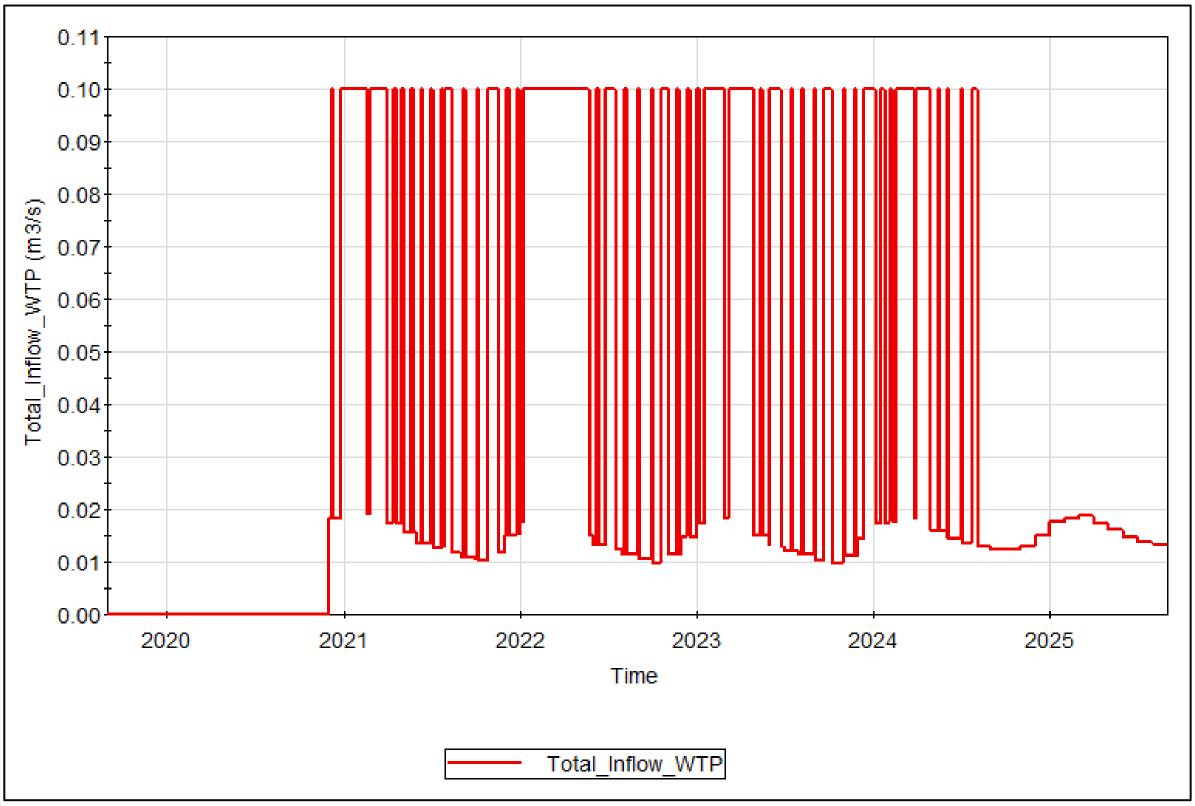

Figure 11-6: Modelled WTP Input Flow Rates

To gain perspective on this proposed WTP discharge regime, the available data for current flow conditions for the downstream gauges GS8150097 and GS8150204 (Figure 11-7) were compared to conditions predicted with the addition of the WTP discharge. Gauge GS8150097 is downstream of the Rum Jungle Mine project boundary by approximately 5.6 km, whilst gauge GS8150204 is located approximately 3 km downstream of GS8150097 beyond the confluence of the East Branch and West Branch.

Table 11-2: Impact of proposed WTP discharge regime during Main Pit backfilling

Gauge Station:	**GS8150097**		**GS8150204****	
Parameter	**Current Condition**	**Predicted Change**	**Current Condition**	**Predicted**
Flow Period	Early Dec to early Jun	Year round	Dec to mid-Oct	Unchanged
Peak Flow	Feb-Mar	Unchanged	Jan-Mar	Unchanged
Annual Volume	10-65 GL	Increase by 0.6 GL	90-310 GL	Increase < 0.6 GL
Wet Season Flow Rate	0.6-4 m^3/s	Increase by 0.034 m^3/s*	7-18 m^3/s	Increase < 0.034 m^3/s

**Averaged groundwater contribution for a year*

*** Relatively small data set*

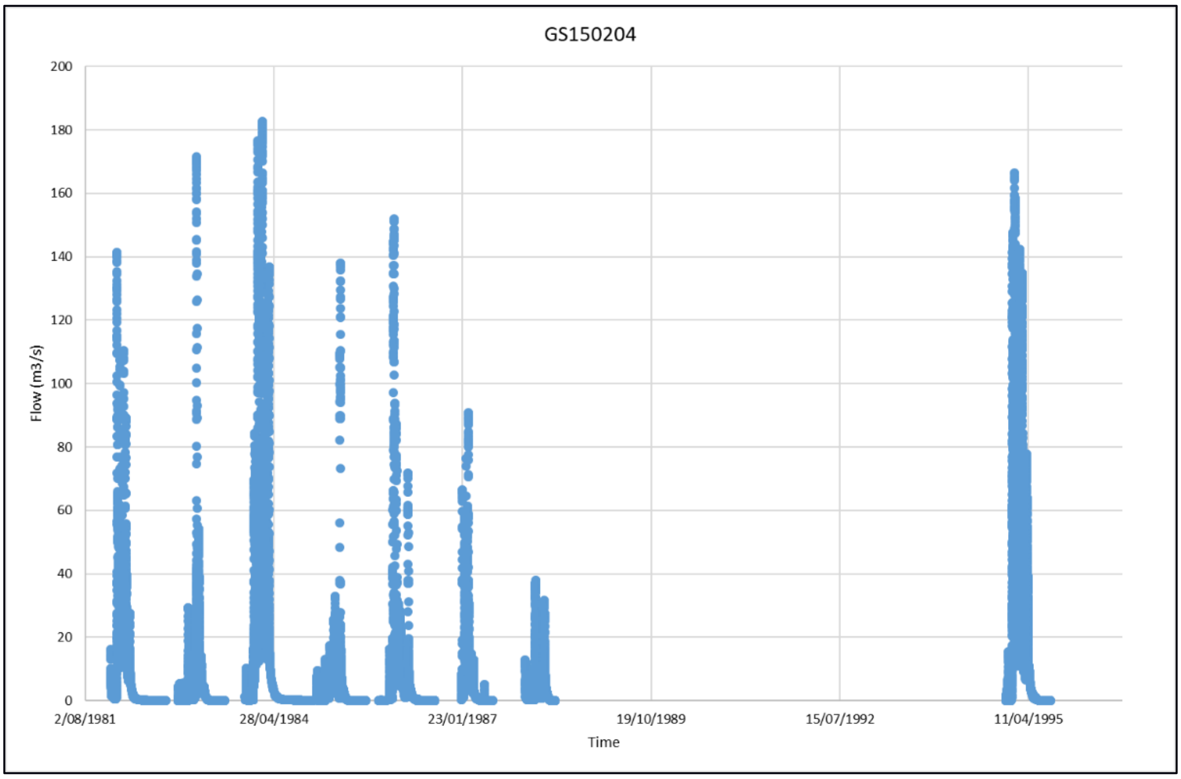

Figure 11-7: GS8150204 flow rate available data

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

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

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

11.2.2. Impacts due to Groundwater Drawdown

As discussed in Chapter 14 – Terrestrial Flora and Fauna, the vine forest within the mine site is, to some degree, a terrestrial GDE. There is the potential that changes (positive or negative) in groundwater levels of surrounding aquifers due to project activities could be detrimental to that ecosystem. This could occur because of the live storage and/or groundwater remediation programs proposed south of the Intermediate and Main Pits.

11.3. Mitigation and Management

Many aspects of the health and resilience of aquatic ecosystems are related to water quality and hydrological regimes. Chapter 10 – Inland Water Environmental Quality and Chapter 12 – Aquatic Ecosystems detail the mitigation management measures that will be employed for this project to minimise impacts to water quality and aquatic ecosystems. This section focusses on mitigation measures that are specifically designed to minimise impacts to hydrological processes – *i.e.* those relating to Construction phase altered flow regimes and surface water quality management.

11.3.1. Altered Surface Flow Regimes

The impact to hydrological processes due to altered surface water flow regimes during the Main Pit backfilling operations will be moderated by the maximum use of treated water in the dust suppression and construction processes onsite. The dry time of year correlates to the highest water demand period for dust suppression and construction because all work areas will be subject to low humidity, warm conditions and high equipment movement rates. The availability of this treated water offsets the need to abstract from clean water sources for the purpose of dust suppression and construction. Water demand for dust suppression and WSF construction is estimated at 1,250 m^3/day.

Surface water management during construction

A key element of the Stage 3 construction works is the backfilling of the Main Pit. This is currently scheduled to take approximately three years and is planned to run through both the Wet and Dry seasons. In order to do this task, surface water flows onsite will have to be well managed to avoid impacts to worker safety, to backfilling equipment and to protect offsite water quality during the backfilling process. Components of this water management process include:

1. Ensuring 100% of East Branch flows are diverted to the existing diversion channel (*i.e.* EFDC).
2. Ensuring the maximum local pit catchments are re-diverted away from Main and Intermediate Pits.
3. Utilising Intermediate and Main Pits as ‘live storage’ volumes to absorb potential high rainfall events and reduce the chance of pit overtopping as far as possible. To this end:
    a. Intermediate Pit will be drawn down to 8-9 m below the invert elevation of the outlet; and
    b. Main Pit will be drawn down to an operational elevation of 1-2 m below the invert elevation of the outlet.

1. Continuous pumping and treatment of Intermediate and Main Pit waters during the three year operational phase to maintain these levels. The water treatment volume will be equal to the volumetric displacement due to Main Pit backfilling, groundwater inflows and surface water inflows (Wet season only).
2. A WTP to treat the surface and ground waters prior to release from site.
3. An EMP in the event of predicted extreme rainfall events (for example cyclones) to ensure worker safety, and protection of equipment and property.

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

- The Intermediate Pit acts as a sink for some AMD-impacted groundwater flows from the Intermediate and Main WRDs. Drawdown of the Intermediate Pit will draw an increased flow of AMD-impacted groundwater into the Intermediate Pit thus deteriorating the water quality in that pit. Excessive drawdown of Intermediate Pit is likely to cause significant deterioration to Intermediate Pit’s water quality.
- The Intermediate Pit is connected by groundwater to the East Branch and water quality of the Intermediate Pit itself can cause impact to the East Branch *via* groundwater movement.
- The Intermediate Pit is connected by groundwater to the GDE to the north of Intermediate Pit. This vine forest would be adversely impacted by excessive drawdown of Intermediate Pit.

- The Main Pit is to be backfilled by an overwater conveyor and barge setup. This requires a minimum freeboard in which to operate. Additionally, geotechnical stability of the Main Pit crest is at risk under excessive pit water drawdown. This would present an unacceptable safety risk.
- The nominated operational water levels were modelled against rainfall events that have occurred within the 45 year dataset of events captured at gauge GS8150097. This configuration of pit water elevations would allow for capture of all high rainfall events within the dataset except for Tropical Cyclone Carlos (a 5% Annual Exceedence Probability (AEP) event over 48 and 144 hour durations – sufficient for the short duration backfilling task).

It is likely that Main Pit's water quality will deteriorate during backfilling operations because the existing chemocline is likely to be disturbed and vertical water column mixing may occur. Additionally, the placement of waste rock materials that have been on surface for up to 70 years into the water-filled void is likely to cause solutes within the waste rock to dissolve. It is imperative that pH control of the Main Pit Lake is maintained to precipitate high risk heavy metals and to reduce further acidification. However, soluble salts such as calcium, magnesium, potassium and sodium sulphate are likely to readily dissolve into solution. The water quality during backfilling is difficult to predict; therefore, the most critical controls for environmental protection are the WTP and the maintenance of a 'live storage' volume as described above. The Water Management Plan (see Appendix) will be updated prior to commencement of Stage 3 works and implemented throughout the project.

Stage 3 East Branch water course re-instatement

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

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

The reinstated channel will be designed in accordance with leading practice guidelines for channel restoration and reinstatement – *e.g.* ACARP (2014). This will include the following considerations:

- Replicating, as far as practicable, the morphological and hydraulic characteristics of the existing and adjacent East Branch channel. These might include factors such as width, depth, instream bars and benches, bed material and substrate, roughness elements, slope, length and vegetation.
- Incorporate natural features present in the landscape and in local watercourses.
- Maintain equilibrium, functionality and stability.
- Consider longer term sediment supply, transport and fate within the context of the local conditions.

Key considerations for the reinstatement will include:

- The need to ensure passage for aquatic fauna through the pits and the reinstated channel. This will require flow velocities to accord to appropriate limits and the inclusion of areas of temporary refuge for migrating aquatic fauna using roughness elements, backwaters and the like.
- Establishment of a resilient vegetation community using appropriate and acceptable species to enhance natural values and provide erosion protection, particularly given the seasonal rainfall characteristics and potentially high flow rates. This will require establishment of a stable soil surface, and establishing both fast growing groundcover and slower growing shrubs and trees *via* seeding and the use of tube stock.
- Levees, as necessary, to reduce the risk of an avulsion or breakout of flows from the reinstated channel during higher flow events.
- Low weirs and diversion structures as appropriate to ensure the required flow split between the existing diversion and the reinstated channel is achieved.

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

- Engineered entry and exit transition zones between the reinstated channel and both the Main and Intermediate Pits to ensure that erosion does not occur at these flow transition points.

- Covers over waste rock in Main Pit, including rip rap rock armour.
- Re-profiling of the pit rim edge area to allow vegetation to establish.
- Overland drainage management to prevent uncontrolled runoff into the Main Pit from overland flow and any associated erosion and gullying.

An appropriately-qualified person will be engaged to support this design to ensure that geomorphological elements are incorporated and that the 1% AEP design IFD is met.

11.3.2. Groundwater Drawdown

Groundwater drawdown over the Stage 3 project is expected to be impacted by the groundwater treatment process throughout the life of the Stage 3 works and the Intermediate Pit drawdown over the three year Main Pit backfilling process. The vine thicket to the north of Intermediate Pit is a GDE that may be impacted by these project works.

The groundwater recovery and treatment process is not expected to impact this ecosystem in the longer term as once Main Pit is backfilled and Intermediate Pit water levels return, this pit water body will buffer fluctuating groundwater levels during the remaining Stage 3 works and into the long-term future.

The Intermediate Pit drawdown though could impact this vine thicket ecosystem as the Intermediate Pit water body is hydraulically connected to the groundwater to the north. The impact is expected to be mitigated by the short three year duration. The modelled drawdown in the north is shown here in Figure 11-8 and Figure 11-9. This model does not include water in the unsaturated zone which will remain within the root zone of this GDE.

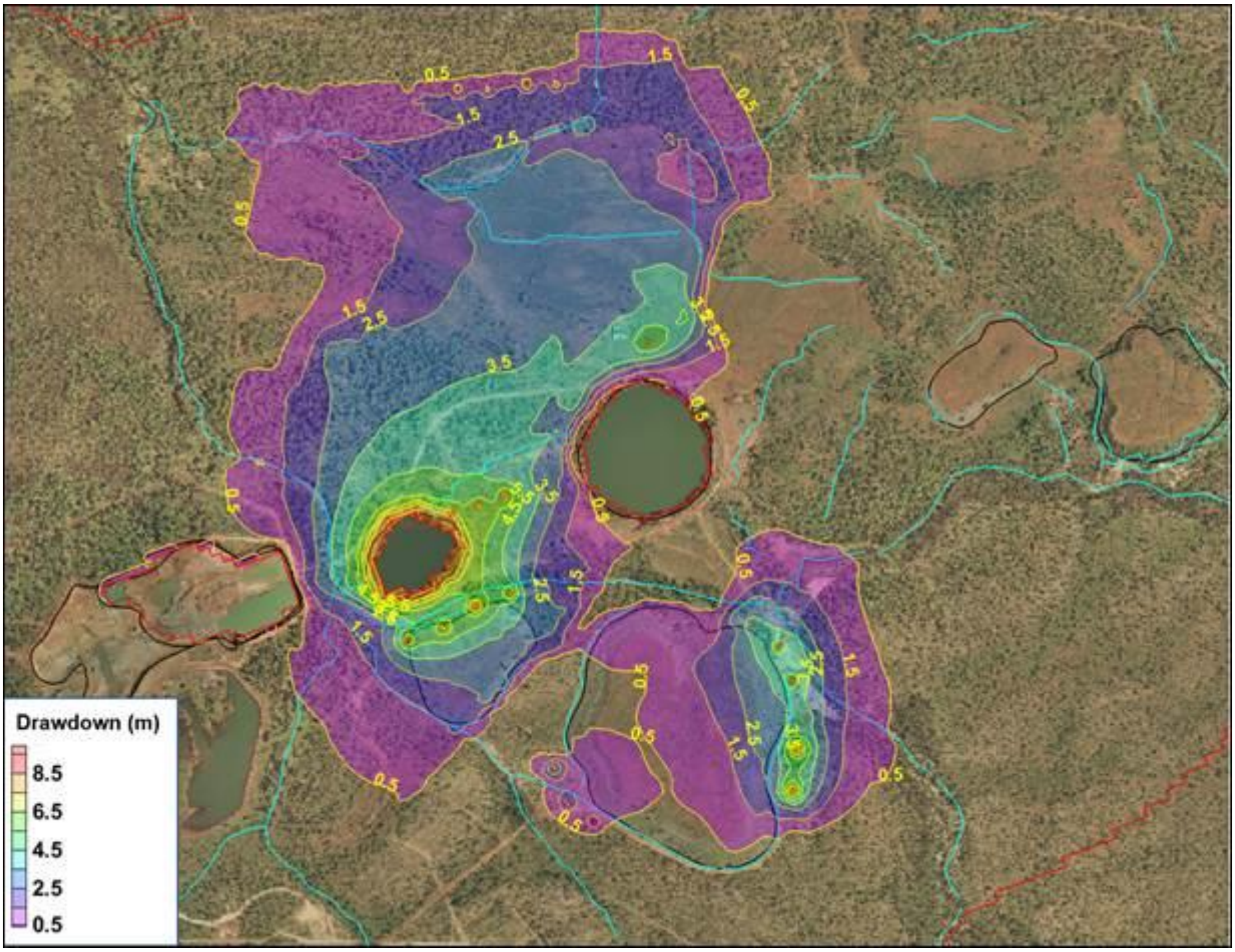

Figure 11-8: Predicted drawdown at Year 4 of Stage 3 (Dry season) – Intermediate Pit drawn down for Main Pit backfilling and recovery bores operational

Overall, the predicted drawdown for the backfill process varies from 5.5 m on the southern boundary of the GDE to 1.5 m drawdown in the north west of the vine thicket. MB10-17 is the monitoring well closest to the GDE and water levels during the Dry season are on average 11.5 to 13.5 m bgs; therefore the pit dewatering results in an average Standing Water Level of 14-16 m bgs.

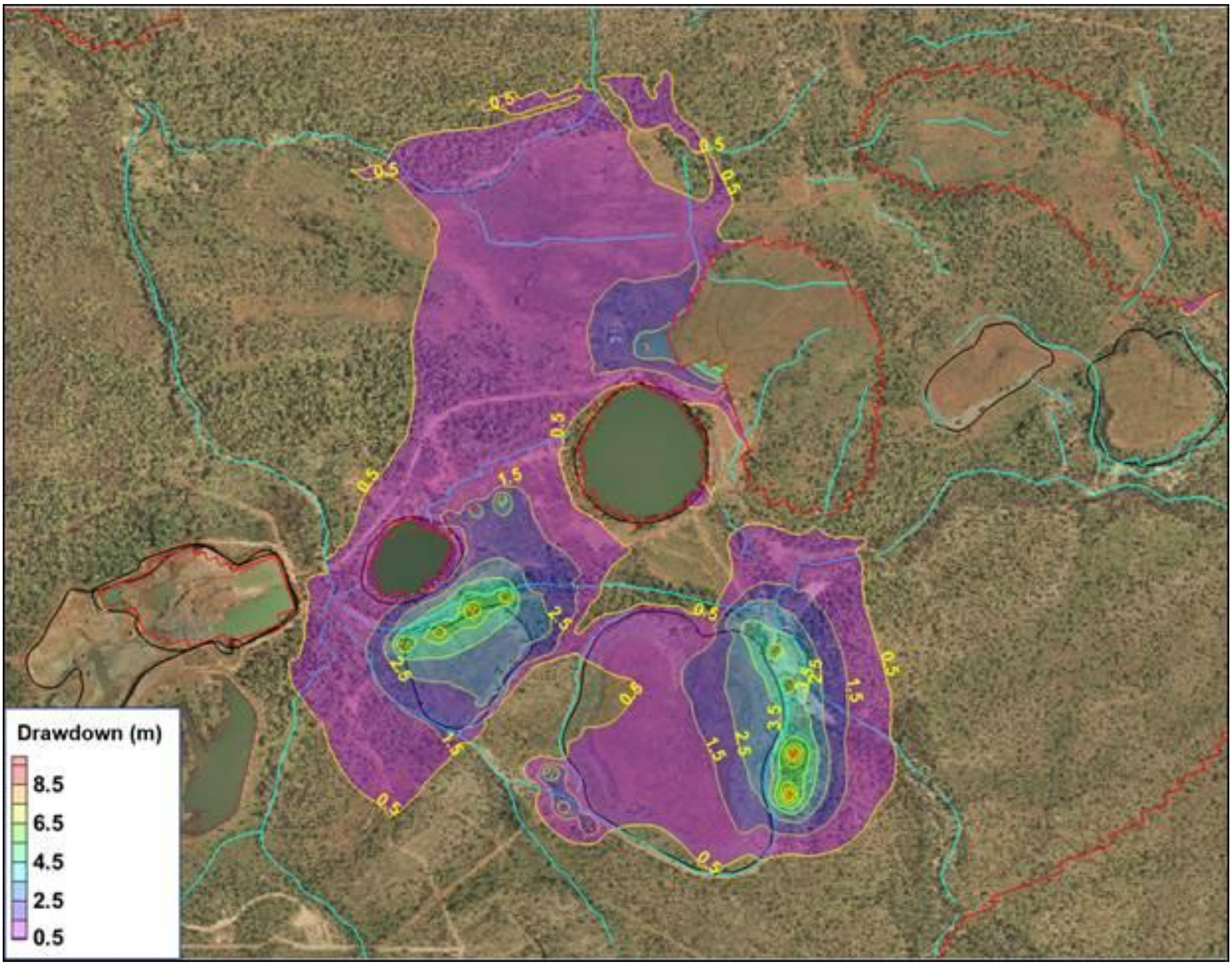

Figure 11-9: Predicted drawdown at Year 10 of Stage 3 - only recovery bores active

The risk of impact to the GDE during the Main Pit backfilling process is balanced by the need to maintain the 'live storage' volume within Intermediate Pit during backfilling to mitigate the risk of overtopping the impacted surface waters to the EBFR. The risk appetite for overtopping was determined to be lower than that for the groundwater drawdown. Potential impact to the GDE could be reduced by reducing the 'live storage' capacity and accepting a higher potential likelihood of overtopping during high rainfall events.

11.4. Monitoring and Reporting

Monitoring of surface water quality and quantity will form the primary components of the Construction phase monitoring regime to ensure that shorter term Construction phase impacts are minimised as far as possible. The monitoring program for groundwater (quality and quantity) is detailed in Chapter 10 – Inland Water Environmental Quality. The following sections present an overview of the monitoring program for hydrological processes.

11.4.1. Objectives

The objectives of the monitoring program for hydrological processes are to ensure worker safety, protection of equipment and environment by:

- Establishing a dataset of actual discharged water volumes and quality over time in which to compare downstream monitored ecosystem changes during the three year Main Pit backfilling program.
- Ensuring that the reinstated channel remains stable and fulfils its design objectives by construction and operations monitoring for (1) channel stability, (2) ecosystem processes and (3) vegetation establishment.
- Ensuring that Intermediate and Main Pit water levels are maintained at the proposed operational elevations to ensure that high rainfall event storage is adequate.
- Ensuring that operations management and staff are aware of forecast high rainfall events well in advance in order to prepare workers and equipment for that event.

The ESCP requires that regular site wide turbidity in water monitoring is complete. Visual inspections on all erosion and sediment control structures will be required as outlined in the Plan.

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

The monitoring of aquatic fauna passage and recolonisation of site after the Stage 3 construction works are complete is outlined in Chapter 12 – Aquatic Ecosystems.

Monitoring of water discharge to the East Branch should be automated and undertaken on a continual basis during the Main Pit backfilling and the groundwater treatment phases. Water quality monitoring is described in Chapter 10 – Inland Water Environmental Quality.

11.4.2. Monitoring Plan

The following Table 11-3 summarises the proposed Monitoring Plan for the purpose of risk mitigation related to hydrological processes. A detailed Water Monitoring Plan will be developed as part of the WDL approval's process. As a minimum, the current water monitoring program described in Chapter 10.3 will continue throughout Stage 3 with appropriate additions as described throughout the EIS.

Table 11-3 Proposed Monitoring Plan

Location	Parameters	Target	Frequency	Internal Management Reporting
Main Pit Water Level	Level	58-59 mRL	Continuous	Daily
Intermediate Pit Water Level	Level	49-50 mRL	Continuous	Daily
WTP Discharge to East Branch	Flow Rate	NA	Continuous	Daily
Sed. Control Ponds - Mud Level	% full	NA	Daily	Daily
Groundwater Points – Pits	Level	NA	Weekly during Pit Backfill	Weekly
Groundwater Points – WRDs	Level	NA	Weekly during Groundwater SIS	Weekly
Vine Thicket	Veg Health	Unchanged	Monthly in dry season	Monthly

11.5. Statement of Residual Impact

Most of the existing hydrological processes and aquatic ecosystems within the project footprint – especially in the East Branch – are already compromised because of historic mining practices and present-day contamination processes. One of the primary goals of the project is to remedy this as much as possible; nevertheless, there remains the possibility that certain project activities could have the opposite effect. Minor alteration of surface water flows are unavoidable. However, the Proponent proposes that the temporary (*i.e.* three Dry seasons) and spatially-constrained nature of this potential impact is an acceptable compromise in order to efficiently and effectively backfill the Main Pit void. The potential impact is also moderated by the existing condition of the East Branch and the small volume and flow rates of released water in comparison to those in a typical Wet season.

At the end of project completion, the EBFR flow will be split across the current EFDC and the newly reinstated EBFR watercourse. The split of flows across this will be maximised as far as possible through the original course. The final landform around Main Pit will be safe, stable and suitable for revegetation as required by site Custodians. The vegetation system will act as a 'screen' to hinder the view of this water body as requested by Custodians.

The groundwater elevations post-construction are expected to rebound to current conditions as the two pits will aid in the re-establishment of groundwater elevations.

Assuming proper adoption of the mitigation measures, the residual incremental risks relating to aquatic ecosystems and beneficial users have all been assessed as Medium to Low.

11.6. References

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Taylor G., Spain A., Nefiodovas A., Timms G., Kuznetsov V. and Bennett J. (2003) *Determination of the Reasons for Deterioration of the Rum Jungle Waste Rock Cover*. Australian Centre for Mining Environmental Research, Brisbane.

Verhoeven T.J. (1988) *Rum Jungle Rehabilitation Project*. Power and Water Authority, Darwin.

11.7. References included in Appendix

GHD (2019f) *Rum Jungle Stage 3 EIS Risk Register* – Rum Jungle Project Team.

Hydrobiology (2013) *Environmental Values Downstream of the Former Rum Jungle Mine Site – Phase 1*. Prepared for Department of Mines and Energy, Northern Territory Government.

Hydrobiology (2016) *Rum Jungle Impact Assessment: Final Report*. Prepared for Department of Mines and Energy, Northern Territory Government.

12. Aquatic Ecosystems

Figures

Tables

12.1. Environmental Values

12.1.1. Overview

The project area exists within the Finniss River catchment. In this chapter, that watercourse is referred to as the Finniss River (main or trunk) until a confluence where it branches into the East and West Branches. As shown in Figure 12-1, the majority of the project footprint is within the catchment of the East Branch. The exceptions are Mt Fitch and Mt Burton which are adjacent to the West Branch, and the low permeability material borrow area which is adjacent to Meneling Creek (which flows into the West Branch).

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

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

- The West Branch (and, indeed, the main Finniss River) is a large, permanent watercourse. It typically has steep banks (3 to 5 m high) that are terraced, a relatively-extensive floodplain and is characterised by sandy, heavily-vegetated levees. There are billabongs associated with the watercourse and floodplains, and downstream it flows through the Finniss River coastal floodplain SoCS which supports several listed threatened species.
- The East Branch is a semi-permanent stream within a distinct channel that dries to a number of pools in the mid to late Dry season depending on the amount of rainfall in the preceding Wet season. The bed is typically broad with low, earthy banks 1 to 3 m high with many sandy to rocky mid-stream shoals. Although riparian vegetation on the East Branch shows obvious signs of degradation, it currently supports a reasonable density and diversity of riparian species. The East Branch riparian corridor typically merges rapidly with surrounding Eucalypt woodland areas; there is little to no surrounding floodplain areas.

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

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

In light of the knowledge gleaned by a technical panel during Stage 1 of the project, a zone breakdown of the Finniss River system was developed in order to allow for the different environmental values and WQOs in different parts of the river system based on natural geomorphological characteristics, major tributary junctions, and the declared SoCS in the lower Finniss River. The zones are described in Table 12-1. Those most relevant to the EIS are shown in Figure 12-1.

Table 12-1: Finniss River zones

Zone	Condition
1. East Branch & tributaries: upstream of the mine	Slightly-Moderately Disturbed
2. East Branch: within mine site to Old Tails Creek	Highly Disturbed
3. East Branch: Old Tails Creek to Hannah's Spring	Highly Disturbed
4. East Branch: Hannah's Spring to confluence with West Branch	Highly Disturbed
5. West Branch: upstream of confluence with East Branch	Slightly-Moderately Disturbed
6. Finniss River: confluence to Florence Creek	Slightly-Moderately Disturbed
7. Finniss River: Florence Creek to SoCS inland boundary	Slightly-Moderately Disturbed
8. Finniss River: SoCS upstream limit to freshwater / saltwater interface	High Conservation Value
9. Finniss River: estuary	High Conservation Value

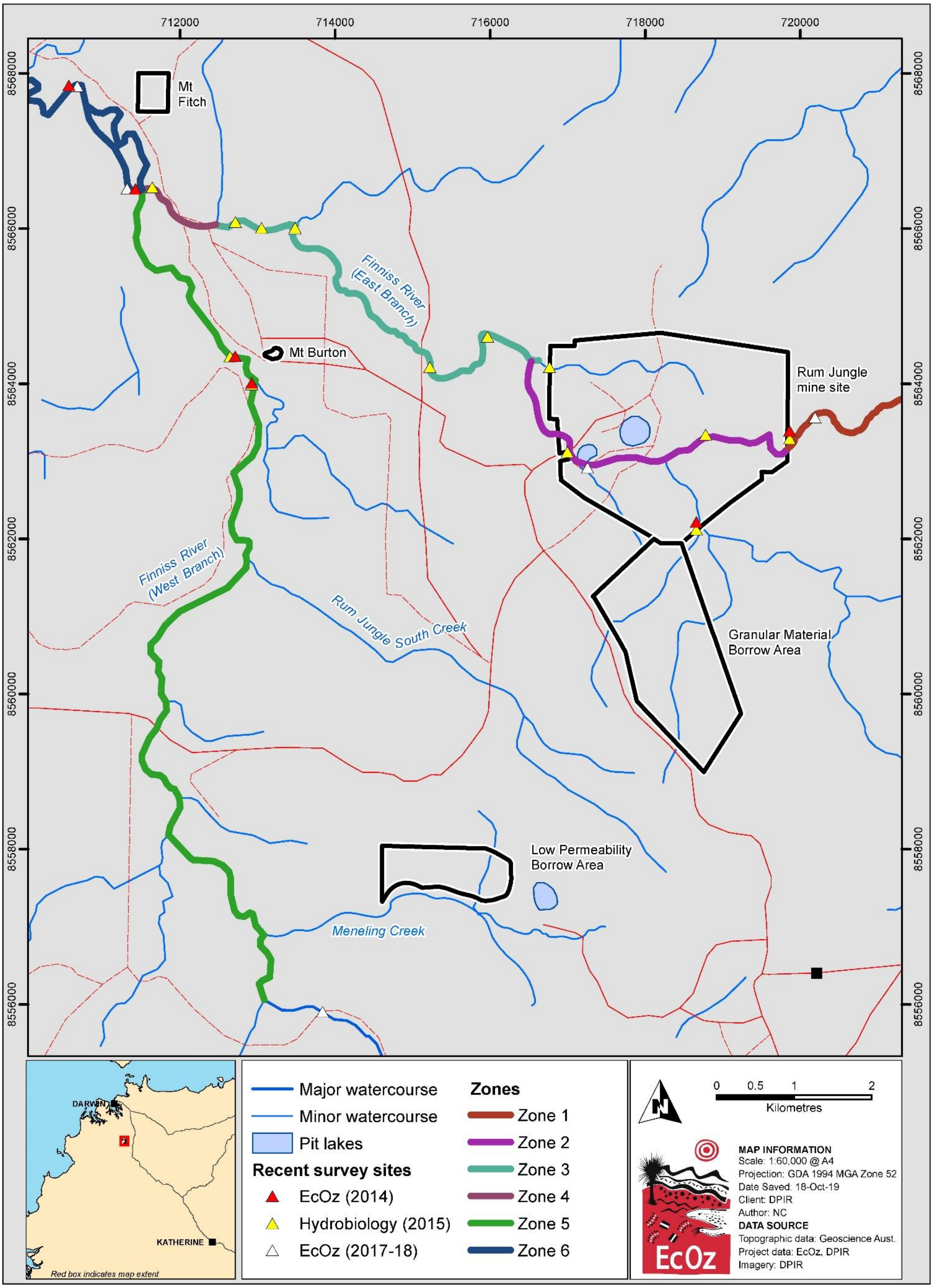

Figure 12-1: Surface water features, river zones and recent survey sites within the project footprint

12.1.2. Riparian Vegetation and Aquatic Macrophytes

Due to the long history of mining at Rum Jungle, baseline vegetation data for the Finniss River riparian zone, both upstream and downstream of the East Branch confluence, and along the East Branch itself, are essentially absent from the published literature. Aquatic macrophyte (visible plants) survey data for the Finniss River and its tributaries and billabongs are also non-existent. For this reason, this section will focus on riparian zone vegetation and a strategy for amending this data gap is outlined in the Section 12.4 of this chapter.

Riparian vegetation is ‘a distinct forest community occurring on the banks of rivers or streams that directly influences the adjacent water body’ (DENR, 2018).

Information sources

There are no baseline (*i.e.* pre-mining) riparian vegetation surveys for the Finniss River catchment. Riparian vegetation within the region (including the project footprint) is included in terrestrial vegetation surveys discussed in Chapter 14 – Terrestrial Flora and Fauna. In addition, Hydrobiology surveyed riparian vegetation along the branches and trunk of the Finniss River in 2013, and Eco Logical conducted assessments of riparian corridors within the mine site area in 2014. Hydrobiology (2016a) recorded canopy and woody understorey species at 13 fluvial sites, ranging from ~18 km upstream (in the East Branch) to ~30 km downstream of the mine site. Eco Logical surveyed six transects along the East Branch (and branching creeks), the diversion channel and Fitch Creek, recording plant cover, regeneration, erosion and weeds. Both surveys were in accordance with the *Tropical Rapid Appraisal of Riparian Condition Version 1 (for use in tropical savannas)* (Dixon *et al.*, 2006).

Description

There is riparian vegetation of varying quality and extent along watercourses throughout the project footprint. Metcalfe (2002) provides an over-arching description of riparian vegetation within the project footprint, noting that:

- The riparian community was the most diverse vegetation type within the survey area (a 37.5 km^2 area centred on the Browns Oxide mine site).
- The banks of the West Branch are heavily vegetated by large trees to 20 m with a typically mid-dense, varied understorey layer from 4 to 8 m high. The river levees are prime habitat for native Bamboo (*Bambusa arnhemica*). Other dominant riparian tree species include *Syzygium armstrongii, Ficus racemosa, Maranthes corymbosa* and *Buchanania arborescens*. Common mid-stratum species include *Diospyros calycantha, Canthium schultzii, Elaeocarpus arnhemicus, Barringtonia acutangula* and young Bamboo. An indicative photograph is presented in Figure 12-2.
- For much of the East Branch, the riparian corridor typically merges rapidly with surrounding Eucalypt woodland areas – having little or no surrounding floodplain areas. Vegetation fringing the river typically includes a narrow band of Black Wattle (*Acacia auriculiformis*) with Paperbarks (*Melaleuca cajuputi* and *M. leucadendra*), *Terminalia carpentariae* and *Corymbia polycarpa*. Common mid-stratum species include *Pandanus spiralis*, *B. acutangula* and the occasional Weeping Tea Tree (*Leptospermum longifolium*). An indicative photograph is presented in Figure 12-3.
- Weeds are common in the disturbed terrain surrounding the river banks (see below).

The Rum Jungle site contains 69 ha of different riparian vegetation (*e.g.* Figure 12-4) – comprising 4 ha of riparian grassland; 5 ha of *A. auriculiformis* woodland to open forest; 9 ha of riparian corridor (*i.e.* in the vicinity of creeks and channels); and 51 ha of paperbark (*Melaleuca* sp.) woodland to open/closed forest. Eco Logical (2014 – see Appendix) note that the *A. auriculiformis* woodland to closed forest has the same dominant species and stand structures as that of the *A. auriculiformis* vine forest described in Chapter 14 – Terrestrial Flora and Fauna, but that the associated species are very different and are more commonly associated with wetter habitats. Within the riparian corridor, the understorey is very diverse, but with many weeds transported by the creek/channel present (primarily Gamba Grass and Olive Hymenachne).

Mt Burton is situated on a tributary of the West Branch which is lined by significant areas of dense riparian vegetation. Riparian vegetation present along minor drainage lines in the granular material borrow areas was classified (EcOz, 2019 – see Appendix) as *Melaleuca viridiflora, C. polycarpa* +/- *Lophostemon grandiflorus* mid woodland over *L. grandiflorus, P. spiralis, M. viridiflora* shrubland and tussock grassland. Meneling Creek is bordered by *Melaleuca* species closed forest with the introduced Guinea Grass (*Megathyrsus maximus*) as the dominant ground layer.

Figure 12-2: Photograph of West Branch riparian vegetation (near confluence)

Figure 12-3: Photograph of East Branch riparian vegetation (downstream of the mine site)

Figure 12-4: Photographs of riparian vegetation on the East Branch in the centre of the mine site

Figure 12-5: Photographs of riparian vegetation (top) and an aerial view (drone image) of drainage line (bottom) in the gravel borrow area

Habitat quality

The Finniss River has been subject to contamination from the Rum Jungle Mine for more than sixty years. The assessment of Hydrobiology (2013a – see Appendix) is that along the main Finniss River:

> *The riparian vegetation assemblage was recovering well from the severe dieback resulting from the Old Tailings Dam failure and other unregulated pollution events during and immediately following the period of active mining. Mature White Paperbark trees (*Melaleuca leucadendra*) were present and abundant in the main branch of the Finniss River both upstream and downstream of its confluence with the East Branch. Other species that might be considered vulnerable to heavy metal toxicity such as Leichhardt Trees (*Nauclea orientalis*), Freshwater Mangroves (*Barringtonia acutangula*), River Pandanus (*Pandanus aquaticus*) and Billabong Trees (*Carallia brachiata*) were also universally abundant.*

Metcalfe (2002) stated that although riparian vegetation on the East Branch showed obvious signs of degradation, it supported a reasonable density and diversity of riparian species. Hydrobiology (2013a – see Appendix) disagree, stating that:

> *The East Branch stood in stark contrast with the main branch of the* [Finniss] *river. Only the paperbark (*Melaleuca viridiflora*) and Black Wattle (*Acacia auriculiformis*) were recorded as present and abundant on the Rum Jungle mine site and in the immediate downstream riparian zone.*
>
> *Care is needed in interpretation of these observations, as the East Branch is clearly intermittent in its flow regime whereas the main Finniss River is perennial or near-perennial. Nevertheless, it is likely that the higher concentrations of heavy metals and other contaminants in the system have limited or are limiting recolonisation by riparian species common to other seasonal braided streams in the western Top End.*

Fire and weeds are also confounding factors when it comes to assessing the impact of Rum Jungle on the East Branch. Hydrobiology (2013a – see Appendix) noted that at that time a meaningful assessment of the environmental values of riparian vegetation was hampered due to the lack of baseline data of naturally-occurring flora assemblages in the Finniss River catchment. More recent surveys undertaken by Hydrobiology (2016a – see Appendix) showed a significant difference in Riparian Condition Index (*i.e.* derived from indices relating to plant cover, regeneration, weeds and erosion) between the main Finniss River and the East Branch, for both Wet and Dry season data, but there was no difference in species richness. The ephemeral nature of the East Branch compared with the perennial main Finniss River was likely the main contributing factor and essentially prevented further assessment of the impact, if any, of the legacy mine on riparian condition and species richness.

Of the six transects within Rum Jungle that were assessed by Eco Logical (2014 – see Appendix), only two contained good quality riparian vegetation; three were considered moderate; and one poor. Habitat quality was good along Fitch Creek (in the southern area of mine site) and to the east of the diversion channel (south-east of Intermediate Pit); however, riparian vegetation to the west of the diversion channel was considered poor (see Figure 23 of Eco Logical (2014)). Eco Logical found that the primary drivers of poorer quality riparian habitat were largely cover of weeds (see below), organic litter derived from weeds, few tree size classes and reduced abundance of logs. Also noted were threats to riparian habitat – namely, adjacent tree clearing (from mining or rehabilitation activities that result in minimal regeneration), weeds (especially Gamba Grass), fire (frequent or late Dry season fires – especially fires fuelled by Gamba Grass – can limit the successful recruitment of riparian trees), feral pigs (which can spread weeds, uproot seedlings, cause erosion and trample groundcover) and channel modification (also from mining or rehabilitation activities). These pressures combine to limit natural recruitment of riparian trees, compromise bank stability and reduce resilience to fire and feral animals (Eco Logical, 2014).

Weeds

Most of the weeds that can occur in the riparian zone can also occur in other terrestrial habitats and so are detailed in Chapter 14 – Terrestrial Flora and Fauna. The exception is Olive Hymenachne (*Hymenachne amplexicaulis*) a perennial, robust grass that can grow above or below water (NTG, 2018b). It is regarded as one of the worst weeds in Australia due to its propensity to block waterways and affect water quality, in turn threatening fish and reducing habitat availability for waterbirds and other native animals (NTG, 2018b).

Kraatz and Norrington (2002) noted that no Olive Hymenachne was observed during field surveys of the mine site. In contrast, EcOz (2018a) recorded Olive Hymenachne at high densities along the eastern half of the East Branch as it runs through Rum Jungle. The species was also present in the western half, but at low densities. Hydrobiology (2013a – see Appendix) recorded Olive Hymenachne along the East Branch upstream and downstream of the mine.

12.1.3. Aquatic Fauna

Information sources

There have been many macroinvertebrate, aquatic or semi-aquatic fauna surveys of the Finniss River system. These are summarised in Table 12-2 and recent site locations are mapped at Figure 12-1.

Table 12-2: Summary of aquatic fauna and macroinvertebrate surveys conducted within areas of the Finniss River relevant to the project

Component	Target	Surveyor	When	Survey methods
Main Finniss River and East Branch	Fish and macroinvertebrates	Jeffree and Twining	1975	• Baited traps, dip nets, seine nets, poisoning and visual observation
	Macroinvertebrates	Pidsley	Dry season of 1994, 1995 and 1996	• Dip nets and baited traps (6 sites)
		Edwards	Circa 2002	• Unknown
	Fish and decapods	Twining	1993-97	• Baited traps, dip nets, seine nets and visual observation
	Macroinvertebrates, diatoms, mussels and fishes	Hydrobiology	Dry season 2014	• Gill-netting, electrofishing, fyke nets, bait traps, cast netting, seine netting, macroinvertebrate and diatom sampling (18 sites)
	Macroinvertebrates, diatoms and fishes		Early and late Dry season 2015	• Gill-netting, electrofishing, fyke nets, bait traps, macroinvertebrate and diatom sampling (18 sites)
	Turtles, water monitors and crocodiles	EcOz (for Hydrobiology)	May 2014	• Active searches, turtle trapping (baited cathedral traps) and spot-lighting (8 sites)
	Water monitors		March and May 2015	• Active searches and camera surveys (Fauna Tech/Keep Guard) (8 sites)
	Fishes and macroinvertebrates	EcOz	June 2017 and May 2018	• Seine, fyke, gill, cast and dip nets, angling and spot-lighting (6 sites)
		GHD	April 2008	• Seine and fyke netting, fish trapping, dip netting and active searches (8 sites)
Main Finniss River	Fishes	Davy	May/June, August/September and November 1974	• Entangling, poisoning, fyke netting and active searches (6 sites)
		Jeffree	July/August 1992 and 1995	• Netting (6 sites)
Main Finniss River, East Branch and Rum Jungle Creek	Semi-aquatic vertebrates and turtles	EMS	June 2002	• Spot-lighting, diurnal bankside observations and turtle trapping (8 sites)
	Semi-aquatic vertebrates		March 2005	• Spot-lighting and diurnal bankside observations (2 sites)

In 2014-15, EcOz (2014a, 2014b, 2015 – see Appendix) conducted surveys targeting the threatened Mitchell's and Mertens' Water Monitors (*Varanus mitchelli* and *Varanus mertensi*) in the West and East Branches. Those surveys were a component of a monitoring program to assess biological impairment in the riparian zone associated with the Rum Jungle Mine, as well as part of an assessment on culturally significant aquatic species. There are no survey guidelines for these species, and so methods were developed to observe the monitors during the day when they were most active (in accordance with methods used by Doody *et al.* (2006)). There were five survey periods across a year; in each, eight sites were actively searched both on foot and by boat looking for basking monitors along the river banks. For each survey, motion-activated camera traps (Keep Guard 690) were installed at each site, overlooking areas where the species were considered likely to occur, such as river banks used by monitors as basking platforms.

Fish and macro-crustaceans

More than 30 fish species have been recorded in the Finniss River trunk and branches during the surveys discussed above. There are factors that can be attributed to year-to-year variations in the frequency, timing, duration and intensity of flow (*i.e.* the flow regime), as dictated by seasonal rainfall (Bunn and Arthington, 2002). Over time, fish populations have evolved specific life strategies around the natural flow regimes and changes to these may result in reduced duration and suitability of spawning habitats, and decreased ability for fish to move longitudinally and laterally within a river (Lytle and Poff, 2004).

In a comparison of historical fish survey data, Hydrobiology (2016a – see Appendix) found overall that fish communities from sites downstream of mine inputs prior to the 1980s rehabilitation were significantly different from unexposed sites, being depleted in abundance and diversity. Hydrobiology (2013a – see Appendix) note that field studies during the 1990s demonstrated the occurrence of five to seven fish species in the contaminated region of the East Branch. These species penetrated to varying degrees upstream along a gradient of water contaminant concentrations. These occurrences indicated that varying degrees of tolerance to the contaminant concentrations had developed among these fishes (Gale *et al.*, 2003). Two species of decapod crustacean were also observed in the East Branch during these field investigations.

Although the number of fish and decapod crustacean species present did represent a recovery, compared with the pre-remedial status of the East Branch, it still fell well short of the potential diversity of up to 15-18 fish species and 5-6 species of macro-crustaceans that could be found in similar habitats elsewhere within the Finniss River system. Moreover, in the 1990s there were areas of the East Branch where neither fish nor decapods were found (Twining, 2002).

Results from fish surveys in 2014-15 by Hydrobiology (2016a – see Appendix) revealed that the East Branch and the West Branch are composed of distinctively different fish communities. In the West Branch-main Finniss River continuum, diversity gradually increases downstream; in the East Branch, Zone 2 (section within the mine site) is a clear barrier to many species with few able to reach Zone 1 further upstream. Fish abundance and species richness were lower values at sites closest to the mine.

In the most recent surveys, EcOz recorded 23 species in 2017 and 19 species in 2018. A West Branch site exhibited the highest species numbers at 15, and an East Branch site upstream of the mine site displayed the least diversity at just three species. EcOz only had one site within the East Branch that was downstream of the mine site, so any changes in fish diversity over distance could not be determined.

Hydrobiology (2016a – see Appendix) concluded from its longitudinal study of fish survey results (*i.e.* prior to rehabilitation, ~10 years (1990s) and ~30 years post-rehabilitation (2010s)) that:

> *Fish communities from sites downstream of mine inputs prior to the 1980's remediation were significantly different from unexposed sites, being depleted in abundance and diversity. However, this was not the case for samples post-remediation, where there appeared to have been recovery of fish communities at the exposed sites in Zone 6* [i.e. immediately downstream of the confluence]*. There was clear evidence that downstream and upstream communities were more alike post-remediation. Despite this observation, abundances at Zone 6 were reduced in the most recent sampling rounds (2010's) relative to the 1990's. However, flow in this reach of the Finniss River is particularly variable and is likely to be a substantial confounding factor affecting abundances.*

Benthic diatoms

Diatoms are important components of the algae present in the benthic zone – *i.e.* the sediment at the bottom of a watercourse. Diatom assemblages develop in a particular area in response to environmental factors, including metal concentrations; therefore the species that can be found in given water body will inform about localised environmental conditions. Hydrobiology (2016b – see Appendix) noted that one species known to be a very reliable indicator of metal contamination by its presence – *Achnanthidium minutissimum* – showed a clear and obvious reduction in its abundance and its proportional contribution to communities further downstream of the mine. Furthermore, it was not present in samples from the East Branch upstream of the mine and largely absent from sites in the West Branch and main trunk. Other taxa, also noted as tolerant of high metal concentrations, showed a similar pattern. These results appear to be very consistent with those of a study by Ferris *et al.* (2002) wherein a gradient of improving diatom condition was observed through the East Branch downstream from the mine site.

In contrast to the community data, values of total abundance and species richness were not particularly useful in determining differences among and between zones. In particular, the diatom assemblage of the East Branch, while less diverse and abundant than the sites in the Finniss River system, was dominated by species that were classified as preferring alkaline or neutral pH waters. This suggests the East Branch assemblage tends to be dominated by generally tolerant taxa and that indicators like diversity and abundance are not particularly useful.

Macroinvertebrates

Macroinvertebrates serve as excellent bio-indicators as they have very narrow ecological requirements and are often used to assess the health of a stream (Benetti *et al.*, 2012), if the assessment is cognisant that there are seasonal variations due to the ephemeral nature of some reaches of the system. Macroinvertebrate surveys carried out by Davy in 1974 and Pidsley between 1994 and 1996, returned low diversity for the main Finniss River and West Branch sites surveyed. In contrast, the 2007 and 2008 GHD surveys reflected the 2017 and 2018 EcOz survey results, returning a relatively high diversity of species at all of these sites.

Surveys in 2014 and 2015 by Hydrobiology (2016b – see Appendix) found that sites within and immediately downstream of the mine had lower values of abundance, taxonomic diversity and taxa richness than control sites upstream of the mine (*i.e.* in the East Branch upstream of the mine site and in the West Branch upstream of the confluence). The community assemblage at many sites in the East Branch downstream of the mine were shown to be statistically-distinct and were typified by high proportions of midges, compared with most other sites which had a more even spread of taxa and high proportions of mayflies. The exception was the main Finniss River downstream of the confluence of the branches which was distinct from all other sites. Both abundances and richness appeared to show a gradient of lower values within and immediately downstream of the mine area, but progressively higher towards the confluence, where values again decreased. A similar pattern of relative abundance and richness was previously reported by Edwards (2002). For sites in the East Branch, both the GHD and EcOz surveys also recorded lower macroinvertebrate diversity compared with at the West Branch and main Finniss River sites.

Hydrobiology (2016a – see Appendix) report on the change in mussel populations in the past two decades. Markich *et al.* (2002) reported that mussels were absent from the Finniss River for 10 km downstream of the East Branch junction. However in the 2014, mussels were collected just downstream of the confluence. This indicates that there had been substantial recovery of the mussel populations in the main Finniss River since the 1990s.

Other fauna

The riparian fauna survey in 2014-15 by EcOz (EcOz, 2014a, 2014b, 2015 – see Appendix) concluded that overall there does not appear to have been any relationship between possible mine site drainage and the distribution of terrestrial vertebrates downstream of the mine. It was noted, however, that the effort to monitor terrestrial vertebrate species must be very substantial in order to accurately detect a change for a species. A total of 123 native terrestrial vertebrate species – comprising of 14 amphibians, 77 birds, 13 mammals and 19 reptiles were surveyed. Notably, despite there being suitable habitat, there are no Estuarine Crocodile records for the East Branch. Threatened riparian and aquatic fauna are discussed in the next section.

Summary

Since 1973, there have been several historical aquatic surveys of both fish and macroinvertebrates carried out in the Finniss River system. For surveys that used comparable methods, results indicate that:

- Macroinvertebrate and fish species diversity are higher in the West Branch and main Finniss River than in the East Branch.
- For the West Branch and main Finniss River, macroinvertebrate and fish species diversity decreases moving upstream.
- For the East Branch, macroinvertebrate and fish species diversity is greatly reduced at sites close to the Rum Jungle Mine site.
- For the East Branch, sites upstream of the mine site have good macroinvertebrate and diatom diversity (although lower than for the West Branch and main Finniss River). Fish abundances were comparatively low due to passage issues.

Hydrobiology (2016b – see Appendix) conclude that there are generally consistent findings for the four groups of aquatic organisms examined above and showed that there were no indications of impact in the Finniss River downstream of the East Branch. This was consistent with the findings of surveys conducted in the 1990s, except indicating further recovery of mussel populations after 1995, and consistent with continuing general recovery of the main Finniss River after rehabilitation of the mine site in the mid-1980s.

12.1.4. Threatened Species

There are records of three threatened species from the aquatic ecosystems relevant to this project:

- **Lorentz Grunter** (*Pingalla lorentzi*)
- **Mertens' Water Monitor** (*V. mertensi*)
- **Mitchell's Water Monitor** (*V. mitchelli*).

The locations of these records are shown in Figure 12-6. Using the same methodology as that described in Chapter 14 – Terrestrial Flora and Fauna, a threatened species 'likelihood of occurrence' assessment determined that the two water monitor species have a high likelihood of persisting within the project footprint (with seasonal movement in the East Branch), but that the lack of recent records of the Lorentz Grunter reduces its likelihood of occurrence within the project footprint to low.

Lorentz Grunter

A threatened fish species – currently described as Lorentz Grunter (*P. lorentzi*) – was recorded close to the confluence of the East and West Branches in 1992, approximately 8 km downstream of the mine site. The species is only known from four river basins in Australia (three in Queensland) and appears to be limited in the NT to the Finniss River (Pusey *et al.*, 2017). Genetic work is still ongoing, but despite the species being a very isolated population that was never part of the Lake Carpentaria drainage, some genetic markers put it closest to the Cape York populations (which were part of the Lake Carpentaria drainage), while others make it closest to the Fly River populations in Papua New Guinea which have not been connected to the Lake Carpentaria drainage for over 25,000 years, and during the last sea level maximum were isolated from both the Cape York and Finniss River populations by the Torres Strait land bridge. Pending some further DNA analysis, a more appropriate name for this species is *Pingalla cf. lorentzi* (Ross Smith, pers. comms. 2 October 2019).

There have been many fish surveys within the Finniss River and its tributaries between 1975 and 2017 – including five post-1992 – and only one of those surveys recorded Lorentz Grunter at two sites more than 50 km downstream from the confluence.

Fish species are not listed under the the TPWC Ac however the Lorentz Grunter is classified as Vulnerable.

Mertens' Water Monitor

Mertens' Water Monitor (*V. mertensi*) is a medium to large-sized semi-aquatic monitor, seldom seen far from water. The species is typically observed basking on rocks, logs or branches over-hanging rivers, swamps and lagoons throughout its broad range. It occupies both coastal and inlands waters across far northern Australia from the western Cape York Peninsula in Qld to the Kimberley in Western Australia (WA) (Christian, 2004), and has been recorded in all the Top End river systems (Ward *et al.*, 2006). All local populations of this species have experienced significant declines when Cane Toads have invaded because this genus is susceptible to poisoning due to toad ingestion.

Even after the arrival of Cane Toads to the area, Mertens' Water Monitors have been recorded numerous times along the Finniss River, including the East Branch downstream from the mine site (EMS, 2005) (Eco Logical, 2014; EcOz, 2014a, 2014b, 2015 – see Appendix) – see Figure 12-6 for locations. The species was also recorded in 2015 on the EBFR on the eastern side of the mine site and in 2014 immediately to the south of the mine site. All the records that far upstream, however, were during the Wet season. For reasons not yet clear, the species seems to largely avoid the East Branch during the Dry season, even when water is available. It is possible that as the Dry season encroaches and water levels lower, the species moves downstream. Additionally, a Mertens' Water Monitor was recorded on the edge of the pit at Mt Fitch (EcOz, 2015 – see Appendix). Based on these records, it appears that in suitable habitat (*i.e.* areas of permanent fresh water), this species persists in the area – making seasonal movements upstream in the Wet season. This could include the creeks within the granular material borrow area.

The Mertens' Water Monitor is listed as Vulnerable under the TPWC Act, but is not listed under the EPBC Act. General occurrence of a Vulnerable species in a region is not, in itself, sufficient to meet the definition of an 'important' population. Whilst the species' numbers have declined as a consequence of Cane Toads, there does not appear to be a range decline for this species, based on the fact that there are still many post-toad records across its historic distribution. Therefore, there is no evidence that the local occurrence of Mertens' Water Monitor within the project footprint constitutes a key source population, one that is necessary for maintaining genetic diversity or one near the limit of the species' distribution. For these reasons, the occurrence of this species within the project footprint is not considered an ‘important’ population (as defined in *EPBC Significant Impact Guidelines 1.1* (DoE, 2013) and so the species is not afforded especial attention in the remainder of this chapter.

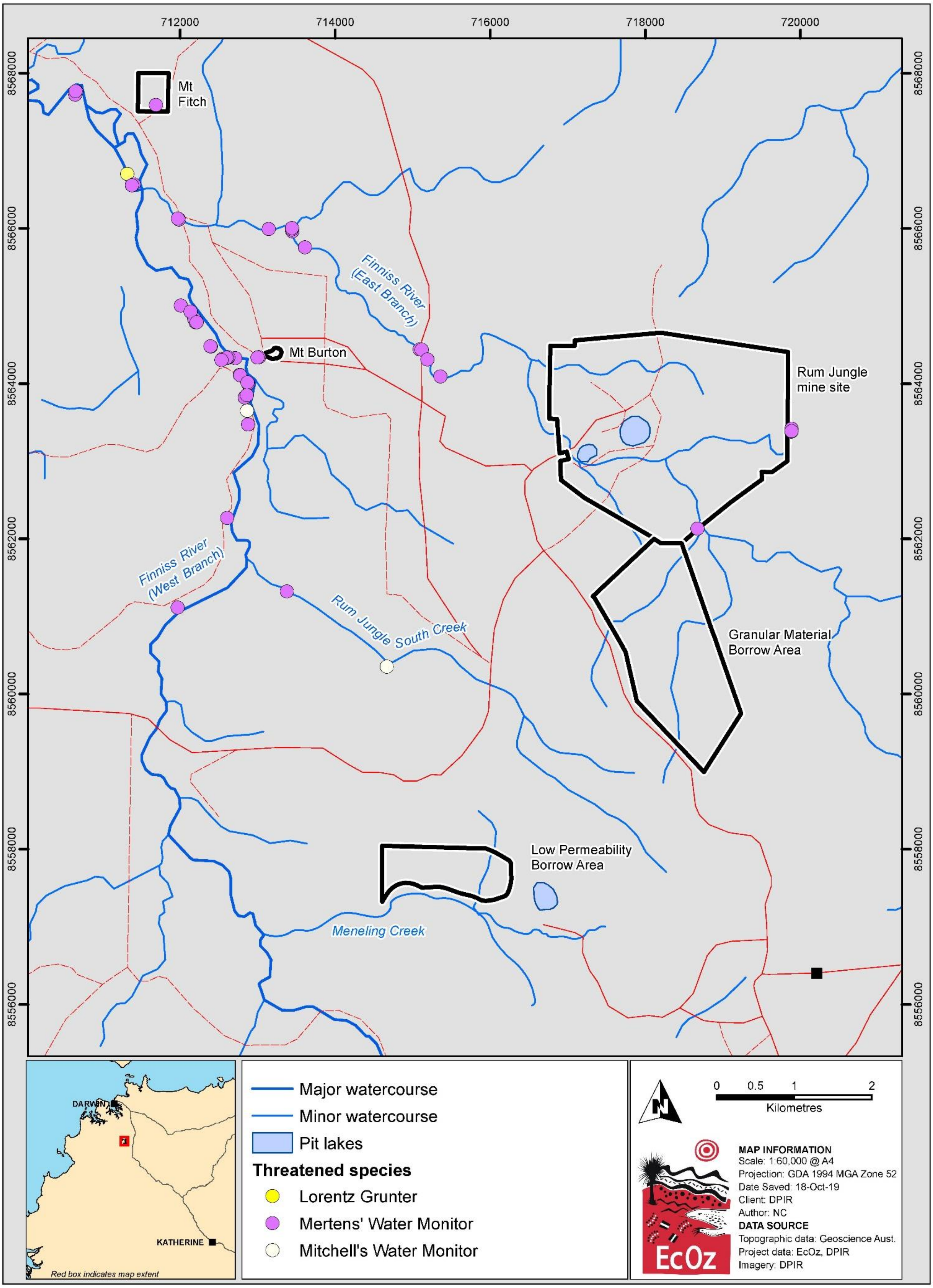

Figure 12-6: Location of threatened species occurring in aquatic ecosystems within the project footprint

Mitchell's Water Monitor

Mitchell's Water Monitor (*V. mitchelli*) is also a medium to large-sized semi-aquatic monitor, inhabiting margins of freshwater watercourses, swamps and lagoons. The species is often arboreal. Mitchell's Water Monitor occurs in the Top End of the NT and the Kimberley in WA. In the NT, the species has been recorded in most catchments flowing into the Timor Sea, Arafura Sea and the Gulf of Carpentaria. All local populations of this species have experienced significant declines when Cane Toads have invaded because this genus is susceptible to poisoning due to ingestion of the toxic toads.

Mitchell's Water Monitor was recorded upstream from Mt Burton in Rum Jungle Creek in 2002 (EMS), adjacent to Mt Burton in 2015 (EcOz, 2015 – see Appendix) and considerably downstream from the project footprint in 2014 (EcOz, 2014a – see Appendix) – see Figure 12-6 for locations. There are no records of this species in the East Branch.

In comparison to the ecologically- and behaviourally-similar Mertens' Water Monitor, Mitchell's Water Monitors have been recorded less frequently in more recent years, despite equal survey effort and ample suitable habitat being present. Reasons for this decline are unknown, though it is possible that this species is more affected by high Cane Toad densities and contamination from the mine site drainage. Based on the decreased number of observations, it appears this species has a low likelihood of occurrence in the area.

Mitchell's Water Monitor is listed as Vulnerable under the TPWC Act, but is not listed under the EPBC Act. General occurrence of a Vulnerable species in a region is not, in itself, sufficient to meet the definition of an 'important' population. Whilst the species' numbers have declined as a consequence of Cane Toads, there does not appear to be a range decline for this species based on the fact that there are still many post-toad records across its historic distribution. Therefore, there is no evidence that the local occurrence of Mitchell's Water Monitor within the project footprint constitutes a key source population, one that is necessary for maintaining genetic diversity or one near the limit of the species' distribution. For these reasons, the occurrence of this species within the project footprint <u>is not</u> considered an 'important' population (as defined in *EPBC Significant Impact Guidelines 1.1*) and so the species is not afforded especial attention in the remainder of this chapter.

12.2. Potential Impacts and Risks

The *Risk Register* (GHD, 2019f – see Appendix) identifies 14 potential impacts that project activities detailed in Chapter 2 – Proposal Description could have on the biodiversity values detailed above. The severity of these impacts are assessed according to the spatial and/or temporal scale of the 'maximum credible consequence'. For aquatic ecosystems, that consequence is a reduction in ecosystem integrity, as measured by the abundance and/or diversity of species, and <u>cognisant of the existing condition of the ecosystem</u>. As noted above and in Chapter 10 – Inland Water Environmental Quality, some of the existing aquatic ecosystems are already compromised because of historic and present day contamination from the Rum Jungle Mine site. Weeds are also already present in and along many of the watercourses. In other words, the watercourses within the project footprint – especially the East Branch – are highly disturbed ecosystems. One of the primary goals of the project is to remedy this as much as possible; nevertheless, as detailed below, there remains the possibility that certain project activities could have the opposite effect.

The 14 potential impacts that project activities could have on aquatic biodiversity values can be categorised broadly as either loss of habitat or reduction in habitat quality, leading to a decrease in the diversity and/or abundance of species. Each of these potential impacts with an inherent risk category of Low are summarised in Table 12-3; these do not require specific mitigation measures and will not be addressed any further in this EIS.

Table 12-3: Potential impacts to aquatic ecosystems that have a Low inherent risk

Description of impact	Potential event
Aquatic Ecosystems	
Cumulative water quality impacts….	When Rum Jungle is discharging remediated water to the East Branch of the Finniss River
Reduction in habitat quality due to…	Contamination from floodwaters leading to a decrease in the diversity and/or abundance of species
	Changes in flow regimes leading to a decrease in the diversity and/or abundance of species

Impacts associated with loss of habitat or reduction in habitat quality, leading to a decrease in the diversity and/or abundance of species, rated as a Medium or High risk are discussed below.

12.2.1. Impacts due to Water Contamination

A key driver behind this project is restoration of the compromised water quality within the East Branch. Whilst it is expected that the end-product will result in improved water quality, during works there is the potential for project activities to contribute additional contamination to the river.

Sources of water contamination are:

- Overtopping of the Main Pit-Intermediate Pit system during backfill operations causing poor quality water that exceeds WQOs to enter the East Branch.
- Uncontrolled release, spill or passive discharge of hazardous materials such as hydrocarbons or asbestos.
- Leachate from materials used for the construction and maintenance of new access and haul roads and embankments.
- Rainfall runoff from earthworks containing leachable solutes (including AMD and radioactive materials).

The East Branch already has reduced water quality because of activities at this project site. Chapter 10 – Inland Water Environmental Quality details how some of these contaminants are already present in the East Branch and assesses the potential additional impacts on water quality from the events presented above.

12.2.2. Impacts due to Sedimentation

Compromised water quality, and therefore reduced aquatic habitat quality, could also be caused by sedimentation due to destabilisation of soils within the project area. This could occur because of removal of vegetation within any of the disturbance areas or by removing riparian vegetation that normally stabilises the banks of watercourses. This could also occur due to run off from exposed waste rock surfaces during the Construction phase.

12.2.3. Impacts due to Altered Flow Regimes

The vast majority of the annual flow volume in the section of the EBFR that bisects the former mine site is during the Wet season. That section of the river has standing water for most of the year as flow ceases fairly early on in the Dry season.

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

In order to achieve the Main Pit backfilling, it is likely that Dry season release to the East Branch will occur. This is discussed in detail in Chapter 10 – Inland Water Environmental Quality.

12.2.4. Impacts to Aquatic Fauna Passage

Passage of aquatic fauna through the mine area is inhibited currently, with only five fish species and two shrimp species recorded above the mine in the 2014-15 sampling of Hydrobiology (2016a – see Appendix) that would require passage through the mine area to colonise those sites after the Dry season. This is likely due to a combination of physical (*e.g.* the weir at the top of the diversion channel and the culverts draining into and out of Main and Intermediate Pits) and chemical barriers within the mine site. During construction, the configuration of the flow paths through the mine area will be somewhat altered as part of the rehabilitation works, including both the diversion channel and the pit pathways. Also, the contaminant concentrations in the East Branch may be increased (see Chapter 10 – Inland Water Environmental Quality). The impact of these on the ability of organisms to colonise the headwaters of the East Branch would be dependent on the timing and volume of wet season flows, but given the currently small number of species that are able to make that journey and the relatively short duration of the Construction phase, the net impact on ecosystem health in the headwaters would be minimal.

A key step in the rehabilitation plan for site is to reconstruct a suitable East Branch water course that conveys water in an alignment as close as possible to the original course. This is discussed in Chapter 11 – Hydrological Processes. This restoration process is expected to result in a positive impact on the seasonal passage of aquatic fauna upstream of the Rum Jungle site.

12.2.5. Impacts due to Weeds

Although not as substantial a threat as for terrestrial biodiversity, there is a risk that project activities exacerbate aquatic weed infestations in the East Branch. Terrestrial weed impacts are discussed in Chapter 14 – Terrestrial Flora and

Fauna; however, there is one weed species that is particularly relevant to aquatic ecosystems – Olive Hymenachne (*H. amplexicaulis*). This species is present within the East Branch – including upstream of the mine site. It is a perennial, robust grass and is regarded as one of the worst weeds in Australia due to its propensity to block waterways and affect water quality, in turn threatening fish and reducing habitat availability for waterbirds and other native animals (NTG, 2018b).

12.3. Mitigation and Management

Many aspects of the health and resilience of aquatic ecosystems are related to water quality and hydrological regimes. Chapter 10 – Inland Water Environmental Quality and Chapter 11 – Hydrological Processes detail the mitigation management measures that will be employed for this project to minimise impacts to water quality and flow regimes. This section focusses on mitigation measures that are specifically designed to minimise impacts to aquatic ecosystems – *i.e.* those relating to weed management and aquatic fauna passage.

12.3.1. Sedimentation Management

The Construction phase of the project will see multiple working areas active during the Wet season. The exposed surface area on each facility work area will be reduced as far as possible through the project design phase. Examples of this include vertical deconstruction slicing of the existing WRDs in preference to horizontal deconstruction methodology and 'cellular' construction of the WSF. This will reduce the exposed horizontal surface areas during the Wet season hence reducing potentially erosive faces.

All active working areas will require an ESCP to deal with impacted runoff from these areas and this will include pre-Wet season work programs to address the action items within the Plan. A *Water Management Plan* (DPIR, 2019 – see Appendix) and further information pertaining to the ESCP can be found in that Plan.

An construction land clearing approvals process (Vegetation Clearing Procedure) will be implemented to ensure that land disturbance is minimised to only that which is required including sequential borrow stripping as required. Creek line clearing buffers have been designed into the project as *per* the *Land Clearing Guidelines* (DENR, 2019).

12.3.2. Management of Aquatic Fauna Passage

As mentioned above, the Rum Jungle site is acting as a physical and chemical barrier to the passage of aquatic fauna however there is evidence of some aquatic fauna migration through site. It is possible that the Construction phase may temporarily impact further on aquatic fauna passage. However after rehabilitation, it could be expected that the restored East Branch quality, hydrologic regime and water course would allow for the return of seasonal passage of fauna through site. This may also allow for the colonisation of onsite features such as the Main Pit Lake.

A restoration plan is required for the onsite section of the East Branch course to recreate the morphological features of the existing East Branch channel downstream of site. Features pertaining to facilitation of aquatic fauna passage should include architectural features that maximise edge of channel roughness and backwater eddies such as boulder outcrops, variable banks and bars. Design should incorporate appropriate stream flow velocities to allow for endemic fauna passage. The revegetation program for this area will incorporate elements required to support this including both structural habitat plants and food plants within the riparian zone.

An appropriately qualified person will need to be engaged to support this design.

12.3.3. Weed Management

Although a WoNS, there is no statutory weed management plan for Olive Hymenachne. Heavy grazing in the Dry season can decrease seed production, but this is not an option for this project. Mechanical or physical removal is not recommended due to this species' highly effective vegetative reproduction from small fragments.

According to the *Northern Territory Weed Management Handbook* (WMB, 2018), the best time to treat Olive Hymenachne is from April to May and then from November to December. The recommended method for control is Glyphosate 360 g/L foliar spray at a rate of 11 mL/L. Management of the species at Rum Jungle will be confounded by its occurrence downstream and upstream of the mine site. Olive Hymenachne will likely require ongoing active management unless a control program is developed for the entire catchment of the East Branch.

12.4. Monitoring and Reporting

Monitoring of surface water quality and quantity will form the primary components of the Construction phase monitoring regime to ensure that shorter term Construction phase impacts are minimised as far as possible. The monitoring program for quality and quantity are detailed in the *Water Management Plan* (DPIR, 2019 – see Appendix), Chapter 10 – Inland Water Environmental Quality and Chapter 11 – Hydrological Processes. The following sections present an overview of the monitoring program for aquatic ecosystems, as *per* Hydrobiology (2013b, 2016a – see Appendix) which forms the foundation for longer term assessment of the success of the proposed rehabilitation program in restoring downstream aquatic ecosystem health.

12.4.1. Riparian Vegetation and Aquatic Macrophytes

Baseline vegetation data for the Finniss River riparian zone, both upstream and downstream of the East Branch confluence and along the East Branch itself, are essentially absent from the published literature. Aquatic macrophyte (visible plants) survey data for the Finniss River and its tributaries and billabongs are also non-existent.

The Riparian Vegetation Monitoring Plan outlined here attempts to rectify these deficiencies by establishing a baseline prior to rehabilitation works at the Rum Jungle Mine site and generating a knowledge-base for the assessment of trends during and following the rehabilitation process.

Objectives

The objectives of vegetation monitoring are as follows:

- Establish baseline riparian vegetation data for the Finniss River and the East Branch, both above and below the Rum Jungle Mine site. Establish permanent vegetation monitoring sites within the riparian zone of the Finniss River and the East Branch, both above and below the Rum Jungle Mine site.
- Identify a methodology for determining short- and long-term trends in riparian vegetation condition following rehabilitation of the mine site.
- Report on the spread or control of weeds along the Finniss River and the East Branch over time.
- Survey the presence and abundance of aquatic macrophytes in the fluvial environment and record changes in abundance over time.
- Develop a strategy for reporting of monitoring program results to stakeholders.

Field methodology

The proposed Riparian Vegetation Monitoring Plan combines the two primary methodologies developed for vegetation survey and monitoring in the Australian tropics, and routinely deployed in the Top End. The field survey techniques and data standards for vegetation analysis in the NT were developed during the Conservation Commission of the NT project to map the NT vegetation from satellite imagery (Wilson *et al.*, 1990). The *Tropical Rapid Appraisal of Riparian Condition* (TRARC) (Dixon *et al.*, 2006) was developed by the Tropical Savannas Cooperative Research Centre and participating agencies to facilitate assessment of the riparian zone using simple indicators of condition. The latter also provides a series of useful indices that may be used to identify short- and long-term trends in vegetation condition both during and following the proposed rehabilitation.

In line with those accepted standards, the proposed Monitoring Plan will consist of a series of permanently-located vegetation monitoring sites within the riparian zone immediately adjacent to the river channel. Each site will consist of a 100 m long stretch of the river within which a pair of vegetation plots will be centrally located one on each side of the main river channel. Sites will be chosen to reflect the dominant vegetation in each reach of the river, and vegetation plots should be located appropriately therein without preconceived bias.

All sites will be surveyed using precision GPS and vegetation monitoring plots permanently marked with star pickets or similar structures. Vegetation monitoring plots will be 20 m × 20 m square, initially marked out by fibreglass tape. Plots may be narrower than 20 m in areas where the river levee and consequent riparian zone is restricted by terrain. Each site will be photographed for future reference.

<u>Sites</u>

Three monitoring sites will be located on the Finniss River upstream of the East Branch confluence, three sites immediately downstream of the confluence, three sites in the mid-section of the receiving environment and three sites further downstream towards Bad Crossing. On the East Branch, three sites will be located upstream of the mine site and three sites downstream towards the confluence. Additional single sites should be located on Hannah’s Spring, Mount Burton Spring and the lower section of Florence Creek.

There may be some merit in locating a series of monitoring sites on the Finniss River floodplain downstream of Bad Crossing, but anecdotal evidence suggests that the impact on riparian vegetation of historical tailings releases during mine operations did not extend beyond Bad Crossing. If this was seen to be worthwhile, then sites should be located immediately upstream, immediately downstream and at the point of entry of the Finniss River channel onto the floodplain.

Monitoring sites should be visited twice each year, firstly at the end of the Wet season when vegetation growth is at a maximum and secondly in the mid Dry season prior to the flush of new growth associated with the build-up in humidity ahead of the next Wet season. It is recognised that access to some sites for the late Wet season visit may be restricted by a prolonged or wetter than average Wet season.

<u>Attribute Data</u>

Terrain data recorded at each site should include landform pattern, slope and aspect; base geology, surface soil, percent rock outcrop and surface gravel. Recent fire history should also be recorded.

For the 100 m length of the site, TRARC values should be recorded for large trees, logs, high impact weeds, canopy continuity, exposed tree roots, and any slumping, gullying or undercutting of tree roots. The complete TRARC proforma and associated score-sheets are available online (Land and Water Australia, 2006).

Specific vegetation plot data should include the overall vegetation structure, the dominant growth form and projected foliage cover for each of the three main layers (canopy, mid-storey and ground), the percentage cover and average height of each growth form present, and a complete floristic list of species present in each layer. Species dominance for the canopy layer should be determined by basal wedge; for the other layers, by projected foliage cover.

The location of woody plants within the 20 × 20 m vegetation plots should be recorded on a 1 m grid, and each plant attributed according to projected canopy area, diameter at breast height (dbh) and general health status. A hemispherical canopy photograph should be acquired at the centre point of each vegetation plot for empirical canopy closure comparison. The relative abundance of any invasive weed species should also be recorded.

The presence and abundance of aquatic macrophyte species should be recorded for a 100 m length of the main river channel at each monitoring site, including immediately adjacent overflow channels and billabongs where present. The location and extent of established weed-beds, if any, should be mapped using GPS.

Condition indices

Trends in vegetation condition at each site should be monitored using a series of condition indices developed from a set of specific indicators. The majority of these indicators are included in or modified from the TRARC methodology (Dixon *et al.*, 2006). TRARC combines the indicator values into four main indices, and further into a single index as an expression of 'pressure' on the riparian environment, but this may not be appropriate for the Rum Jungle situation and simple Analysis of Variance may provide a better assessment of variation over time. The specific indicators are listed below:

- Canopy cover (percentage cover of trees in the canopy layer)
- Canopy continuity (percentage of longitudinal bank covered with canopy trees)
- Mid-layer cover (percentage cover of trees in the mid-layer)
- Groundcover (percentage of cover of ground layer vegetation)
- Organic litter (percentage cover of leaves and fallen branches < 10 cm diameter)
- Fallen logs (abundance of logs > 10 cm diameter)
- Canopy health (appearance of canopy health on a score of 1 to 5)
- Dominant tree regeneration (abundance of juveniles 0.3 - 3 m)
- Other tree regeneration (abundance of juveniles 0.3 - 3 m)
- Woody weeds (proportion of weed versus native canopy cover)
- Other weeds (percentage cover of weeds in the ground layer).

Hemispherical canopy photography, if undertaken, provides an empirical measurement of canopy cover expressed as a percentage. This figure can be used as an alternative to the estimate normally made visually by the practitioner. The limitations of this methodology are the requirement for precise location of the tripod each time and the fact that all vegetation layers are represented in a single figure. Any plant regeneration in close proximity to the camera lens will be disproportionately represented in the cover percentage.

Trends in aquatic macrophyte colonisation should be assessed based on presence/absence and, if abundant, on total area of macrophyte-bed within the 100 m stretch of river at each monitoring site.

12.4.2. Aquatic Fauna

Aquatic fauna surveys will follow the methods employed by Hydrobiology (2016a – see Appendix). Sampling will be undertaken at 18 sites distributed across seven zones that relate to distances downstream of, or locations upstream, of inputs of mine-derived contaminants and sources of dilution.

Fish surveys will use the following methods:

- Gill netting
- Electrofishing
- Fyke nets
- Bait traps.

Macroinvertebrate sampling will use a submersible pumped water sampler; diatom sampling will involve collecting sediment surface film from backwater/depositional areas.

Tissue metal concentration samples will be taken from the following species at each site consistent with the methods and tissue types used by Hydrobiology (2016a – see Appendix), depending on their availability from the sampling regime:

- Bony Bream (Nematalosa erebi)
- Hyrtl's Tandan (Neosilurus hyrtlii)
- Northern Trout Gudgeon (Mogurnda mogurnda)
- Black-banded Rainbowfish (Melanotaenia nigrans)
- North-west Australian River Prawn (Macrobrachium bullatum)

Samples of Angas' Mussels (*Velesunia angasi*) will be collected for analysis for ^{210}Pb, ^{210}Po, ^{226}Ra and ^{228}Ra.

Diatoms, benthic macroinvertebrates and fish will all be analysed using similar statistical approaches and methods to those employed by Hydrobiology (2016a – see Appendix). Total abundances and taxonomic richness will be tested for significant differences between sites, zones and years. Patterns in community structure will also be investigated. The results will also be compared with those from Hydrobiology (2016a – see Appendix).

12.5. Statement of Residual Impact

Most of the existing aquatic ecosystems within the project footprint – especially in the East Branch – are already compromised because of historic and present-day contamination and weeds from the Rum Jungle Mine site. One of the primary goals of the project is to remedy this as much as possible; nevertheless, there remains the possibility that certain project activities could have the opposite effect. Unmitigated, some project activities have a high likelihood of having a significant impact on aquatic ecosystems. All of these potential impacts, however, can be controlled through the mitigation measures detailed in other chapters that have been developed to minimise impacts to water quality or water quantity. Complementing those are some tailored measures relating to aquatic fauna passage.

Assuming proper adoption of the mitigation measures, the residual incremental risks relating to aquatic ecosystems have all been assessed as Medium to Low.

The Monitoring program outlined in this chapter should provide a foundation from which future success of the rehabilitation project on restoration of aquatic ecosystem health can be established.

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13. Social and Economic Impact

Figures

Tables

13.1. Socio-Economic Environment

This chapter addresses the information requirements in the EIS ToR for the Social, Economic and Cultural Surroundings factor.

13.1.1. Policy Context

This section outlines Australian and NT Government, and regional and local policies that apply to the Social Economic Impact Assessment (SEIA) and the management of social issues relating to the project.

Australian Government

<u>Closing the Gap Refresh</u>

Closing the Gap Refresh is a COAG strategy that aims to align with Aboriginal and Torres Strait Islander peoples and communities' priorities and ambition to support and realise their full social and economic participation (COAG, 2018). Of the seven outcomes sought, three are particularly noteworthy for this project:

- Education – Aboriginal people achieve their learning potential and flourish
- Economic Development – strong Aboriginal workforce participation, including youth
- Land and Waters – Aboriginal peoples' land, water and cultural rights are realised, including for economic development.

Closing the Gap Refresh builds on existing legislative requirements, and government policies and programs, including, but not limited to:

- under the *Aboriginal and Torres Strait Islander Act 2005* (Cth), the Indigenous Land and Sea Corporation is to assist Indigenous Australian to acquire land and water-related rights, and assist in the management of Indigenous held land and water
- Indigenous Business Australia, also under the same Act, is to advance Indigenous Australians commercial and economic interests
- the Indigenous Advancement Strategy supports opportunities across culture, education, employment (including higher level vocational education and training (VET)), economic development and the environment
- the *Indigenous Business Sector Strategy* (Department of the Prime Minister and Cabinet, 2018) to help build more sustainable businesses.

<u>Our North, Our Future: White Paper on Developing Northern Australia</u>

The *Our North, Our Future: White Paper on Developing Northern Australia* (CoA, 2015) sets the strategic direction for governments at all levels to collaborate to build a strong, prosperous economy in Northern Australia.

Governments are cognisant that to northern Australia can only be developed in cooperation with Indigenous Australians with ‘a focus on creating opportunities through education, job creation and economic development’ (CoA, 2015, p. 4). To support this goal, the White Paper lay out a policy framework; key objectives relevant to this project are:

- to simplify and modernise land arrangements to improve opportunity
- resource mapping (*e.g.* CSIRO’s Northern Australia Water Resource Assessment)
- to develop the north’s workforce to support future economic opportunities.

<u>Skills</u>

National reforms have been undertaken to strengthen higher education, skills and training to ensure that Australian workers can meet business needs. This includes through supporting an increase to apprenticeship numbers.

<u>Australian Industry Participation</u>

The Australian Industry Participation National Framework (2001) committed all Australian governments to the full, fair and reasonable opportunity for Australian industries to participate in significant public and private investment projects. Procurements or projects receiving Australian Government funding of $20 million or more must adhere to the Australian Industry Participation requirements; an exemption is granted where an equivalent state or territory local industry participation policy mandatorily applies.

Northern Territory Government

The NTG has a goal to empower regional and Aboriginal communities to make their own decisions about the future of their communities. This includes the generation of employment and business opportunities, supported by relevant training and capacity building. The NTG’s Local Decision Making model identifies key priority areas including children and families; housing; health; law and justice; economic development, local government and education, training and jobs. The community of Batchelor is already participating in plans being developed by the Department of Education under this model which will see a Local Engagement and Decision Making Committee established in Batchelor.

There are a range of strategic policies focused on regional economic development and specifically, creating economic development and employment opportunities for Indigenous Territorians. Key strategies relevant to this project include:

- 10 Year Infrastructure Plan (which includes future projects identified for the Coomalie Region)
- Our Economic Future: NT Economic Development Framework
- Masterplan for the Batchelor Airport
- Aboriginal Contracting Framework (Draft)
- NT Government Procurement Policy
- Local Decision Making 10 Year Plan.

The Draft Aboriginal Contracting Framework (ACF) and NTG Procurement Policy are focused on maximising local content in all government procurement. In particular, the ACF is being developed to support Aboriginal employment and business opportunities through government contracting, including both procurement and grants.

Regional and Local

The *Darwin Regional Land Use Plan 2015* (DLPE, 2015) provides a strategic framework to manage future growth in the Darwin Region, including the Coomalie region. The Plan seeks to balance economic and community growth, and protection of the environment by resolving land use competition.

The project falls within the Coomalie local government area which covers approximately 1500km^2 and includes the townships of Batchelor, Adelaide River and Lake Bennett. The vision of the CCGC’s *Strategic Plan 2019-2023* is ‘to sustain and nurture the growth of rural lifestyle and quality of life’ by ‘delivering improved social, economic, environmental and cultural life.’ The main themes of the Plan are:

- Governance: accountability and enabling community input
- Social: respecting culture and diversity, and ensuring broad community engagement and social inclusion

- Economy: promoting the attractiveness of the region to business and industry
- Environment: improving environmental management.

The strategies within the Plan of relevance to the project include:

- Seeking and promoting partnerships to achieve infrastructure goals
- Asset and infrastructure planning to reflect social, economic, environmental and cultural aspects
- Engaging with the community to identify, assess and prioritise delivery across all sectors
- Supporting and attracting business and industry development in the area
- Promoting local employment options to improve individual, family and community wellbeing.

13.1.2. People and Community

Key communities to the project area are:

- Batchelor – closest community to the project area
- Adelaide River – second closest community to the project area
- Amangal Indigenous Village at Adelaide River – Traditional Owner community (approximately 30 people)
- Outer Darwin rural communities – along the Stuart Highway and Traditional Owner residences, including Palmerston Indigenous Village ('15 Mile')
- Darwin – likely to be a key source of technical services.

Batchelor has a population of 507 residents (38% of the region's total population) - 72.3% were born in Australia and 36.3% identify as Indigenous. The median age of residents is 40 years, compared to a median age of 32 in the broader NT Outback area. Regional demographic statistics are set out in Table 13-1.

Table 13-1: Population details from 2016 census (ABS, 2017)

Area	Population	Median age	% Aboriginal and/or Torres Strait Islander	Median age – Aboriginal and/or Torres Strait Islander
Coomalie local government area	1,319	46	24.2	26
Batchelor	507	40	36.9	24
Adelaide River	353	47	25.1	22
Palmerston local government area	33,786	30	11.3	20
Darwin local government area	78,804	34	7.4	25

The areas, other than the urban centres of Darwin and Palmerston, have similar land uses – primarily rural lifestyle, horticulture and agriculture.

The project area includes sites on (granular material borrow), adjacent to (Rum Jungle Mine) or within a few km of (Mt Burton, Mt Fitch) the FRALT. Rum Jungle Mine is the sole portion of the Finniss River Land Claim yet to be granted to the recognised Traditional Owners – the Warai and Kungarakan Peoples. The Traditional Owners have a vision for the Rum Jungle Mine site to be rehabilitated to allow for potential economic activities in a modern context, caring for country and cultural practice. The map at Figure 13-1 outlines the boundaries of land held by the FRALT.

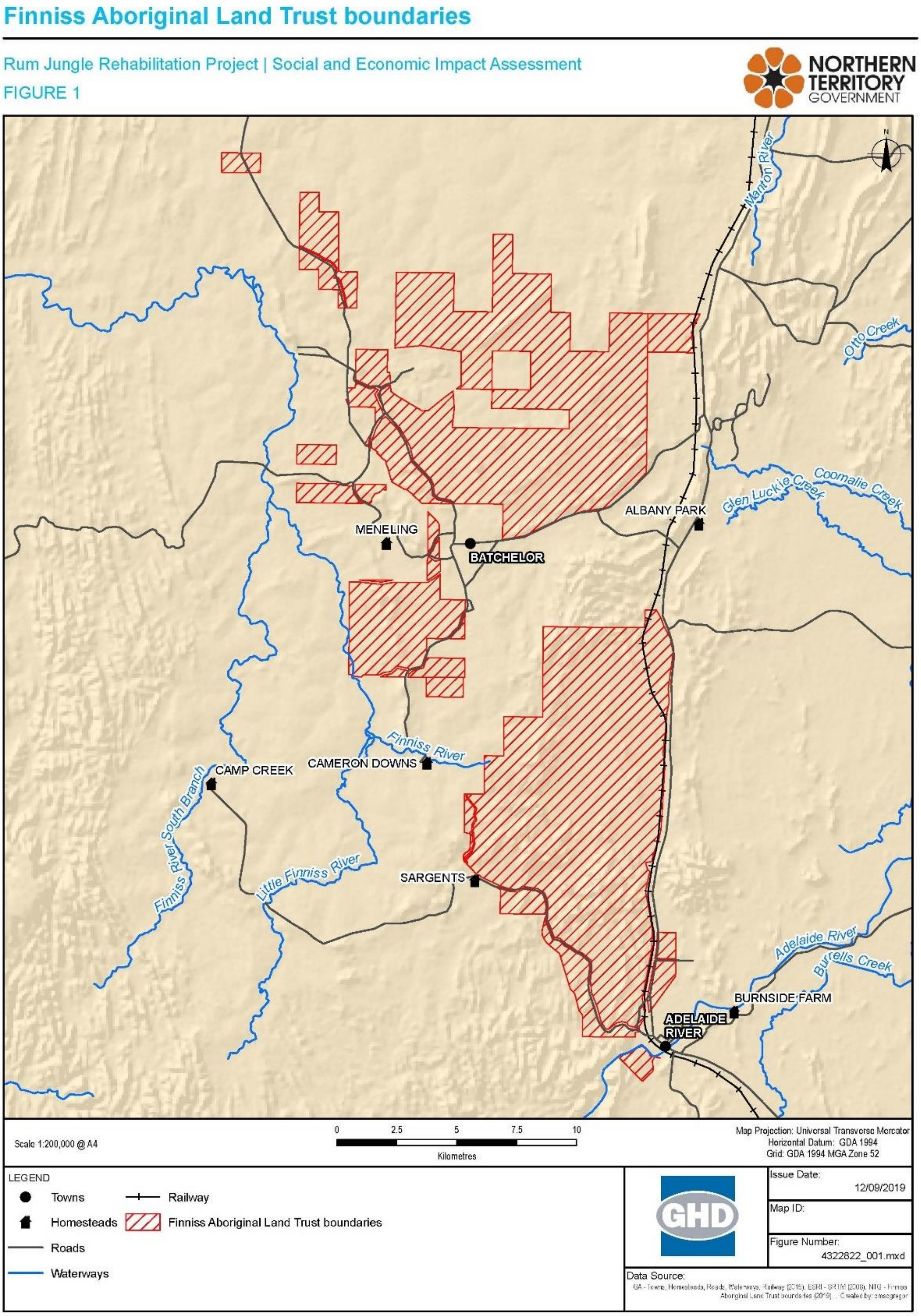

Figure 13-1: Finniss River Aboriginal Land Trust boundaries

Of people aged 15 years and over in the Coomalie local government area, 9.3% held a Bachelor Degree or higher and 15.1% held a Certificate III or IV (ABS, 2017). The proportion of the population holding a Bachelor Degree or higher increased to 14% in the Palmerston local government area and 26.1% in the Darwin local government area; 24% and 12.1% of the population held a Certificate III or IV in the Palmerston and Darwin local government areas, respectively.

13.1.3. Employment and Economies

Northern Territory

The NT economy grew over the decade from 2008-09 to 2017-18, retracting in 2018-19 to $26.1 billion gross state product (GSP). Over this time, the economy has diversified, with a greater share of employment and output across goods and services industries (DTBI, 2019). In terms of the value of industry contribution in the NT to GSP in 2017-18 ($26.2 billion):

- Agriculture, fishing and forestry comprised 2.8%
- Retail and wholesale trade, and education and training both comprised 4.8%
- Service industries comprised 9.0%.
- Construction comprised 11.2%
- Government and community services comprised 14.67%
- Mining and manufacturing comprised 15.8%.

The NTG is focused on stimulating economic activity and attracting private investment opportunities to local industries.

Coomalie Region

The economy of the region has diversified in recent years, expanding to include education, aviation, horticulture and tourism as the key sectors. The key industries in the Coomalie region are:

Tourism

Tourism is a key focus in the region and the primary source of jobs with the presence of tourists being highly seasonal. Batchelor is the primary entry point to Litchfield National Park, a significant attraction for local Darwin residents and visitors to the NT. Litchfield National Park is supported by accommodation, hospitality and retail services in Batchelor as well as some other local attractions such as the Coomalie Arts Centre. Significant government investment is currently being made into the upgrade of Litchfield National Park infrastructure including improvements to roads and visitor facilities. More detail on the visitation to the region and future investment potential is outlined in the *SEIA Rum Jungle Rehabilitation Project Report* (GHD, 2019e – see Appendix).

Mining

The Rum Jungle Mine was operational from 1953 to 1971 and was followed by the Woodcutters Mine which operated from 1985 and 1998 and the Browns Oxide Mine which operated for a brief period of time in 2008 before going into care and maintenance.

Education

BIITE, located in Batchelor, is the primary employer in the region with around 250 staff employed across three campuses, around 150 of those are based at Batchelor. BIITE is an Aboriginal and Torres Strait Islander tertiary education provider, including VET. Courses are offered across education, Indigenous language and knowledge, translator services and a broad range of certificate qualifications ranging from community services, to family wellbeing, Aboriginal health and media to name a few.

The Batchelor Area School provides primary to Year 12 public education and has an enrolment of around 125 students who live across the region. The school also works in partnership with BIITE to offer some VET pathways to senior students.

Agriculture

Agriculture in the region includes cattle, hay-making, mangoes, vegetables and horticulture (including a certified organic farm). In the past, the biggest share of this sector came from meat processing at the old Batchelor Abattoir. This facility is anticipated to re-open in on 3 December 2019, employing up to 40 people.

Aviation

The NTG has released a masterplan to create an aviation precinct at the existing Batchelor Airport. The masterplan has three stages, with stage one planned to be implemented over a 10 year period and the whole project delivered over 30 years. If it proceeds, the project is likely to generate 20 to 30 jobs in the region.

The Coomalie region's economy retracted between 2001 and 2002 (Gross Regional Product (GRP): $164 million) and 2011-12 (GRP: $79 million); in 2017-2018, the region's GRP was $96 million (RDA NT, 2019 – Source: National Institute of Economic and Industry Research 2018, cited in .id, the population experts). The three largest industries in the Coomalie region at this time were:

- Education and training ($44 million; 29.4%)
- Construction ($22 million; 14.8%)
- Accommodation and food services ($14 million; 9.5%).

As can be seen in Figure 13-2, all industry sectors generally increased over the five years to 2013-14 in the Coomalie region – construction showed the largest change (+10.8%) and manufacturing the largest retraction (-10.4%).

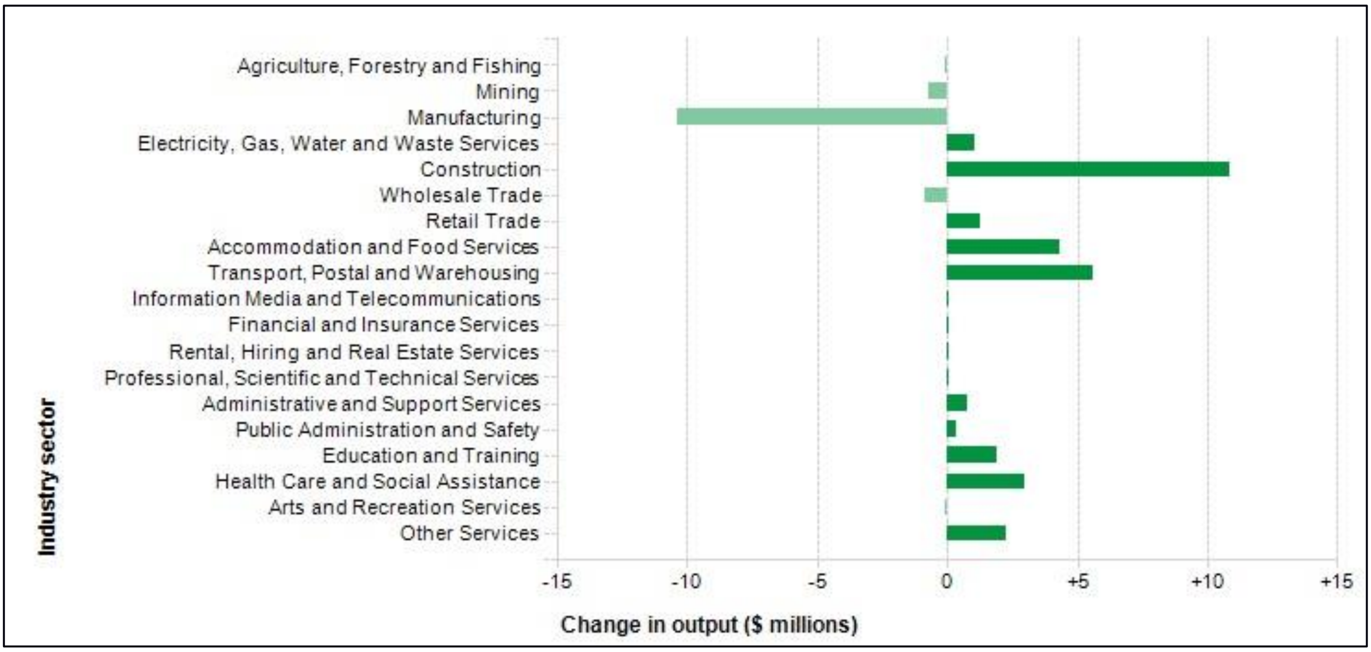

Figure 13-2: Change in output by industry sector 2013-14 to 2017-18, Coomalie region (RDA NT, 2019)

The number of Coomalie region residents employment has steadily increased from 2001-02 (393) to 2017-18 (675) (RDA NT, 2019). The major industry sectors for employment in Batchelor, Adelaide River and the Coomalie region are set out in Table 13-2.

Table 13-2: Industries of employment for Batchelor, Adelaide River and Coomalie region (ABS, 2017)

Industry of employment	Batchelor (%)	Adelaide River (%)	Coomalie (%)	NT (%)
Technical and vocational education and training	26.1	14.3	15.7	0.3
Accommodation (*i.e.* tourism)	9.4	13.2	10.5	2.3
Beef Cattle farming (specialised)	-	6.6	4.4	1.0
Local government administration	-	-	4.1	1.9
Combined primary and secondary education	9.4	8.8	3.9	1.5
State government administration	4.3	-	-	6.2
Gold ore mining	3.6	-	-	0.3
Road freight transport	-	7.7	-	0.9

More than half of the Coomalie region population is employed full-time and approximately one quarter works part-time (Table 13-3) in a range of occupations including professionals, technicians and trades workers, and labourers (Table 13-4).

Table 13-3: Employment in Batchelor, Adelaide River and Coomalie region (ABS, 2017)

Employment	Batchelor (%)	Adelaide River (%)	Coomalie (%)	NT (%)
Worked full-time	56.8	62.5	60.2	67.1
Worked part-time	23.6	21.1	23.0	19.5
Away from work	5.0	5.5	6.9	6.4
Unemployed	14.6	10.9	7.0	7.0

Table 13-4: Occupations in Batchelor, Adelaide River and Coomalie region (ABS, 2017)

Occupation	Batchelor	Adelaide River	Coomalie	NT
Professionals	18.4	9.2	13.6	20.1
Technicians and Trades Workers	16.2	11.8	13.1	15.8
Managers	14.6	12.6	15.1	12.2
Community and Personal Service Workers	14.1	15.1	12.3	13.8
Clerical and Administrative Workers	11.4	14.3	13.6	13.7
Machinery Operators and Drivers	8.1	9.2	11/2	5.7
Labourers	8.1	18.5	12.7	9.4
Sales Workers	6.5	2.5	5.0	6.8

13.1.4. Services and Infrastructure

The administrative centre of the Coomalie local government area is located in Batchelor, the base for council offices and a variety of other local services and facilities. Those relevant to the project include:

Community and recreation

Batchelor features a library, the Coomalie Art Centre and BIITE, as well as a museum, swimming pool, lawn bowls green and football oval. Recreational activities in the area include fishing, bird watching, bushwalking, swimming, camping, horse riding and four wheel driving. The Batchelor Outdoor Education Centre is a long-standing, heavily used facility visited by many schools across the Darwin and Katherine regions for school camps and recreational programs, as well as corporate team building activities.

Emergency Services

Batchelor has a Police Station permanently staffed in addition to another station located in nearby Adelaide River. Additionally, Bushfires NT headquarters is currently based at Batchelor and a Volunteer Fire Brigade is based in the township.

Health

Batchelor Community Health Centre is the primary health facility for residents in the area and also manages medical emergencies for non-residents. The facility is staffed by a number of doctors and nurses however, there is no after-hours doctor. In an after-hours situation, treatment is managed by the nursing staff with advice from an on-call District Medical Officer. Evacuations for patients in need of a higher level of care are made in collaboration with Careflight. Patients are airlifted to either Palmerston Regional Hospital or Royal Darwin Hospital. The region is also serviced by the Adelaide River Community Health Centre and Red Cross Home Care.

Roads and essential services

Roads in the Coomalie region are a shared responsibility between NTG (through DIPL) and CCGC, with the major arterial roads managed by NTG. Other essential services such as waste are managed by CCGC.

13.1.5. Natural Resources and the Environment

The Finniss River runs west through Litchfield National Park. The EBFR runs through the Rum Jungle Mine site and is included within the Finniss River Land Claim (1981). Consequently, water quality is a key concern to the Batchelor community and, in particular, to the Traditional Owners.

13.2. Potential Impacts and Risks

This section assesses the potential impacts that the project will have on the key socio-economic features of the existing environment. The *Risk Register* (GHD, 2019f – see Appendix) identifies 16 potential impacts that project activities detailed in Chapter 2 – Proposal Description could have on the socio-economic factors detailed above. Each of the potential impacts with an inherent risk category of Low are summarised in Table 13-5; impacts with an inherent risk category of Medium or higher are discussed below.

Table 13-5: Potential impacts to socio-economic that have a Low inherent risk

Description of impact	Potential event
Socio-economic	
Impact to the visual amenity of site for public due to…	Overall visual amenity impacted due to introduction of WSFs and borrow areas
Impact the aesthetics of site due to…	Visual impact of historical scrap across project site (*e.g.* tyres, drums *etc.*), due to inappropriate waste management

13.2.1. People and Community

The potential increased opportunities for local residents of the Coomalie region in relation to employment, training and economic development could have a positive impact on the community. There is a desire from both local businesses, residents and Traditional Owners to maximise employment and economic development opportunities through this project. Unemployment is currently high in Batchelor and the project is perceived as an opportunity for existing residents to be employed in varying capacities. Considerable pre-construction work has been undertaken by both the NT and Australian Governments with Traditional Owners to raise their awareness of potential opportunities.

The Proponent anticipates that the project will offer 34 to 45 jobs in the Construction phase of the project, with a significant reduction after that. At least three trainee positions *per* year are also expected to be offered on the project. Should the estimated job and training opportunity goals not be achieved, relationships between the community and government are likely to be negatively impacted, with damage to reputation of the NTG Department managing the project.

There are a number of other key risks associated with community relationships that have the potential to be impacted by this project:

- The potential long lead time to receive funding and approvals for the project could impact negatively, with project knowledge lost and Traditional Owners frustrated by the lack of progress.
- The community expectations of the project are high and a failure to gain the required section 19 Land Use Agreement under ALRA, as well as an agreement with CCGC, to access borrow will have the potential to impact negatively on general community and Traditional Owner relationships.

In terms of Traditional Owners' cultural aspirations, the project is likely to have a positive impact. Work to preserve sacred sites has been undertaken in conjunction with Custodians. Longer term, the project offers the opportunity for Traditional Owners to utilise the site for conservation and cultural practice. The Land Use Plan (see Figure 6-8 or Figure 7-2) identifies some areas where Traditional Owners could conduct cultural, industrial or rehabilitation tourism - however this will be at the discretion of Traditional Owners in the future.

There is a high awareness across the Batchelor community of the project and residents are keen to understand the project's scope, timing, cost and potential benefits. Poor or irregular project communication is likely to impact negatively on the reputation of government and the overall project.

The potential outcome of all of these risks is that the desired social outcomes are not achieved and the project's social licence is lost.

13.2.2. Employment and Economies

Overall, through employment and procurement opportunities, the project construction will contribute to the local and regional economy. This will be achieved through direct and indirect contribution to businesses and direct and indirect employment opportunities.

Potential employment on the project includes roles such as: equipment and machine operators, engineering and technical specialists, and land and environmental management officers.

It is estimated that during the Construction phase, a maximum of 45 direct employment opportunities are available, scaling down to around 15 in the last year of construction. After the consultant's field consultation for the *SEIA Rum Jungle Rehabilitation Project Report* (GHD, 2019e – see Appendix) was complete, changes were made to the construction methodology and schedule which have resulted in updated numbers for the Construction phase and direct employment opportunities. These are likely to change again as detailed design and modelling is finalised. There is an intent to prioritise these opportunities for Traditional Owners and local residents through the NTG procurement processes, assuming these people hold the appropriate qualifications and skills to undertake the roles. Within the community, there are residents who hold certificate and degree level qualifications, and have experience in particular fields including land management, civil earthmoving and environmental management.

A 2015 skills audit identified the (then) current skills and qualifications of the Kungarakan and Warai Traditional Owners. In total, the audit identified 140 candidates who were considered 'work ready'. The Proponent has been actively engaging with Traditional Owners and local training providers, including Ironbark Aboriginal Corporation and BIITE, to raise awareness of the potential project roles so that training programs can be offered to match project needs. The Proponent plans to assist Traditional Owners to leverage existing government training and business support programs so that they are well positioned for maximum participation in the project. It is anticipated that three trainee positions will be available throughout the project.

The Construction phase has been designed in such a way as to improve longer term employment and training opportunities. Additionally, this approach will reduce the material movement rate and allow for better construction quality control.

There may be some competition for labour in the community, with a number of other projects planned for future development in the region. This includes a local meatworks that anticipates it will employ 40 people. It is possible that this project will impact negatively on other local business trying to source employees. Overall, however, the employment impacts are likely to be positive with a reduction in unemployment expected.

In addition to employment opportunities, the project will require services and products such as:

- Bulk lime for addition to waste rock for AMD management
- Bulk fuel for equipment (fleet and fixed supply)
- Borrow material potentially sourced from CCGC land and the FRALT
- Contractor services for earthmoving, drilling and bore installation, WTP construction, commissioning and operation, and repairs and maintenance
- Accommodation
- Meals
- Services such as laundry services.

The Proponent has identified a range of potential direct economic development opportunities for the local and regional community. These range in size from supplying significant volumes of bulk lime product to food and beverage supplies, accommodation for workers who are not Batchelor residents and other services such as laundry, equipment hire and contracting services across various fields. It is anticipated that the NTG's procurement policies and the breadth of existing local service providers will see the majority of project expenditure remain in the NT.

Given Batchelor is small, there may also be new business opportunities in sectors not already in place in the community, for example, laundry services. Batchelor and the broader Coomalie community could benefit positively from these opportunities.

The community expectations around employment and economic development are high and should they not be met, there will be a negative impact on the community relationships and perception of the project.

13.2.3. Services and Infrastructure

The project requires the transport of large amounts of landform cover materials from two separate locations to the Rum Jungle site. One site will require use of the public road network and one site will be accessed *via* an internal access road. The actual number of truck movements (*i.e.* the contribution of the project to the public road network) have been estimated and will be further refined once borrow pit agreements are reached. The most significant traffic impact for the project is likely to be the haulage of low permeability cover materials from the potential CCGC low permeability material borrow pit; however no agreement has yet been reached for the use of this material source. If no agreement is reached, then the impact profile on the public road network is greatly reduced. Subsequently, the potential socio-economic impact assessment relating to traffic flow and road safety have not been finalised and reported in this chapter. However, it is noted that the road authority (DIPL) will set the traffic management requirements that the Proponent must comply with on major arterial roads and have a role in ongoing monitoring of compliance. The Proponent has commenced discussions with DIPL in order to ensure that the correct approvals processes are followed. Once detailed design and detailed scheduling are completed, the Proponent will be well placed to complete the required processes for approval to safely operate within the public road network.

The project may be required to upgrade existing roads as a result of direction from DIPL. Road and other infrastructure upgrades within the region will generally be seen as a positive impact of the project.

There may also be some impact on local service delivery with an increase in workforce from outside of the region, however, this could be a positive impact in the longer term and support confirmation of an increase in existing services. For example, the Batchelor Community Health Centre is funded based on number of patients - an increase in resident population would influence that and local shops would likely see an increase in sales.

Increased activity on the Rum Jungle site may have a small impact on the capacity of existing emergency services in that there will be a need to continue to manage potential issues such as bushfires and respond to accidents onsite. These are described in detail in Chapter 15 – Human Health and Safety. Whilst this is an impact, emergency services do have dedicated resources located within Batchelor so the impact is likely to be minimal if not a net positive impact. The project emergency response team will need to forge links within the existing emergency services framework to augment and contribute to local service provision. This will be addressed in the future Stage 3 Emergency Response Plan which will also include links to services at the Browns Oxide Mine in the event that an agreement can be reached to utilise existing resources or share commonly needed resources. Based on current numbers of potential workers and construction design, the community currently has the ability to absorb any increase in population.

The number of houses for sale and rent in Batchelor is limited; however, provided the project is employing locals, there should be capacity to absorb others by private homeowners renting out properties that are currently up for sale, through accessing accommodation available at BIITE or through existing commercial accommodation. The impact on the housing sector is likely to be positive and generate economic development opportunities for the local community.

13.2.4. Natural Resources and the Environment

As described in the project objectives, the focus of the project is to restore environmental conditions onsite and downstream. Details on the potential impacts to water quality and landform can be found in Chapter 9 – Terrestrial Environmental Quality, Chapter 10 – Inland Water Environmental Quality and Chapter 11 – Hydrological Processes. Construction design has been developed so that key components such as the WSF, laydown areas and WTP are located on ground that is already heavily disturbed. This means that the impact is likely to be minimal aside of short-term erosion and sediment control. Borrow pit locations have been selected so that they are placed in areas that are historically impacted by mining or are infested with the weed Gamba Grass. Additionally, where possible, suitable material will be excavated from under the WSF to be re-used onsite to reduce the quantities of borrow material required. Longer term, the project will result in a positive impact on the site and downstream through meeting the project objectives as outlined in Chapter 2 – Proposal Description.

The project will provide future opportunities for active land and environmental management, and the establishment of related programs at the discretion of Traditional Owners. This could potentially include the establishment of work groups focusing on improving management of the entire FRALT estate.

There may be an ongoing negative impact as a result of the perceived potential risk related to radioactive material onsite and a reluctance for individuals to work onsite. Chapter 16 – Radiation provides more detail on the radiation investigations undertaken on the project site.

The visual amenity impact of the final project landform has been assessed by SLR (2019) and found that of the five receptors assessed, four were ranked as Negligible to Low significance and one Minor to Moderate significance. Additional information is provided in the *Rum Jungle Project – Stage 2A, Landscape and Visual Impact Assessment* (SLR, 2019 – see Appendix).

During the Construction phase, local amenity concerns could include noise, dust, vibration, heavy vehicles and increased traffic. The project's impact on local amenity has been ranked as Low in the *Risk Register* (GHD, 2019f – see Appendix) and therefore will not be discussed any further in this chapter.

13.3. Mitigation and Management

The following mitigation measures will be implemented to address potential impacts arising from the Rum Jungle Rehabilitation Project.

13.3.1. People and Community

A range of mechanisms are recommended to minimise impacts to community. These include:

- A Stakeholder Communication and Engagement Strategy will be developed once project funding is approved for use throughout the Construction and Post-construction Stabilisation and Monitoring phases. The strategy will develop key messaging to allay stakeholder concerns and outline the communication mechanisms for keeping stakeholders informed of the project including key milestones and anticipated impacts; it will be regularly reviewed. The Strategy will also include a process for managing enquiries and complaints related to the project.
- Ongoing consultation and communication with the Traditional Owners will be key to the Strategy so that expectations are managed and construction practices align as best as possible with Traditional Owner aspirations for the site.
- A cultural induction will be delivered by Traditional Owners for all workers on the project and for visitors to site so that the cultural traditions and practices are understood and respected by anyone accessing the site.
- Any impacts directly related to cultural heritage will need to be managed through the future development of the CHMP and the completed *A report on the archaeological survey for Rum Jungle Rehabilitation Project – Stage 2A* (Martin-Stone, 2019 – see Appendix).

13.3.2. Employment and Economies

A range of mechanisms are recommended to maximise the opportunities for local residents and Traditional Owners. These include:

- A Local Industry Participation Plan will be developed to align with the NTG's standard procurement processes and will be used to prioritise the engagement of local businesses and employees under the 30% mandated local content assessment weighting.
- Additionally, recruitment will prioritise Traditional Owner and local employment. An Indigenous Development Plan and Industry Participation Plan will be required of contractors to demonstrate commitment to employment outcomes Indigenous Territorians and to local participation.
- The NTG's Future Tender Opportunities advertising will be used to provide advance notice to local businesses of the procurement opportunities on the project and so that they are prepared at the time of tender advertising.
- A Traineeship Program specific to the project will be developed by the Proponent to maximise training opportunities – primarily in land management, environmental management and construction.
- The Proponent will develop an Opportunity Plan with Traditional Owners with the purpose of actively connecting people to potential opportunities such as identified positions.

13.3.3. Services and Infrastructure

- In order to manage any potential impacts related to housing needs of the workforce, an Accommodation Plan will be developed for the project, in consultation with the CCGC. This will allow early identification of available housing and gaps in capacity. Workers will be encouraged to reside in Batchelor to maximise the positive impact on the community and share the economic benefits locally. One of the key objectives of the strategy will be to minimise the impact on the seasonal tourism industry within the region.
- To respond to any potential emergency service impacts, the project will have an Emergency Response Plan which will be developed between the contractors and the Proponent, and will seek input from local emergency services.
- The project Stakeholder Communication and Engagement Strategy will communicate the expected workforce and project timeframes to stakeholders who may be impacted in terms of any small increased demand on services. These will include CCGC, Batchelor Community Health Centre, Batchelor Area School, Batchelor Police, Bushfires NT and the Volunteer Fire Brigade.

13.3.4. Natural Resources and the Environment

- Any impacts on visual amenity will be managed as *per* the mitigation measures outlined in the *Rum Jungle Project – Stage 2A, Landscape and Visual Impact Assessment* (SLR, 2019 – see Appendix).
- Any impacts on amenity including noise, dust and vibration and perceived risk related to radiation will be managed as *per* the mitigation measures outlined in the *Rum Jungle 2A – Air Noise and Vibration Air Quality Impact Assessment*, *Rum Jungle 2A – Noise and Vibration Impact Assessment* and the *Rum Jungle Radiological Hazard Assessment Report* (GHD, 2019a, 2019b, 2019c; EcOz, 2019b – see Appendix).
- The project Stakeholder Communication and Engagement Strategy will provide regular communication around milestones that are likely to have minor impacts to amenity and will target those most affected by the construction work. This will include the Mt Burton landowner, property owners adjacent to Rum Jungle and Litchfield Park Roads, Traditional Owners, CCGC and the Browns Oxide Mine, adjacent to the Rum Jungle site.

13.4. Statement of Residual Impact

Overall, the key socio-economic benefits of the project are likely to be:

- Business opportunity for existing local businesses, employment and training opportunities for Traditional Owners and locals
- Benefit to Traditional Owners who have a desire to restore health to the land, water and people onsite and to all downstream water users.

The key potential negative socio-economic impacts of the project are likely to be:

- During the Construction phase, localised amenity impacts for nearby residents and recreational users close to the project site
- Small increase in demand for accommodation resulting from potential non-residential workforce, which could impact on local tourism industry
- Small increase in demand for emergency and community services resulting from project activities and workforce.

The SEIA recommends the following mitigation measures to address identified socio-economic impacts and enhance benefits:

- Stakeholder Communication and Engagement Strategy
- Local Procurement Plan (Local Industry Participation Plan)
- Workforce Management Plan
- Cultural induction for all employees and contractors
- Accommodation Plan
- Health protocol for non-resident workers.

Overall, once the recommended mitigation measures are implemented, residual socio-economic impacts are expected to have a rating of Low to Medium for all except one risk ranked High which is the failure to meet community expectation for improvement in community services as a result of the project. This risk item is ranked as High as there is a significant opportunity for Council, on behalf of the community, to improve direct economic gain from the development of the potential borrow pit. This injection of cashflow into the Council income stream has potential to improve service provision; however this is ranked as a High risk as there has not been substantial progress in the development of any agreement over the low permeability material borrow pit use. As such, the likelihood of the agreement remains low until such time as the community has been well consulted, and a general community and Council consensus can be reached.

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13.6. References included in Appendix

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14. Terrestrial Flora and Fauna

Figures

Tables

14.1. Environmental Values

This chapter addresses the information requirements in the EIS ToR for the Terrestrial Flora and Fauna factor.

14.1.1. Information Sources

In preparation for this project, as well as for other nearby projects, many ecological surveys have been undertaken. These surveys have studied vegetation communities, faunal assemblages, threatened species and invasive species. This section collates data from surveys conducted between 2002 and 2019, to present an overview of the environmental values as they pertain to terrestrial flora and fauna. The information will be used to inform an assessment of the potential impacts that project activities could have on environmental values. Much of the content of this chapter is derived from the *Review of Terrestrial Ecology Surveys Relevant to the Rum Jungle EIS* (EcOz, 2019a – see Appendix).

14.1.2. Context

Bioregion

The project footprint is located within the Pine Creek Bioregion, which occupies approximately 28,500 km^2 and comprises foothill environments west of the western Arnhem Land sandstone massif. The major vegetation types are *Eucalyptus* tall open forests and woodlands. There are also areas of monsoon rainforest patches, *Melaleuca* woodlands, riparian vegetation and tussock grasslands.

Land systems

Christian and Stewart (1968) define a land system as ‘an area or group of areas throughout which there is a recurring pattern of topography, soils and vegetation’. These have been mapped across the NT by the government and are at a significantly smaller scale than a bioregion (*i.e.* bioregions constitute many different land systems).

NTG mapping at 1:250,000 scale shows that the project footprint occurs within six different land systems. These systems – as well as adjacent ones – are mapped in Figure 14-1, and their characteristics are outlined in Table 14-1. Finer scale, land unit mapping only covers a minor proportion of the project footprint and so has not been included in this report.

14.1.3. Fire

The northern savannas constitute the most fire-prone landscapes in Australia (Russell-Smith and Whitehead, 2015) and regular fires have always been a natural part of the environment in the Top End. However, frequent fires can result in fewer flora species and reduced structural complexity (McKay, 2017), both of which can also significantly diminish the habitat quality for fauna and facilitate weed invasion.

Regional fire history and fire scar mapping was obtained through the Northern Australia Fire Information website. The majority of the project footprint was last burnt between 2017 and 2019 – see map at Figure 14-2. In the past 10 years, the majority of the project footprint has been burnt every year – this is a very high frequency, which is likely to be the detriment of native species diversity – see Price and Baker (2007).

The small patch of monsoon vine forest on the eastern border of mine site has burnt seven times in the past 10 years. Over the past decade, Mt Burton has only burnt once or twice (with the wet vine forest to its south remaining unburnt).

The entire extent of the granular material borrow area was burnt in 2018. The western half of the low permeability material borrow area was most recently burnt in 2017, but the eastern half not since 2013.

Late season fires are typically hotter than those occurring earlier in the Dry season. They are often anthropogenic in origin (*i.e.* not caused by lightning) and their effect on native flora and fauna is usually more detrimental. These hotter, more intense fires affect not just the ground and mid-strata, which have evolved to adapt to fire, but also the more fire-sensitive canopy stratum.

In the past 10 years, the granular material borrow area has experienced late burns between two and three times; the low permeability material borrow area none at all. Of all the fires across the mine site, there has been only one that occurred late in the Dry season.

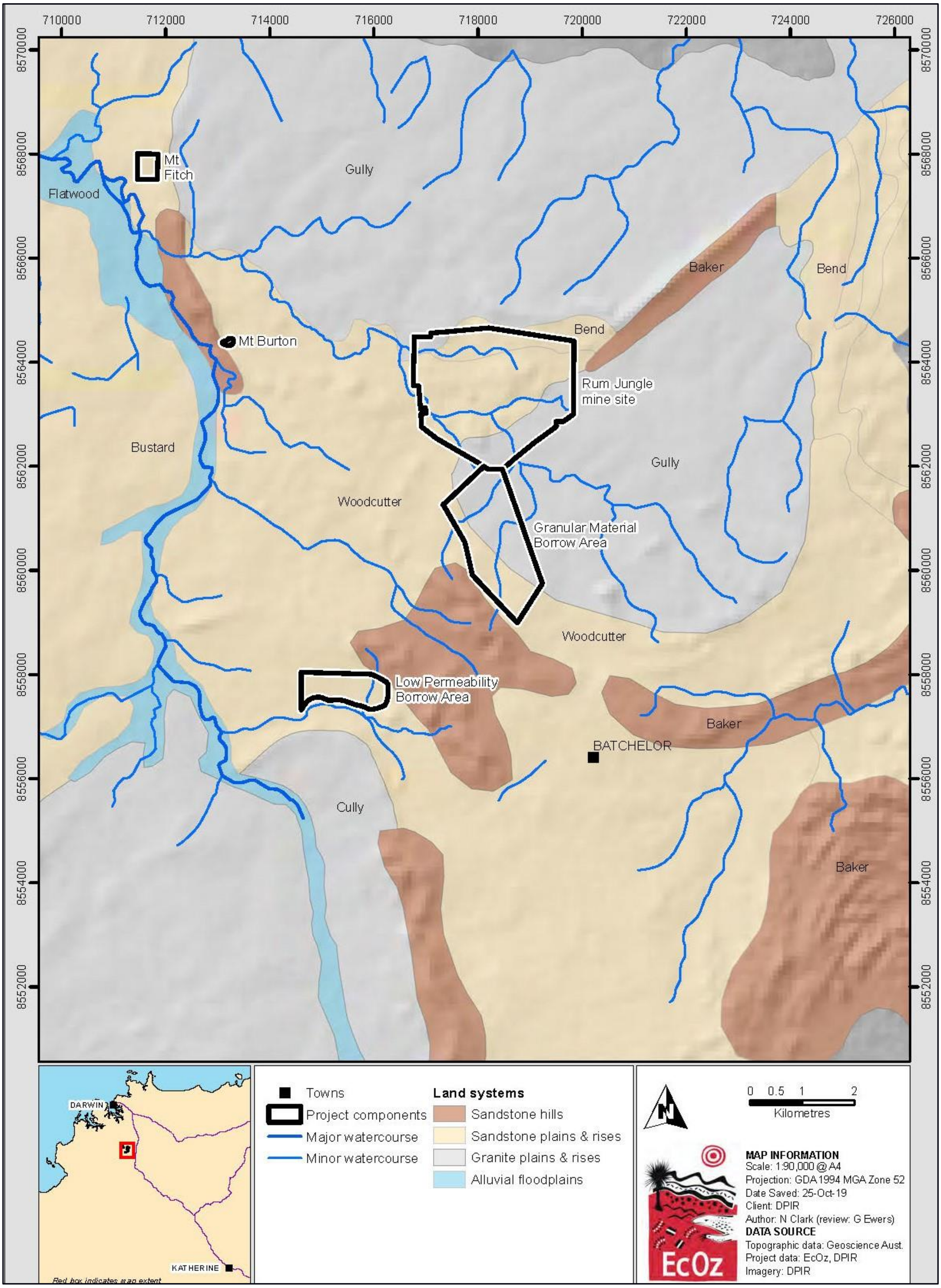

Figure 14-1: Land systems within the project footprint

Table 14-1: Land system characteristics for the Rum Jungle project footprint

Name	Class	Landform	Soil	Vegetation*
Effington	Alluvial floodplains	Level to gently undulating alluvial floodplains of dominantly sandy alluvium.	Kandosolic, Tenosolic and Chromosolic Redoxic Hydrosols. Uniform gradational and texture contrast sandy soils.	Mid-high woodland of *Melaleuca viridiflora, C. polycarpa, Melaleuca nervosa, E. bigalerita, C. latifolia* over *Chrysopogon fallax, Pseudopogonatherum spinescens, Eriachne triseta*.
Flatwood		Level to gently undulating alluvial floodplains of dominantly silty alluvium.	Kandosolic and Chromosolic Hydrosols. Mottled yellow earths and duplex soils.	Mid-high open woodland of *Melaleuca viridiflora C. polycarpa, Melaleuca nervosa, C. latifolia, C. grandifolia* over *Chrysopogon fallax, Pseudopogonatherum spinescens, Eriachne* spp.
Gully	Granite plains and rises	Undulating terrain developed on granite, schist, and gneiss.	Kandosols and Chromosols. Red massive earths and mottled yellow duplex soils.	Woodland of *C. confertiflora, C. foelscheana, E. chlorostachys, Terminalia canescens* and *Petalostigma* species over perennial grasses (*Heteropogon triticeus, Themeda australis, Sorghum plumosum*).
Bend	Sandstone plains and rises	Undulating low strike ridges and rises on folded Burrels Creek greywacke, sandstone and siltstone.	Kandosols and Rudosols. Skeletal soils and shallow gravelly loams.	Mid-high woodland of *C. latifolia, C. foelscheana, E. polysciada, E. tectifica, Erythrophleum chlorostachys* over tropical tall grass (*Sorghum* spp., *Heteropogon* spp., *Chrysopogon* spp.).
Bustard		Very low ridges and hills on Lower Proterozoic sediment and intervening alluvial flats.	Kandosols. Lithosols with minor shallow yellow massive earths and earthy sandy soil.	Low shrubland of Eucalypt spp., *Xanthostemon paradoxus* and *Buchanania* spp.
Woodcutter		Very gently upland surface; probably developed on Tertiary sediments overlying carbonate-rich Lower Proterozoic rocks.	Kandosols. Deep red massive earths and yellow massive earths.	Mid-high woodland of *Erythrophleum chlorostachys, E. miniata, C. confertiflora, C. papuana* and *Petalostigma* species over perennial grasses (*Heteropogon triticeus, Chrysopogon latifolius* and *Imperata cylindricus*).

** C. = Corymbia, E. = Eucalyptus*

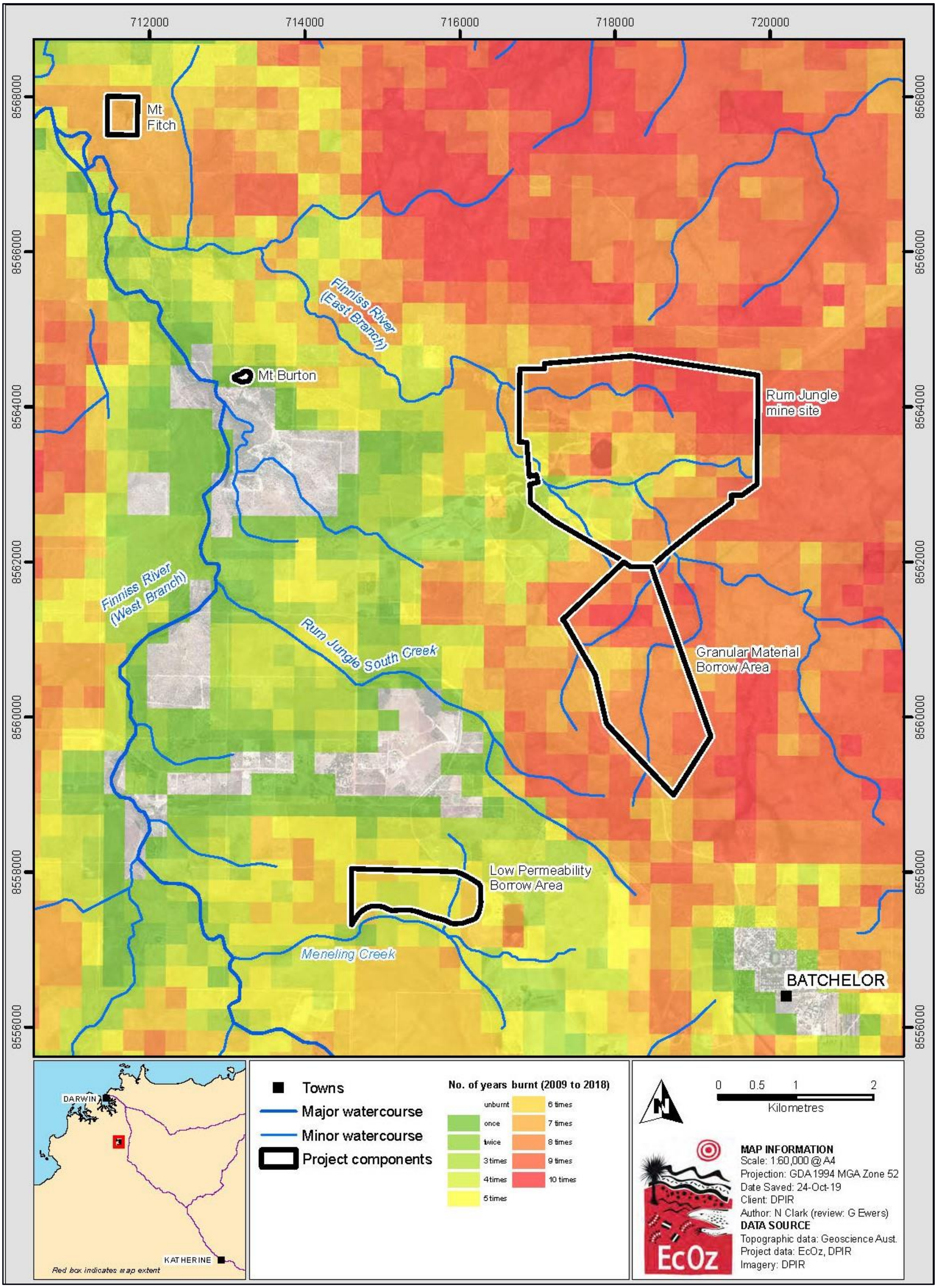

Figure 14-2: Fire history across the Rum Jungle region

14.1.4. Vegetation

Metcalfe (2002) identified and described 10 vegetation communities for the region – see Figure 14-3. The dominant vegetation comprises mainly *Eucalyptus*-dominated woodland and open woodland communities (59% of survey area). This vegetation community – also known as savanna – is common, widespread and characteristic of the region generally. The remaining vegetation is predominantly riparian habitats, *Lophostemon* communities associated with low-lying drainage areas, and Ghost Gum (*C. bella*) open woodlands and Paperbark (*Melaleuca* sp.) communities on surrounding floodplains.

Rum Jungle Mine site

Eco Logical (2014) recorded 29 vegetation communities within the mine site (excluding areas that were not surveyed due to cultural reasons). These can be assigned to five broad vegetation groups:

- **Woodlands** comprised the largest vegetation group, and occur in the north, south and east areas. The most commonly represented vegetation map units are *E. tetrodonta* and *E. miniata* open woodland (map unit 8), and *E. tetrodonta*, *E. miniata* and *Erythrophleum chlorostachys* woodland to open forest (map unit 10). These two are very similar in composition, but the former is generally more open and often lower in stature. Map unit 10 (occurring across 75 ha, mostly in the north and northwest of Rum Jungle) comprised the tallest and densest Eucalypt woodlands on the mine site – see photographs at Figure 14-5. The soils are likely to be deeper than those of the other Eucalypt woodlands in the area. Typically, species composition and stand structure of woodlands in the Top End are influenced by the soils, especially by their degree of saturation in the Wet season (Bowman, 1986); however, the more recent invasion of Gamba Grass, and changes to the frequency and intensity of fires, are now primary influences in determining species' composition and stand structure. Map unit 8 is predominantly to the south and east of previously disturbed areas.
- **Grassland** communities occur in the centre and western areas. These are dominated by the weed species Gamba Grass (*A. gayanus*) which has invaded previously rehabilitated areas – see photographs at Figure 14-6.
- **Riparian zones and wetlands** occur in small areas throughout much of the mine site, and encompass riparian corridors of streams and creeks, and alluvial plains. These significant vegetation types are discussed in more detail in Chapter 12 – Aquatic Ecosystems.
- **Vine forest** dominated by *A. auriculiformis* occurs as a large patch (~16 ha), and a number of smaller degraded remnant patches, in the vicinity (north) of Intermediate Pit – see photograph at Figure 14-21. This sensitive vegetation type is discussed in more detail in Section 14.1.6.
- **Other** vegetation occurs as areas of sparse and patchy regrowth – including on batter slopes, old disused tracks and other clearings.

The vegetation types are mapped in Figure 14-4. In a broader context, the vegetation communities of the mine site are well represented in the Bioregion.

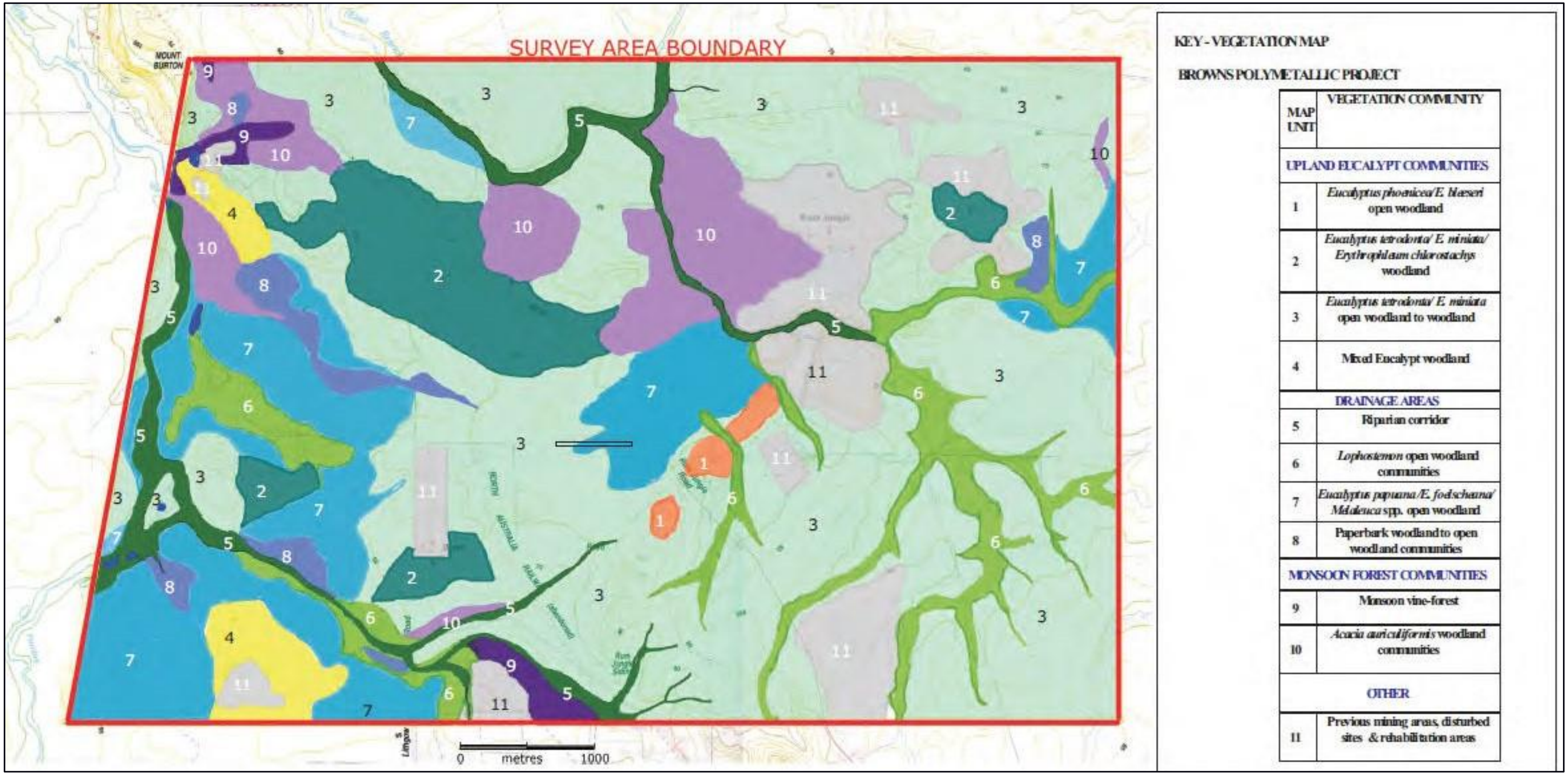

Figure 14-3: Vegetation communities in the region (Metcalfe, 2002)

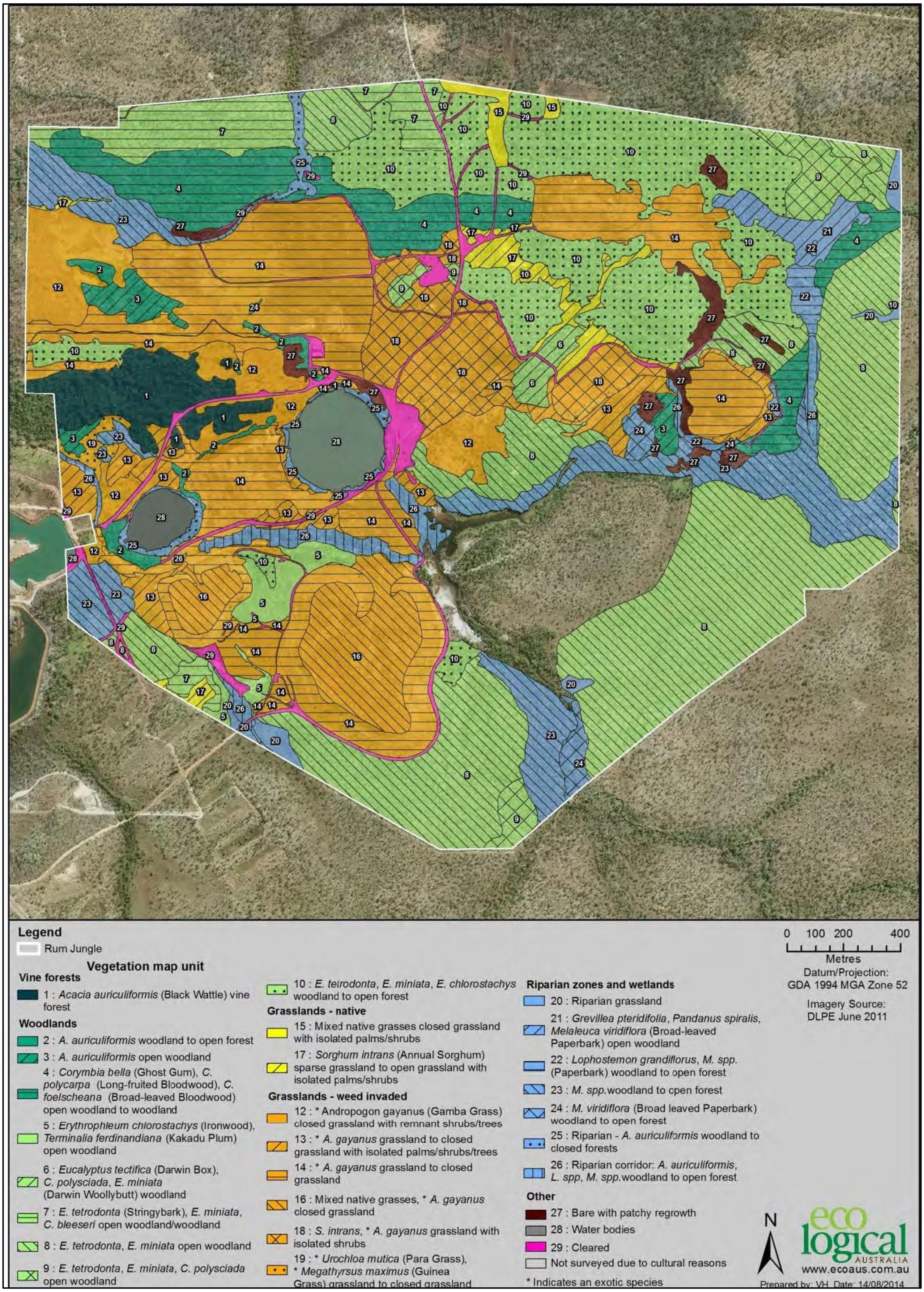

Figure 14-4: Vegetation communities in the Rum Jungle site (Eco Logical, 2014)

Figure 14-5: Photographs of Eucalypt woodland (map unit 10) in the north-west of Rum Jungle

Figure 14-6: Photographs of previously disturbed areas at Rum Jungle that have become grassland

Mt Burton

The Mt Burton part of the project footprint is a barren WRD that is bordered to the north, east and west by a large patch of wet vine forest – see photographs at Figure 14-19. As it is a significant vegetation type, the values associated with the vine forest are discussed in Section 14.1.6. To the south of the WRD is a Cypress Pine (*Callitris intratropica*) grove planted by the landowner. The area has moderate levels of weed infestations – as discussed in Section 14.1.5.

Figure 14-7: Photograph of on top of the waste rock dump located at Mt Burton

Mt Fitch

GHD (2009) described three different vegetation types within the Mt Fitch part of the project footprint:

- *E. miniata* and *Corymbia polysciada* woodland to open woodland
- *C. bella* and *C. polysciada* open riparian woodland
- Open monsoon vine forest.

The actual area that will be disturbed by this project, however, is an area already disturbed by previous mining activities. The site is also used to graze cattle. There are high levels of weed infestations across Mt Fitch – as discussed in Section 14.1.5. As it is a significant vegetation type, the values associated with the vine forest are discussed in Section 14.1.6.

Figure 14-8: Photographs of the Mt Fitch site – between the waste rock dump and the pit (top), and of the side of the waste rock dump (bottom)

Granular material borrow area

Within the proposed granular material borrow area there are five vegetation communities described by EcOz (2019) – four *Eucalyptus* communities and one drainage community. These are mapped at Figure 14-12. There is approximately 53 ha of land that has various levels of regrowth after having been previously quarried (Community 2a). Some example photographs are provided at Figure 14-9, Figure 14-10 and Figure 14-11. *Eucalyptus* community 1 (*E. tetrodonta* +/- *E. miniata, E. chlorostachys* mid woodland) was the most widespread, occurring across much of the granular material borrow area.

Figure 14-9: Photographs of *Eucalyptus* mid woodland (map unit 1) in the granular material borrow area

Figure 14-10: Photograph of previously disturbed *Eucalyptus* low open woodland (map unit 2a) in the granular material borrow area

Figure 14-11: Photograph of *Eucalyptus* mid open woodland (map unit 2) in the granular material borrow area

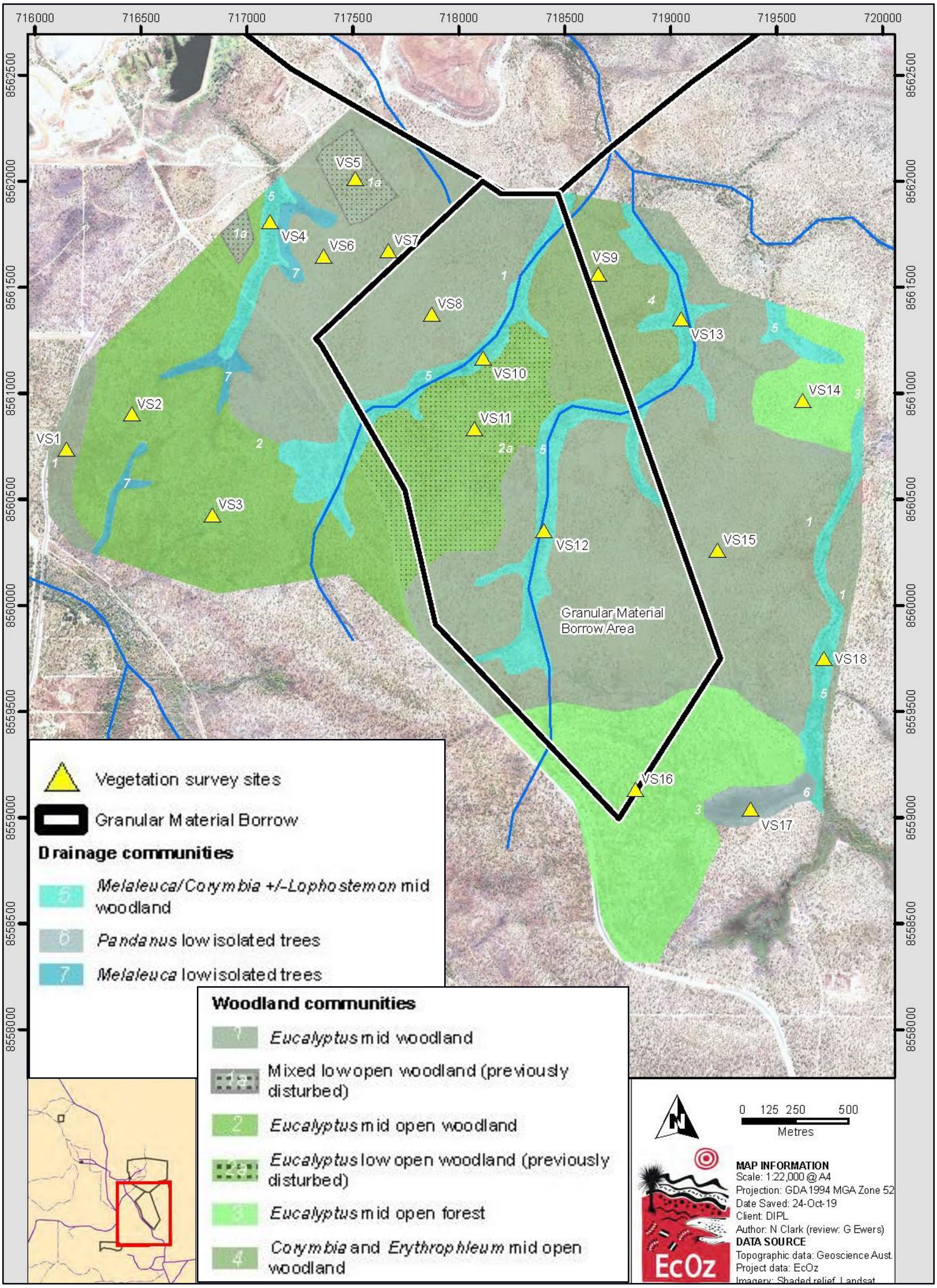

Figure 14-12: Vegetation communities in the granular material borrow area

Low permeability material borrow area

Four broad vegetation types were identified in the proposed low permeability material borrow area by EcOz (2019):

- *Corymbia* species open woodland (60.6 ha)
- *E. miniata* woodland (9.0 ha)
- *E. tetrodonta* woodland (4.3 ha)
- *Melaleuca* species closed forest (18.5 ha).

These are mapped in Figure 14-14. The environmental weed species Guinea Grass (*Megathyrsus maximus*) is abundant within riparian vegetation (*i.e.* the Melaleuca sp. closed forest). All the non-riparian vegetation is heavily infested by Gamba Grass (*A. gayanus*) – see Figure 14-13 for an example.

Figure 14-13: Photograph of the low permeability material borrow area taken from the northern boundary towards the east

Note: The photographer was standing in the tray of a Hilux in order to get image over the Gamba Grass

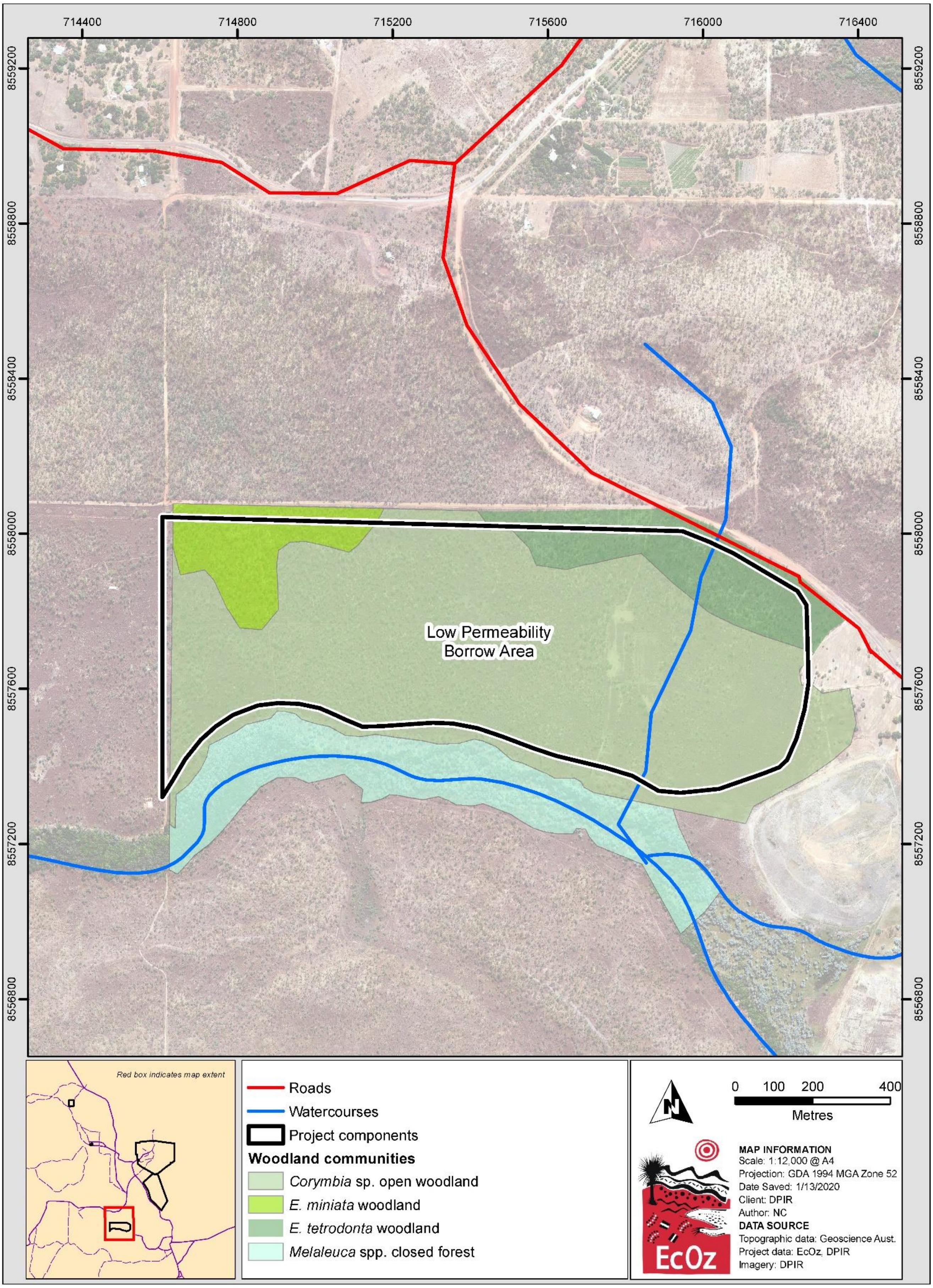

Figure 14-14: Vegetation communities in the low permeability material borrow area

14.1.5. Weeds

Some species of introduced flora are declared to be weeds under the Weeds Management Act because of the harm they can cause. The Australian Government has also categorised some species as WoNS. The remaining introduced flora species are referred to as environmental weeds.

The *Draft Natural Resource Management Strategy for the Coomalie Shire* (Price and Baker, 2003) identified at least 47 weed species that occur in the wider Coomalie region. Revegetation monitoring surveys of the mine site in the mid 1980's detected only localised patches of five weed species; and no Gamba Grass (Ryan, 1985).

Metcalfe (2002) recorded 31 weed species within her large survey area (37.5 km^2). A search of the NTG weed records held in NR Maps found that, within a 30 km radius of the mine site, there are 13,745 records of approximately 60 species. More than 83% of those records are of Gamba Grass (discussed further below). Species with more than 30 records are presented in Table 14-3. There are nine species of declared weeds and one species of environmental weed; four of the declared weeds are also WoNS.

Table 14-2: Most common weed species within a 30 km radius of the Rum Jungle Mine site

Common name	Scientific name	Weed of National Significance	Classification*
Declared weeds			
Cabomba	*Cabomba caroliniana*	X	A, C
Flannel Weed	*Sida cordifolia*	-	B, C
Gamba Grass	*Andropogon gayanus*	X	B, C
Hyptis	*Hyptis suaveolens*	-	B, C
Mimosa	*Mimosa pigra*	X	B, C
Mission Grass (Perennial)	*Cenchrus polystachios*	-	B, C
Olive Hymenachne	*Hymenachne amplexicaulis*	X	B, C
Sicklepod	*Senna obtusifolia*	-	B, C
Spinyhead Sida	*Sida acuta*	-	B, C
Environmental weeds			
Mission Grass (Annual)	*Cenchrus pedicellatus*	-	-

** A – to be eradicated; B – growth and spread to be controlled; C – not to be introduced*

Rum Jungle Mine site

During Rum Jungle monitoring in the late 1990s, Kraatz and Norrington (2002) reported eight weed species on the mine site. In contrast, the 2018 weed survey by EcOz of the mine site recorded 978 weed occurrences of 22 species (see Table 14-3). There are 11 species of declared weeds – all Class B, meaning their growth and spread is to be controlled by landowners – and 11 species of environmental weeds. Four of the declared weeds found at the site are also WoNS.

- Gamba Grass (*A. gayanus*)
- Grader Grass (*Themeda quadrivalvis*)
- Mimosa (*M. pigra*)
- Olive Hymenachne (*H. amplexicaulis*) – a riparian species addressed in Chapter 12 – Aquatic Ecosystems.

Gamba Grass (A. gayanus) is the most widespread weed within the Rum Jungle region – recorded across the extent of the mine site, but at highest densities in the north-west, central and south-west areas (see, e.g. photograph at Figure 14-15). Much of the woodland communities in the south-east and central-north border of Rum Jungle have low densities of Gamba Grass (less than 1 to 10% cover). The species also occurs across the extent of the WRD at Mt Fitch (Figure 14-16) and in the vicinity of the WRD at Mt Burton. All the non-riparian vegetation within the low permeability material borrow area is heavily infested by Gamba Grass (see photographs at Figure 14-13). In the granular material borrow area, Gamba Grass predominately occurs in the riparian areas and drainage lines, sometimes in dense patches. In 2003, Price and Baker identified Gamba Grass as 'probably the most serious environmental problem' in the region. The Coomalie region lies within the Gamba Grass Class B Zone, which imposes a legal obligation on landholders to contain existing infestations and eradicate any smaller or new infestations. A 2008 survey of the region detected Gamba Grass on 91% of properties surveyed. Infestations were highest to the west and south-west of Rum Jungle, with the average density of Gamba Grass cover at Rum Jungle between 1% and 10% (NRETAS 2008). In contrast, the EcOz (2018) survey of Rum Jungle found that 42% of the Gamba Grass recorded was at greater than 50% density – see Figure 14-18 – indicating the species has proliferated on site in the past decade.

In 2003, Price and Baker stated that although Mimosa (*M. pigra*) was formally recorded in about 90 sites throughout the Coomalie region, the species occurred in the headwaters of nearly all creeks and rivers in the region. Metcalfe (2002) found that Mimosa is common in the creek bed downstream of Rum Jungle. EcOz (2018) only found Mimosa at a few sites in the north-west corner of the mine site.

Grader Grass (*T. quadrivalvis*), Hyptis (*Hyptis suaveolens*) and both annual and perennial Mission Grass (*Cenchrus polystachios* and *Cenchrus pedicellatus*) were recorded at varying – but significant – densities across the central-north and south-west of Rum Jungle. These weeds all grow well in disturbed areas and are able to outcompete native grasses and alter fire regimes by promoting hotter fires.

Initial introduction of some species is thought to have occurred through importation of contaminated fill material during the 1980s rehabilitation (Kraatz, 1998). Vehicle traffic, wind and animal transport have undoubtedly contributed to the spread of other locally prevalent weeds. However, whilst many introduced pasture species were deliberately planted during mine site rehabilitation in the mid 1980s, none of these species appear to be extant. Although weed control has been undertaken at the mine site since at least 1993, no species have been eradicated – indeed, weeds have proliferated in both distribution and abundance (apart from Mimosa).

Mt Burton

The Mt Burton WRD is almost entirely devoid of vegetation. The adjacent rainforest is also weed free. Declared weeds recorded in the vicinity of the WRD are Hyptis, Snakeweed, Gamba Grass, Spinyhead Sida and Sicklepod. There are also three environmental weed species (Annual Mission Grass, Red Natal Grass and Calopo).

Mt Fitch

Mt Fitch is characterised by high densities of Gamba Grass, Sicklepod and Hyptis. There is Perennial Mission Grass and Mimosa on the drainage line at the base of the WRD (see Figure 14-16).

Granular material borrow area

The most common weed species in the granular material borrow area is Gamba Grass which was observed in the riparian areas and drainage lines – sometimes in dense patches. There are also some isolated patches of Gamba Grass in woodland, as well as along the tracks in the vicinity of the revegetated borrow areas in the centre of the survey area. Creek lines also contain patches of Hyptis.

Low permeability material borrow area

All the non-riparian vegetation within the low permeability material borrow area is heavily infested by Gamba Grass (see Figure 14-17), with Guinea Grass (*M. maximus*), an environmental weed species, also abundant.

Table 14-3: Weeds recorded during the 2018 survey of the project area

Location	Common name	Scientific name	WoNS	Declared weed	Other weed
Rum Jungle Mine site	Gamba Grass	*Andropogon gayanus*	X	-	-
	Grader Grass	*Themeda quadrivalvis*	X	-	-
	Mimosa	*Mimosa pigra*	X	-	-
	Olive Hymenachne	*Hymenachne amplexicaulis*	X	-	-
	Mission Grass (Perennial)	*Cenchrus polystachios*	-	X	-
	Hyptis	*Hyptis suaveolens*	-	X	-
	Sicklepod	*Senna obtusifolia*	-	X	-
	Spinyhead Sida	*Sida acuta*	-	X	-
	Flannel Weed	*Sida cordifolia*	-	X	-
	Paddy's Lucerne	*Sida rhombifolia*	-	X	-
	Snakeweed	*Stachytarpheta* sp.	-	X	-
	Mission Grass (Annual)	*Cenchrus pedicellatus*	-	-	X
	Calopo	*Calopogonium mucunoides*	-	-	X
	Coffee Bush	*Leucaena leucocephala*	-	-	X
	Guinea Grass	*Panicum maximum*	-	-	X
	Para Grass	*Urochloa mutica*	-	-	X
	Rat's Tail Grass	*Sporobolus* sp.	-	-	X
	Rattle Pod	*Crotalaria* sp.	-	-	X
	Red Natal Grass	*Melinis repens*	-	-	X
	Rosella	*Hibiscus sabdariffa*	-	-	X
	Stylo	*Stylosanthes* sp.	-	-	X
	Wild Passionfruit	*Passiflora foetida*	-	-	X
Mt Burton	Gamba grass	*Andropogon gayanus*	X	-	-
	Hyptis	*Hyptis suaveolens*	-	X	-
	Sicklepod	*Senna obtusifolia*	-	X	-
	Spinyhead Sida	*Sida acuta*	-	X	-
	Snakeweed	*Stachytarpheta* sp.	-	X	-
	Mission Grass (Annual)	*Cenchrus pedicellatus*	-	-	X
	Calopo	*Calopogonium mucunoides*	-	-	X
	Red Natal Grass	*Melinis repens*	-	-	X
Mt Fitch	Gamba Grass	*Andropogon gayanus*	X	-	-
	Mimosa	*Mimosa pigra*	X	-	-
	Mission Grass (Perennial)	*Cenchrus polystachios*	-	X	-
	Hyptis	*Hyptis suaveolens*	-	X	-
	Sicklepod	*Senna obtusifolia*	-	X	-
Granular material borrow area	Gamba Grass	*Andropogon gayanus*	X	-	-
	Hyptis	*Hyptis suaveolens*	-	X	-
Low permeability material borrow area	Gamba Grass	*Andropogon gayanus*	X	-	-
	Guinea Grass	*Panicum maximum*	-	-	X

Figure 14-15: Photograph of burnt trees surrounded by Gamba Grass (located outside western border of mine site)

These trees likely died from intense Gamba Grass-fuelled fires that they are unable to tolerate

Figure 14-16: Photograph of high density infestation of Gamba Grass, Perennial Mission Grass and Mimosa at Mt Fitch

Figure 14-17: Photograph of the high density infestation of Gamba Grass at the low permeability material borrow area

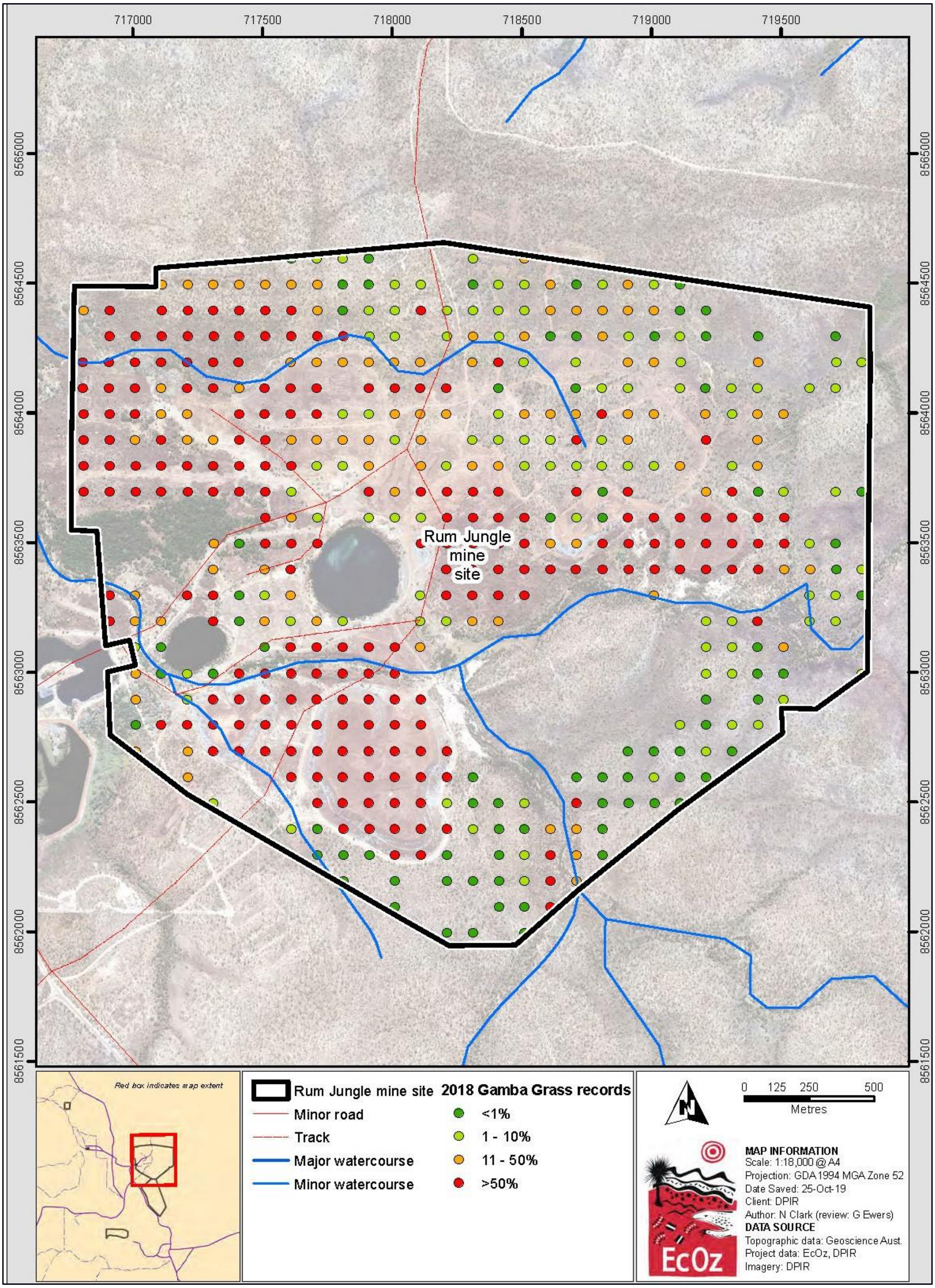

Figure 14-18: Extent of Gamba Grass infestations at Rum Jungle Mine site (EcOz, 2018)

14.1.6. Significant Vegetation

Significant vegetation types are those designated under the *Land Clearing Guidelines* (DENR, 2019). These vegetation types are unique to the NT and/or have inherently high biodiversity values. The following occur within the project footprint:

- Riparian vegetation (which is discussed in Chapter 12 – Aquatic Ecosystems)
- Vine forests (wet and dry)
- Vegetation containing large trees with hollows suitable for fauna.

Vine forest

Various types of rainforest and vine forest occurs in the NT over a broad range of landforms throughout the region of summer (*i.e.* monsoonal) rainfall – essentially north of 18°S (Russell-Smith, 1991). Although only covering 0.2% of the NT, these vegetation types contain 13% of flora species, making them highly diverse and significant vegetation communities. The total rainforest estate in the NT is divided into 15,000 patches (ranging between 1 ha and 4,000 ha, with a median size of 3.6 ha) that are scattered within a vast expanse of mostly Eucalypt-dominated savanna.

There are two broad types of rainforest and vine forest – wet (evergreen) and dry. Both occur within the project footprint – see Figure 14-22.

<u>Wet rainforest</u>

Usually associated with permanent water such as springs (Russel-Smith, 1991), wet rainforest habitats support a floristically-distinctive community in which evergreen trees typically form a closed canopy forest up to 20 m high (Metcalfe, 2002). Tree species are characteristic of areas with perennially high soil moisture.

There is a single occurrence of wet vine forest within the project footprint – described as *wet monsoon vine forest* by Metcalfe (2002) and *closed monsoon vine forest* by GHD (2009). This is at Mt Burton, which is bordered to the north and east by approximately 20 ha of wet rainforest associated with a permanent spring – the extent is shown in the map at Figure 14-20, with an example photograph at Figure 14-19.

Figure 14-19: Photograph of the rainforest adjacent to Mt Burton

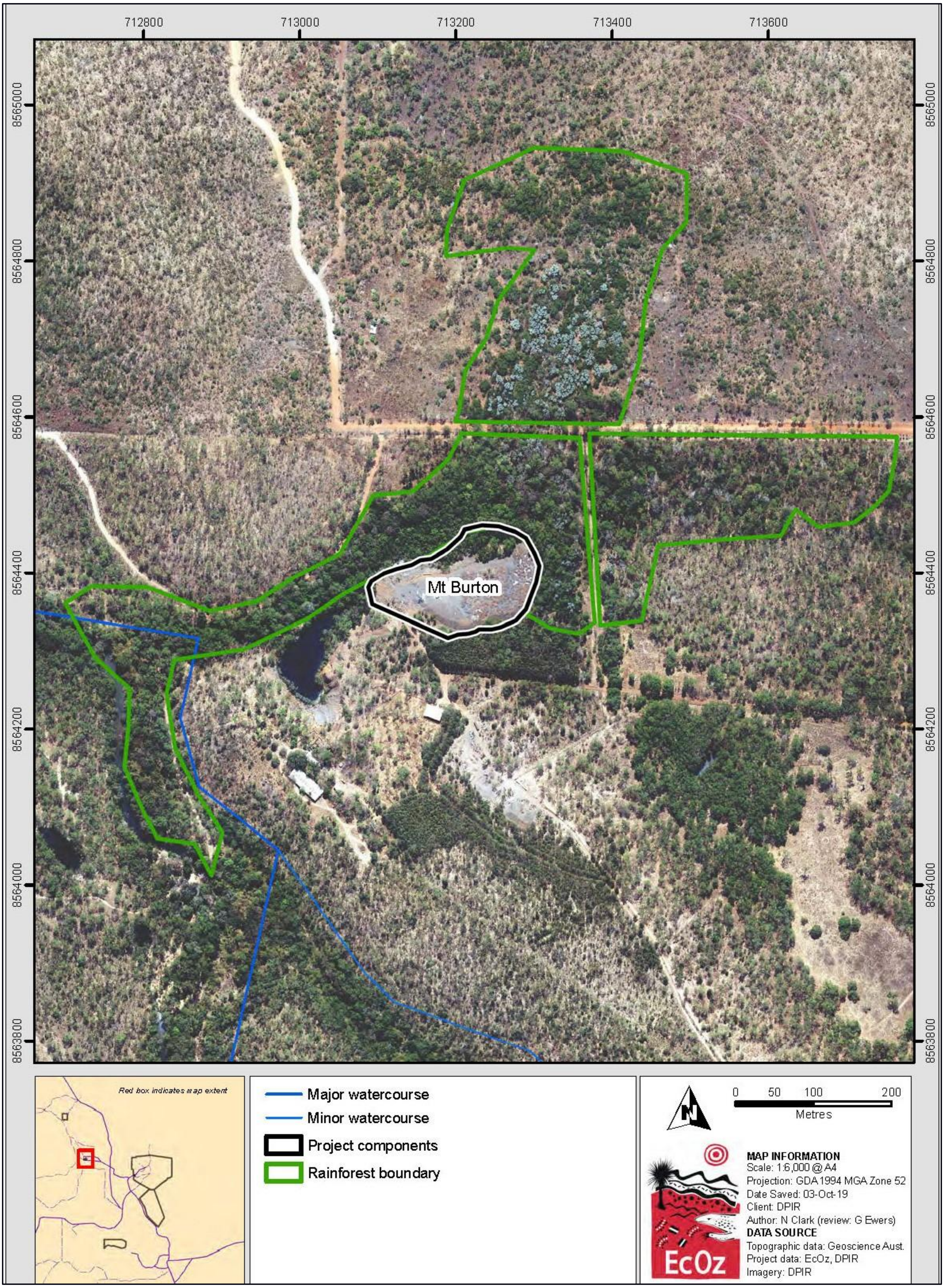

Figure 14-20: Rainforest adjacent to Mt Burton

Dry vine forest

With vegetation broadly similar to that of wet rainforests – and a large number of species in common – dry rainforests have many deciduous components and occur in drier habitats.

Dry vine forest occurs within the Rum Jungle Mine site in the form of what Metcalfe (2002) calls *A. auriculiformis* (Black Wattle) communities – see photograph at Figure 14-21. The dominance of Black Wattle – a rainforest coloniser species – is symptomatic of degraded or regenerating vine forest habitats. Other upper stratum species in this vegetation community include Ironwood (*E. chlorostachys*) and *Terminalia microcarpa*. Large Banyan Figs (*Ficus virens*) and Milkwood trees (*A. actinophylla*) may be key species in the re-establishment of vine-forest vegetation.

According to Metcalfe (2002):

> *These forests typically occur in areas with slightly lower soil moisture than evergreen vine-forests and include parts of the survey area where jungles appear to be recovering from the impacts of disturbance (e.g. clearing, fire, mining etc.). Vegetation structure reflects the lack of perennial water supply with open forest and woodland structural formations more common than closed canopy forests.*

Eco Logical (2014) mapped a 16 ha patch of the vegetation type in the centre of the eastern border (see Figure 14-4) with a number of smaller degraded remnant patches nearby. The species richness (43 plant species) was relatively low in comparison to similar *A. auriculiformis* vine forests surveyed in the region – Metcalfe (2002) recorded 89 species.

Eco Logical (2014) note that aerial photos from 1977, 1981 and 1990 indicate that dense vegetation communities – possibly vine forests – were once more widespread in this area. Several areas that were dense vegetation on historic aerial photographs were found in the Eco Logical survey to support many large dead trees with occasional large mature trees and a dense understorey of invasive weeds such as Gamba Grass. In additional to land clearing for the development of the Browns Oxide Mine, the decrease in dense vegetation was most likely due to weed invasion, with the higher fuel loads created by weeds increasing the frequency and intensity of fires, killing fire-sensitive vine forest species and preventing vine forest regeneration.

There are also are some patches (each <1 ha) of dry vine forest immediately north of the Mt Fitch pit – extent is shown in the map at Figure 14-23.

Figure 14-21: Photograph of vine thicket community in the west of the Rum Jungle Mine site

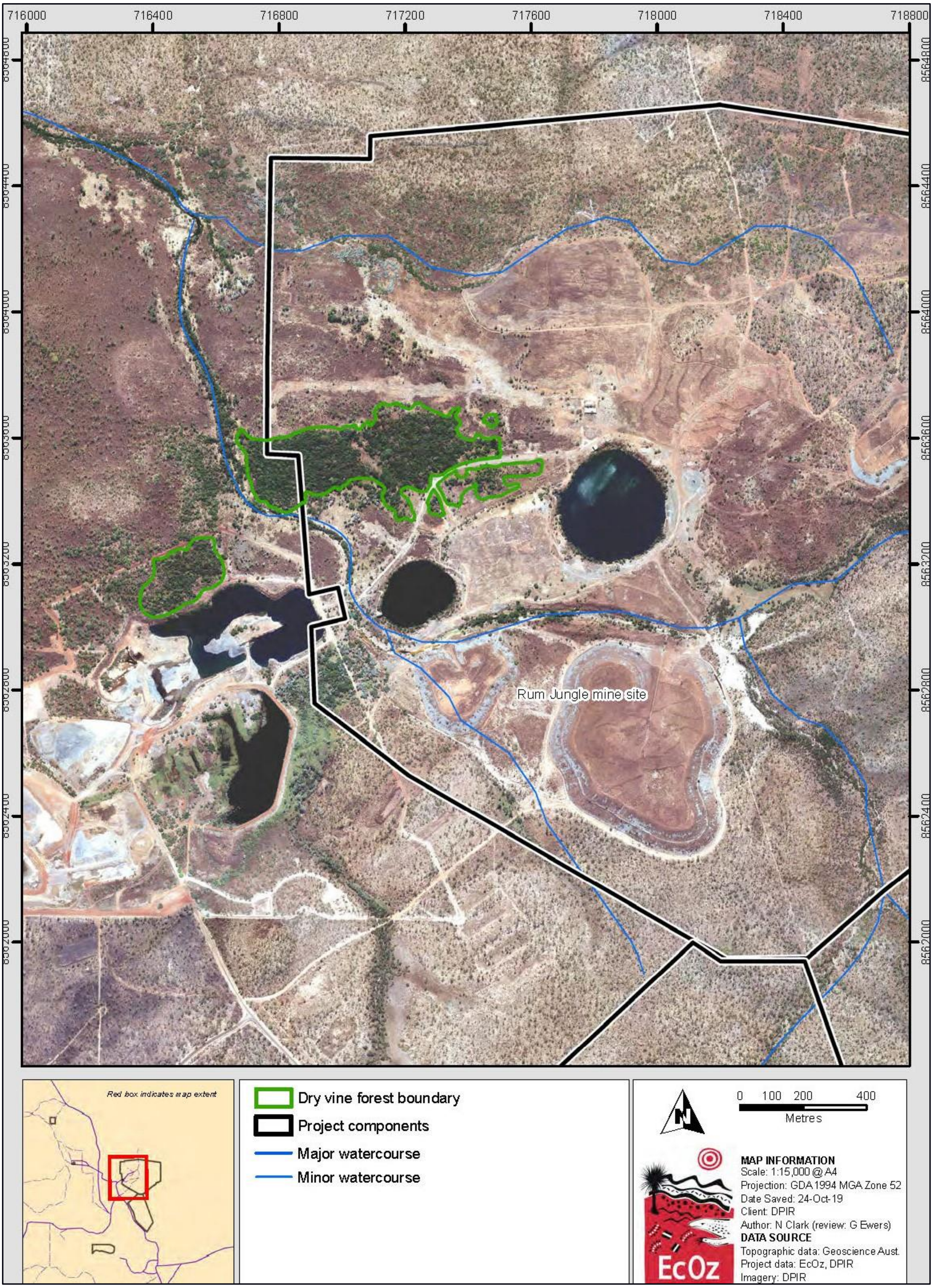

Figure 14-22: Vine forest within the Rum Jungle Mine site

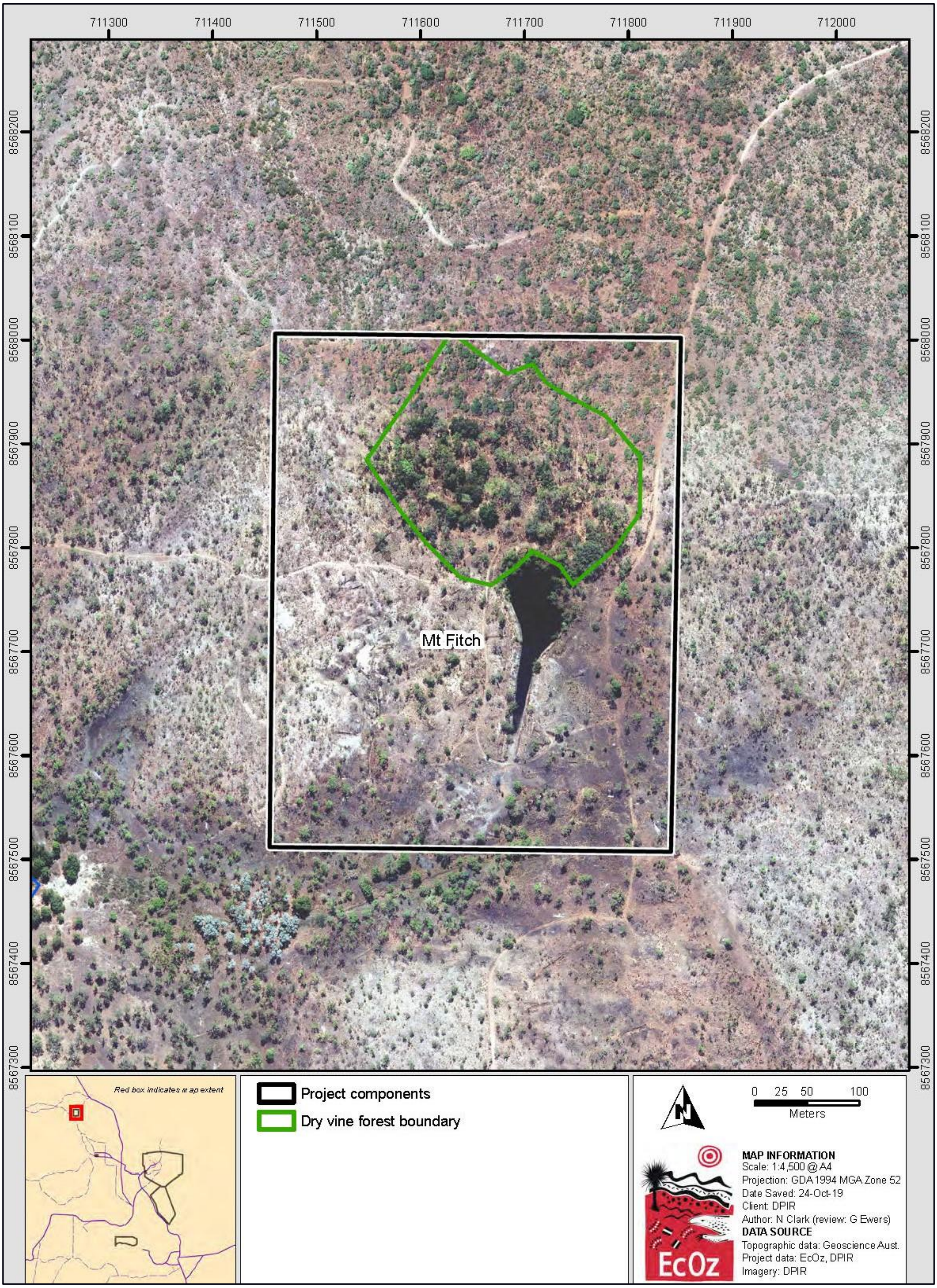

Figure 14-23: Vine forest at Mt Fitch

Large hollow-bearing trees

Tree hollows provide valuable habitat for a range of native fauna. In the NT, a Eucalypt forest that has either five or more Eucalypt stems growing greater than 50 cm in diameter at breast height (dbh) *per* ha and/or 30 or more Eucalypt stems greater than 40 cm dbh *per* ha, is considered to be of high value for biodiversity (DENR, 2019).

Eco Logical (2014) classified the amount of tree hollows (plus other shelter in fallen wood) within the woodland vegetation groups of Rum Jungle as ‘good to excellent’, depending on the fire history and maturity of the habitat. Vegetation unit 10 (*E. tetrodonta* / *E. miniata* / *E. chlorostachys* woodland to open forest) was described as the tallest and densest Eucalypt woodland community (Eco Logical, 2014), therefore likely to have the highest occurrence of tree hollows – see Figure 14-4. This vegetation community occurs in the centre and north of the mine site. In the granular material borrow area, trees with dbh greater than 50 cm were largely limited to occurring along drainage lines outside of the borrow pit boundaries. The *Eucalyptus* woodland communities may contain some hollow-bearing trees, but these are occasional.

14.1.7. Groundwater-Dependent Ecosystems (GDEs)

GDEs refer to ‘natural ecosystems that require access to groundwater to meet all or some of their water requirements on a permanent or intermittent basis, so as to maintain their communities of plants and animals, ecosystem processes and ecosystem services’ (Richardson *et al.*, 2011). The *Atlas of Groundwater Dependent Ecosystems* maps three types of GDEs – *subterranean*, *aquatic* (*i.e.* ecosystems dependant on surface expression of groundwater) and *terrestrial* (*i.e.* ecosystems which accesses sub-surface groundwater to meet some or all of its water requirements).

Subterranean GDEs have not been mapped for the NT, but there is no surface evidence of cave systems within the project footprint. The Atlas presents the Main Pit, Intermediate Pit and West Branch of the Finniss River as being the only aquatic GDEs in the vicinity of the project footprint. The Atlas identifies the riparian vegetation and the vine forest within the project footprint as terrestrial GDEs (see Figure 14-22).

14.1.8. General Fauna

In the past two decades, the project footprint and surrounds have been subject to standard biodiversity surveys in anticipation of this project, as well as for the Browns Oxide project and, more recently, Yarram Iron Ore project. Although the results of each survey cannot be directly compared (due to the significant differences between survey methods, timing, effort and site locations), there is an apparent decline in the number of species recorded over time. EMS first surveyed in 2002 and 2005, and recorded the highest number of all fauna groups in the area. Many species, including the threatened Floodplain Monitor (*Varanus panoptes*), have not been recorded in the region again since those surveys. In 2014, Eco Logical recorded only around 50% of the mammal species present during the EMS survey, and approximately 60% of both reptile and bird species. These declines coincide with the arrival of the toxic Cane Toad in late 2004/early 2005, weed proliferation and the increase in mining activities in the area (particularly the establishment of the Browns Oxide Mine).

14.1.9. Pest Animals

Price and Baker (2003) noted that the distribution of feral animals across the Coomalie region was very poorly known and that the control of Feral Pigs and Feral Cats should be given priority.

The introduced fauna species listed in Table 14-4 are widespread and abundant within the Bioregion, and hence are known or likely to occur within the project footprint. Cane Toads, Feral Cats and Feral Pigs are each listed as a Key Threatening Process under the EPBC Act.

Table 14-4: Pest animals that are known, or likely, to occur within the project footprint

Common name	Scientific name	Impacts
Feral Cattle*	*Bos taurus*	Physical damage to the environment – especially riparian habitats – leading to erosion.
Swamp Buffalo*	*Bubalus bubalis*	
Donkey	*Equus asinus*	
Horse	*Equus caballus*	
Wild Dog	*Canis lupus*	Prey on many species of native animals.
Feral Cat*	*Felis catus*	
Pig*	*Sus scrofa*	Physical damage to wetlands.
House Mouse	*Mus domesticus*	Not currently considered a great threat to biodiversity. May impact upon native vegetation via seed predation.
Asian House Gecko*	*Hemidactylus frenatus*	Not currently considered a great threat to biodiversity. May out-compete native species of gecko.
Black Rat*	*Rattus rattus*	Prey on native bird eggs, and may impact upon native vegetation via seed predation.
Cane Toad*	*Rhinella marina*	Known to cause population reductions in a range of predatory species (due to poisoning by ingestion).

** Species has been recorded within the project footprint.*

14.2. Threatened Species

The information requested in the EIS ToR identified certain threatened species that required investigation and assessment. In addition, to determine which other threatened species have the potential to occur in the project footprint, an analysis of bioregional flora and fauna records was undertaken.

The purpose of this section is to:

- Provide an assessment of the likelihood of occurrence within the project footprint of NT and/or nationally-listed threatened terrestrial species
- Assess the significance of any threatened species that are likely to be present.

Three threatened species that are more closely aligned to aquatic ecosystems – Mertens' Water Monitor, Mitchell's Water Monitor and Lorentz Grunter – are discussed in Chapter 12 – Aquatic Ecosystems.

The International Union for the Conservation of Nature (IUCN) nominates a set of criteria used to identify species at risk of extinction. These criteria are used to define categories of risk – see Figure 14-24 – which are used by the NTG to determine which threatened species are listed under the TPWC Act and by the Australian Government to determine which threatened species are listed under the EPBC Act. This report focusses on species that are listed as Vulnerable, Endangered or Critically Endangered under the TPWC Act, the EPBC Act or both.

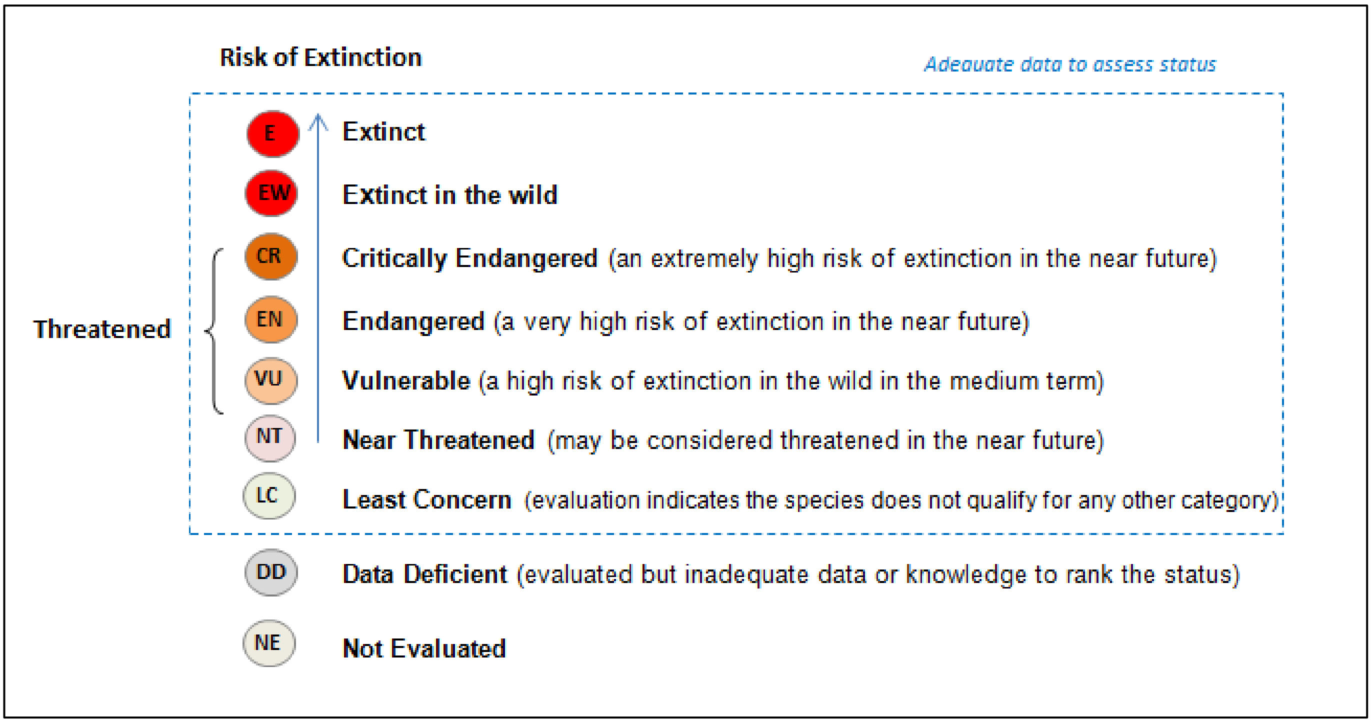

Figure 14-24: IUCN red list categories of risk for species

Threatened species records for the footprint and surrounds are listed in Table 14-5 and shown in Figure 14-25. Similarly to general fauna observations discussed previously, there have been records of fewer threatened species in recent surveys. Despite having been previously recorded in the project footprint, certain threatened species may no longer occur in the region. In the past two decades, much of the project footprint and surrounds have been altered to varying degrees in terms of habitat availability and quality – be it from additional land clearing, proliferation of weeds and/or invasion of the Cane Toad. The EMS (2005) survey report notes that Cane Toads arrived in the local area in the weeks or months prior to March 2005 (when the field work was undertaken) and it was surmised that the effects of this invasion on native fauna would be apparent.

The only threatened species records from within the mine site were of Partridge Pigeon by DPIR in 2016, Fawn Antechinus (*Antechinus bellus*) and Northern Quoll (*Dasyurus hallucatus*) by GHD in 2009, and Black-footed Tree-rat (*Mesembriomys gouldii gouldii*) by EcOz in 2019. The latter species was also recorded in the same survey within the granular material borrow area.

Despite multiple targeted bat surveys, the Bare-rumped Sheathtail Bat (*Saccolaimus saccolaimus*) has not been detected in the region. In EcOz (2014b), it is considered possible that the species was recorded using acoustic detectors at a site on the main Finniss River downstream of where the two branches converge. However, that report stresses that only three of the four criteria for unambiguous identification of the species were met. A follow-up survey by EcOz (2015) recorded unambiguous calls of the closely-related Yellow-bellied Sheathtail Bat (*Saccolaimus flaviventris*).

Table 14-5: Threatened terrestrial species recorded in the project footprint (highlighted) and the surrounding region

Species	Year	Location	Surveyor	Notes
Darwin Cycad	2002-19	Rum Jungle and granular material borrow area	Multiple	Locally abundant in suitable habitat, including in surrounding woodland
Partridge Pigeon	2014	North of Rum Jungle	Eco Logical	-
	2005	East of Rum Jungle	EMS	At a number of sites within the Browns Oxide site (which has since been disturbed)
	2007	South-west of Rum Jungle	GHD	-
	2008	South-west of Rum Jungle	GHD	-
	2015	North-west of Rum Jungle	EcOz	-
	2016	Rum Jungle	MCD	Record of call only
	2019	Granular material borrow area	EcOz	-
Red Goshawk	2002, 2005	West of Rum Jungle	EMS	Browns Oxide site (which has since been disturbed)
Masked Owl	2008	South-west of Rum Jungle, Rum Jungle and Mt Fitch	GHD	Identification based on call recognition
Black-footed Tree-rat	2019	Rum Jungle and granular material borrow area	EcOz	-
	2002	West of Rum Jungle	EMS	Browns Oxide site (which has since been disturbed)
Northern Brush-tailed Phascogale	2002	West of Rum Jungle	EMS	Browns Oxide site (which has since been disturbed)
Fawn Antechinus	2002, 2005	West of Rum Jungle	EMS	Browns Oxide site (which has since been disturbed)
	2007, 2008	Rum Jungle	GHD	-
Northern Quoll	2002, 2005	Browns Oxide	EMS	Browns Oxide site (which has since been disturbed)
	2007, 2008	Rum Jungle	GHD	-
Pale Field-rat	2002	West of Rum Jungle	EMS	Browns Oxide site (which has since been disturbed). Record of burrow system only
	2005	West of Rum Jungle	EMS	-
	2012	West of Rum Jungle	LES	Proposed Yarram Iron Ore project site
Floodplain Monitor	2002	West of Rum Jungle	EMS	Browns Oxide site which has since been disturbed

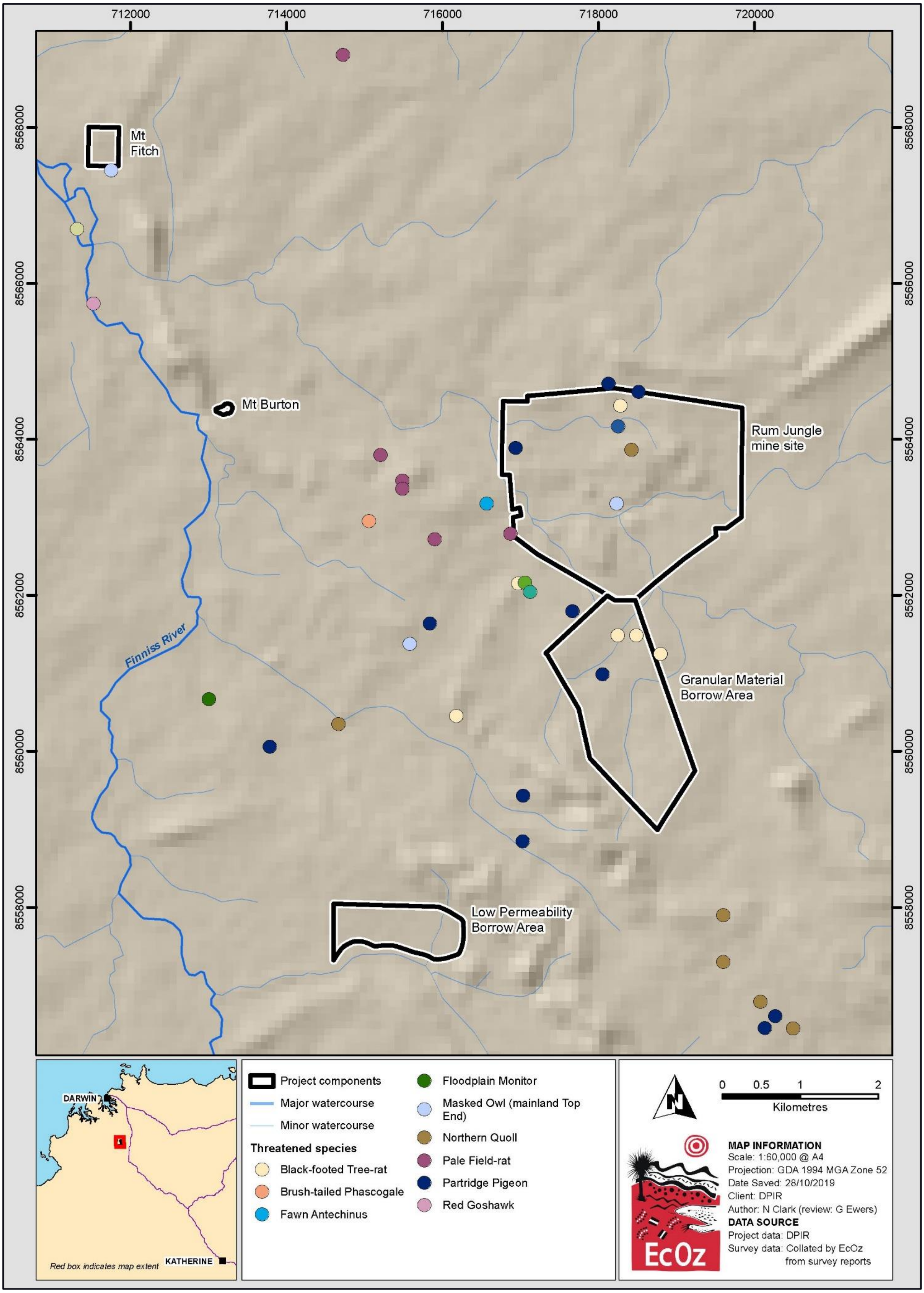

Figure 14-25: Historic threatened species records in the vicinity of the project footprint

14.2.1. Likelihood of Occurrence

Method

As detailed in the *Review of Terrestrial Ecology Surveys Relevant to the Rum Jungle EIS* (EcOz, 2019a – see Appendix), a list of 59 threatened species that have the potential to occur in the terrestrial ecosystems within the Pine Creek Bioregion was generated from desktop databases. For each of these species, the likelihood of it occurring within the project footprint was then assessed based on any desktop and field information relating to habitat requirements, distribution, and the number and dates of proximate records (including those from past surveys listed in earlier sections of this report). Likelihood ratings were defined as follows:

a) HIGH – it is expected that this species lives within the project footprint because there is core habitat and recent proximate records.

b) MEDIUM – this species may live within the project footprint because there is suitable habitat; however, there is evidence that lowers its likelihood of occurrence (known range contraction of the species in the region, no recent records with the search area, substantial loss of habitat within the project footprint since previous records, species is naturally-rare or occurs at a low density *etc*).

c) LOW – this species may occur, as a vagrant, within the project footprint; however, there is only marginally-suitable habitat.

d) NONE – there is strong evidence (no suitable habitat and/or the species is considered likely to be regionally-extinct) that this species will not occur within the project footprint.

A meeting was held with the Flora and Fauna Division, DENR, on the 1 August 2019 to ensure that these results aligned with the view of the Department.

Results

Five species were identified as having a high or medium likelihood of occurring within the project footprint:

- Darwin Cycad (*C. armstrongii*)
- Partridge Pigeon (eastern subspecies) (*Geophaps smithii smithii*)
- Black-footed Tree-rat (Kimberley and mainland NT subspecies) (*M. gouldii gouldii*)
- Masked Owl (mainland Top End subspecies) (*Tyto novaehollandiae kimberli*)
- Red Goshawk (*Erythrotriorchis radiatus*).

For the latter two species, however, the areas of the project footprint that will be directly disturbed by land clearing are unlikely to represent important habitat. Masked Owls and Red Goshawks forage across a broad range of Top End habitats, but have much more specific breeding and roosting habitat requirements. Within the project footprint, the habitat most likely to support breeding Masked Owls is forest containing large, hollow-bearing trees. This habitat type does not occur at Mt Fitch or Mt Burton, nor within the low permeability material or granular material borrow areas. The tallest and densest Eucalypt woodlands within the mine site are those mapped as unit 10, and predominantly occur in the north of the site – which will not be disturbed.

The Red Goshawk has a conspicuous nest which is typically built in large trees – frequently the tallest and most massive in a tall stand – and invariably within 1 km of permanent water (Aumann and Baker-Gabb, 1991). Vegetation mapping has not identified any tall forests within the project footprint that may provide nesting trees and no Red Goshawk nests have been observed in the surrounding areas. The riparian vegetation along the East, and particularly West, Branches of the Finniss River is very likely to represent suitable nesting habitat; however, these areas will not be disturbed by project activities.

Discussion

The Darwin Cycad, the eastern subspecies of Partridge Pigeon, and the Kimberley and mainland NT subspecies of Black-footed Tree-rat have a reasonable chance of occurring within the disturbance area. These species warrant further consideration within this chapter; all other species have a low likelihood of being present within the disturbance area and so are excluded from further assessment.

Notably, some species for which there are proximate historic records are no longer considered likely to occur. This is because environmental conditions have changed in such a way that the likelihood of these species being extant in the project footprint has been significantly reduced

Fawn Antechinus has been recorded four times within the mine site – twice in 2008 in *C. bella* open woodland in the central-north of the site, and twice in 2007 in *Eucalyptus* woodland in the centre-north of the site (GHD, 2009) – as well as several times to the west of the Browns Oxide site (pre-development) (EMS, 2005). The more recent small mammal surveys by Eco Logical (2014) and EcOz (2019) failed to record the species, despite having survey sites in the same habitat types proximate to the previous records. The limits of its range are poorly known but it is suggested that there has been a range contraction as recent surveys have failed to locate any individuals across central and east Arnhem Land (referenced in Woinarski *et al.*, 2014), where it was historically known to occur.

The **Northern Quoll** was recorded within the Browns Oxide site in 2002 and 2005 prior to its development (EMS, 2005) – the latter year being approximately when cane toads first arrived in the region. The species was also recorded within the mine site in 2007 and 2008 (GHD, 2009); however, it has not been recorded since. This species now has a very low likelihood of persisting within the project footprint. The mortality of Northern Quolls due to Cane Toad ingestion has been very high wherever these two species co-occur, and there are few post-Cane Toad records of Northern Quoll anywhere. More recent small mammal surveys across the extent of the mine site (Eco Logical, 2014) and in remnant vegetation that will be disturbed within the project footprint (EcOz, 2019) did not record the species.

The **Pale Field-rat** was recorded twice in the Browns Oxide Project prior to development (EMS, 2005) and numerous times within the Yarram site (Low Ecological Services, 2012). Low Ecological Services found that the species occurred in the tall *Mnesithea rottboellioides* grasslands and to a lesser extent, in the monsoon-vine thickets within the centre of the Yarram site, most likely due to its proximity to the grasslands. EMS trapped the species in *Melaleuca* woodland and recorded characteristic burrow systems throughout *E. tetrodonta*, *E. miniata* and *E. chlorostachys* open forest. The recent small mammal surveys mentioned above did not record the species.

Northern Brush-tailed Phascogale was recorded in 2002 when spotlighting within the Browns Oxide site (pre-development) (EMS, 2005). Although this species probably occurs naturally in low densities, it has only been recorded in Kakadu National Park, Coburg Peninsula and the Tiwi Islands throughout the last 10 years, despite many extensive general wildlife surveys across broad regions during that time (Woinarski *et al.*, 2014). There has likely been a significant recent decline in range and/or population size (Woinarski *et al.*, 2014). The recent small mammal surveys mentioned above did not record the species.

There are nine historic records for **Gouldian Finch** all assigned to a waypoint in the south-east corner of the Browns Oxide site (just to the south-west of the mine site). These range from 1897 to 1995, and each of them has within its metadata the note: *Gay Crowley / Riikka Hokkanen clean-up of Gouldian Records 2009*. When Gay Crowley was contacted by EcOz she could not recall the provenance of these records. It is suspected that these are regional records that were, at some stage, clumped together and given a generalised geo-reference of latitude -13º, longitude 130º. Despite being a conspicuous species, no surveys have recorded Gouldian Finch and there is no breeding habitat (wooded hills of Snappy/Salmon Gums) for this species present within the project footprint. It is possible that this species occurs, from time to time, within the project footprint, but there is a low likelihood that it is resident.

Floodplain Monitor was recorded by EMS in 2002 at a drainage area along Rum Jungle Creek (immediately west of Browns Oxide project area) but has not been observed in the region since. This species has undergone extensive declines due to Cane Toad ingestion, and there are few records of the monitor persisting where the two species co-occur (Doody *et al.*, 2009). The Floodplain Monitor now has a very low likelihood of persisting within the project footprint.

14.2.2. Assessment of Significance

The process for assessing the potential for the project to have a significant impact on NT and/or Commonwealth-listed threatened species is presented in Figure 14-26. The first step in assessing whether the project will have a significant impact on a threatened species known or likely to occur in the project footprint, is to determine whether it does so in an important population – as defined in *EPBC Significant Impact Guidelines 1.1* (DoE, 2013). This is because, in most circumstances, by definition, a project's activities can only have a significant impact on an 'important population' of a threatened species.

If an important population occurs or is likely to occur, the impact assessment must then consider whether, after mitigation and management, the project is likely to cause a significant impact on that population. This will inform decision-making as to whether approval should be granted and what, if any, conditions are required. It will also inform offset calculations for any matters protected under the EPBC Act.

In accordance with the guidelines, any occurrence of a Critically Endangered or Endangered species within the project footprint constitutes a population, and all populations are ‘important’. For threatened species that are listed as Vulnerable, an ‘important population’ is a population that is necessary for a species’ long-term survival and recovery. This may include populations identified in recovery plans and/or that are:

- Key source populations either for breeding or dispersal
- Populations that are necessary for maintaining genetic diversity
- Populations that are near the limit of the species’ range.

A ‘population of a species’ is defined under the EPBC Act as an occurrence of the species in a particular area – including (but not limited to):

- A geographically-distinct regional population, or collection of local populations, or
- A population, or collection of local populations, that occurs within a particular bioregion.

In each case, only ‘important populations’ are considered within this chapter to be of conservation significance. It is these that will be the primary focus of the significant impact assessment in Section 14.3.6. However, the mitigation and management measures presented in Section 14.3.6 that are designed to reduce impacts upon terrestrial biodiversity will also benefit all the threatened species present within the project footprint.

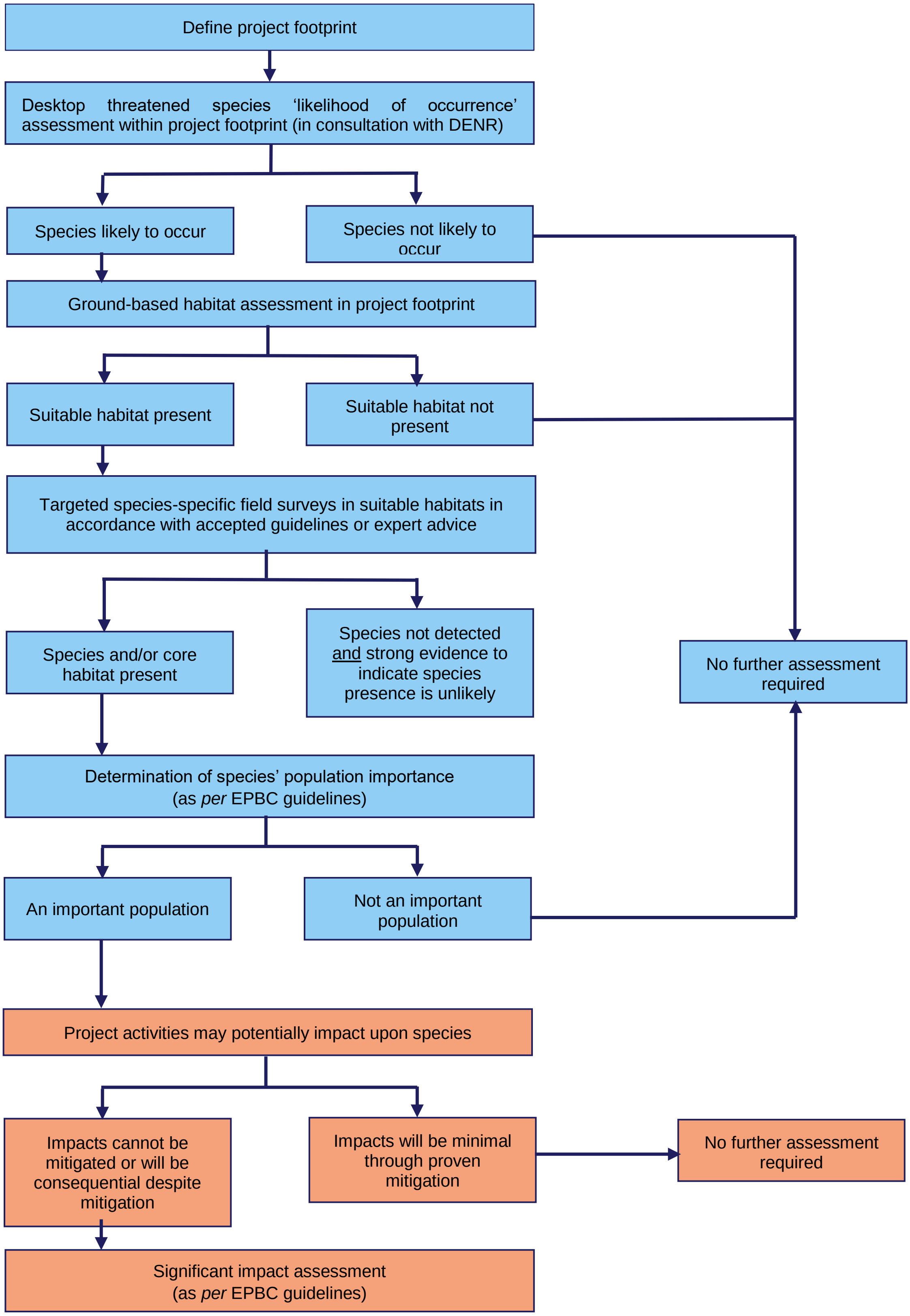

Figure 14-26: Flowchart of the threatened species' impact assessment process

Darwin Cycad

The Darwin Cycad (*C. armstrongii*) is the only threatened flora species recorded within the project footprint and its surrounds. The species is endemic to the NT and is widespread in the Darwin region, Tiwi Islands and Coburg Peninsula – extending south to the vicinity of the Adelaide River (Kerrigan *et al.*, 2006). The species is locally abundant within most of its range, yet qualifies as being Vulnerable due to a predicted reduction in population size because much of its habitat is threatened by development as part of the ongoing expansion of Darwin, and very little is included within conservation reserves (Kerrigan *et al.*, 2006). Mortality in the hotter, more intense fires that result when Darwin Cycad habitat is infested with introduced grass species such as Gamba Grass is also a key threat (Kerrigan *et al.*, 2006).

Flora surveys recorded Darwin Cycad as abundant in numerous locations across the region. It has been recorded within Rum Jungle (Eco Logical, 2014), Yarram (Low Ecological Services, 2012) and Browns Oxide (URS, 2010) mine sites, as well as the broader region (GHD, 2009; Metcalfe, 2002). It was predominately recorded in the mid and/or lower stratum of mixed *Eucalyptus* species woodland habitats (Metcalfe, 2002; Egan, 2005; Eco Logical, 2014) in more dry upland areas (GHD, 2009), but was also recorded in degraded *A. auriculiformis* and *E. chlorostachys* woodland (URS. 2010). GHD (2009) noted that the species was less common in sites showing signs of disturbance. Suitable woodland habitat within the project footprint is mapped at Figure 14-27.

As listed in Table 14-6, density estimates of cycads within and proximate to the project footprint ranged from 48 to 200 plants *per* ha (Eco Logical, 2014; Egan, 2005). Eco Logical (2014) reported that large differences in the density estimates were likely due to different woodland vegetation communities – there were 429 plants *per* ha encountered in the *E. tetrodonta, E. miniata* and *Eucalyptus phoenicea* open woodland, while there were none found in a neighbouring *E. tetrodonta* and *E. miniata* woodland. Eco Logical (2014) suggest that is perhaps a consequence of Gamba Grass infestations and the associated high intensity fire events. However, even the highest densities are considerably lower than those recorded at sites further north in the NT. Watkinson and Powell (1997) recorded densities ranging between 592 plants *per* ha at a site approximately 20 km north-west of Rum Jungle, to 1,056 plants *per* ha at a site in Humpty Doo. Therefore, even the highest densities within the project footprint would be considered low in a regional context.

Table 14-6: Darwin Cycad density estimates within and proximate to the project footprint

Consultant	**Location**	**Density estimate (plants *per* ha)**
Egan (2005)	Browns Oxide site	75 – 200
Eco Logical (2014)	Rum Jungle site (north)	135
	Rum Jungle site (south)	48
Eco Logical (2015)	North of Rum Jungle	48 – 178
	West of Rum Jungle	130
	Granular material borrow area	178

The Darwin Cycad is listed as Vulnerable under the TPWC Act but is not listed under the EPBC Act. Although there are recent records of the species within and proximate to the project footprint, these do not constitute a key source population nor one near the limit of the species' distribution. For these reasons, the occurrence of this species within the project footprint is not considered an 'important' population (as defined in *EPBC Significant Impact Guidelines 1.1*). The species is, however, a culturally-significant species, as discussed in Chapter 8 – Historic and Cultural Heritage. As discussed in Section 14.4.1, measures will be employed to minimise the impact of land clearing on this species.

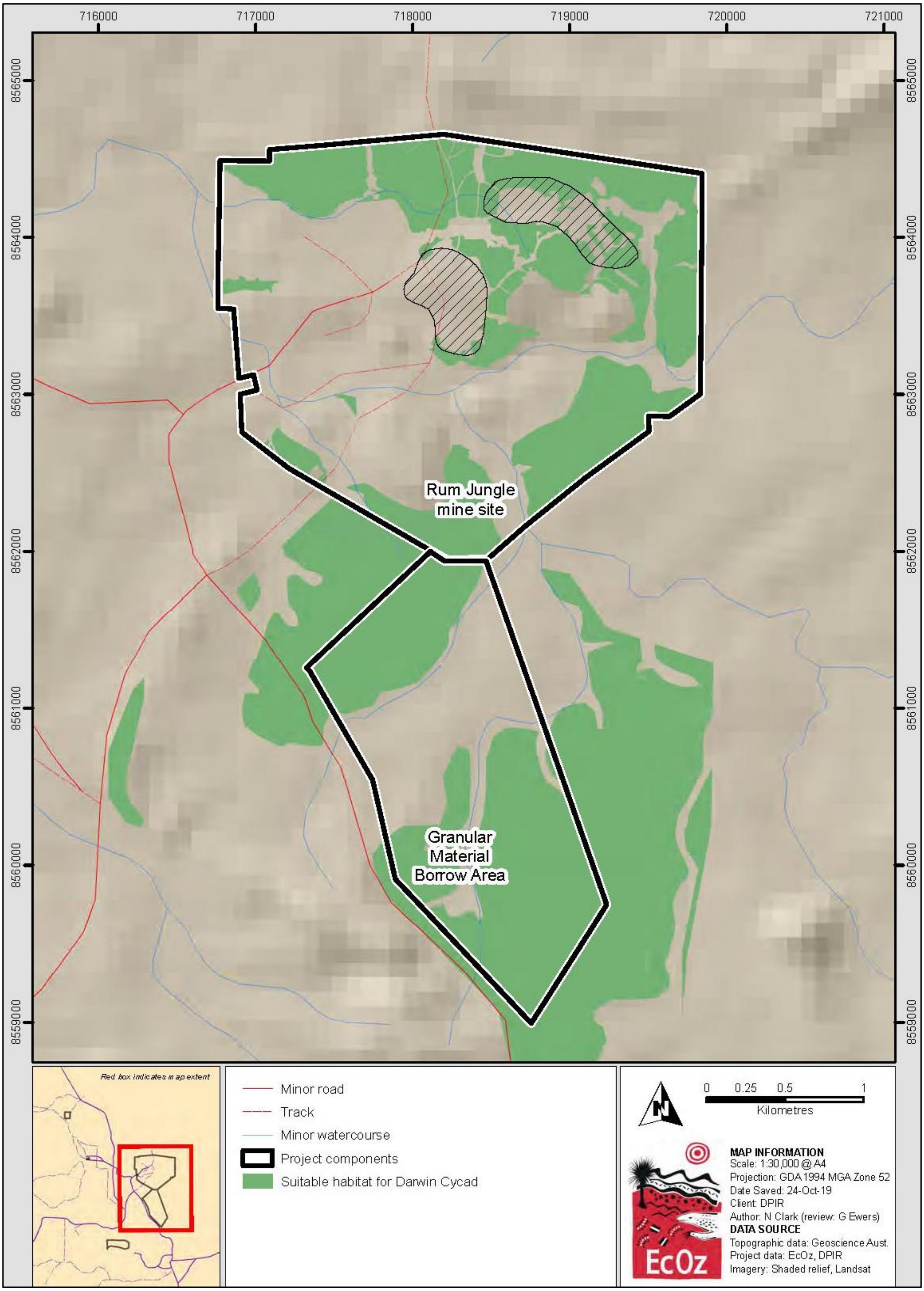

Figure 14-27: Suitable Darwin Cycad habitat within the project footprint

Partridge Pigeon

The eastern subspecies of Partridge Pigeon (*G. smithii smithii*) occurs across the Top End and the Kimberley; however, it has declined or disappeared from much of the lower rainfall parts of this range over the last century (Woinarski, 2006). The species is largely sedentary; however, individuals can travel distances of 5 to 10 km in the Wet season on search of food and water resources (Woinarski, 2006). Home ranges vary seasonally between 8 and 31 ha (Fraser, 2001). It is primarily found in open forest and woodland dominated by *E. tetrodonta and E. miniata* that has a structurally diverse understory (DEWHA, 2010). According to Fraser (2001), the Partridge Pigeon favours a structurally-patchy savanna understorey at a relatively intricate scale. In all seasons, the species prefers to feed in areas that have an open ground layer (*e.g.* following fire); however, it are more likely to nest at sites where there is high vegetation cover. These vegetated areas are also often used as roost sites and when retreating from disturbance.

The major threat to the Partridge Pigeon is change in fire regime to one where fires extend over large areas and the mosaic of fire ages is erased (Fraser *et al.*, 2003; Garnett *et al.*, 2011). Associated with larger, more intense fires is an increase in predation pressure by feral cats following the reduction in habitat cover (Woinarski, 2004). Furthermore, the species is threatened by the invasion of exotic pasture grasses, such as Gamba Grass (*A. gayanus*), which then provide greater fuel loads and promote large fires that further change the natural vegetation structure (Garnett *et al.*, 2011).

The project footprint lies within the core of the Partridge Pigeon's range and there are two confirmed recent records (2014) from just north of the mine site, as well as recent detection of Partridge Pigeon calls (2016) in the centre-north of the mine site. Standard surveys have recorded the Partridge Pigeon within or proximate to the project footprint (see Figure 14-25) – usually from incidental observations. The species has been recorded recently in woodland/open woodland near the northern boundary of Rum Jungle (EcOz, 2015; Eco Logical, 2014). The targeted survey by MCD (2016) resulted in no observations but two calls suspected to be from Partridge Pigeons were recorded in the centre-north of the mine site.

In 2019, EcOz recorded Partridge Pigeon twice at the same site in the granular material borrow area south of the mine site (see Figure 14-25) and a pair were also incidentally observed on a track about 1 km further south. Both areas were previously disturbed – the location of the incidental record heavily so, with the regenerated shrub layer dominated by Turkey Bush (*Calytrix exstipulata*) and proximate to a thick Gamba Grass infestation. Neither of these factors nor the high fire frequency of the region are optimal for Partridge Pigeons and thus the incidental sighting was somewhat unexpected. It is likely that Partridge Pigeons occur in the project footprint wherever there is remnant woodland with an understory of grasses that is not infested with Gamba Grass.

The Partridge Pigeon is listed as Vulnerable under both the TPWC Act and the EPBC Act. There is no evidence that Partridge Pigeons in the region constitute a key source population or one that is necessary for maintaining genetic diversity. Moreover, the project footprint is located well within the known distribution of this species, not at its limits. For these reasons, the occurrence of this species within the project footprint is not considered an ‘important’ population (as defined in *EPBC Significant Impact Guidelines 1.1*).

Black-footed Tree-rat

The Kimberley and mainland NT subspecies of Black-footed Tree-rat (*M. gouldii gouldii*) is a small nocturnal rodent that dens mostly in tree hollows and feeds primarily on fruits and seeds. It occurs mostly in woodlands and open forests with large trees, and a moderately diverse mid-storey in near-coastal areas.

Black-footed Tree-rats forage on the ground and in trees with an average home range in un-fragmented open forests of 67.3 ± 10.4 ha and in fragmented habitat of 27.1 ± 8.4 ha (Rankmore, 2006). The sub-species is predominantly frugivorous – preferring both fleshy and hard fruits and seeds – with Pandanus fruit a particular favourite (Friend and Calaby, 1995). The diet also includes some invertebrates, flowers and grass (Morton, 1992; Rankmore, 2006; Rankmore and Friend; 2008).

Being nocturnal, Black-footed Tree-rats prefer to nest in tree hollows during the day but have also been recorded nesting in Pandanus where hollows are limited (Pittman, 2003). The sub-species prefers open forests and woodlands dominated by *E. miniata* and *E. tetrodonta*, with a developed shrubby understorey (Friend and Taylor, 1985; Friend, 1987). A well-formed understory with large diameter trees is typical of a low frequency or intensity of fires; and frequent, intense fires may also be detrimental by reducing the abundance of hollow-bearing large trees (Price *et al.*, 2005).

Once found across the north of the Kimberley across to the coast of Gulf of Carpentaria, the range is now contracted to areas near Darwin, south to Litchfield National Park and around Kakadu National Park (Woinarski *et al.*, 2014). There has been only a single record of the subspecies occurring in the Kimberley since 1987 (DBCA, 2017). The Black-footed Tree-rat has undergone a marked decline in range and abundance with over 50% of the population estimated to have declined over the last decade. This decline has been linked to predation by Feral Cats and inappropriate fire regimes (Woinarski et al., 2014).

Black-footed Tree-rat was recorded by EcOz (2019) in the *Eucalyptus* woodland in the northern-centre of the mine site. In the same survey, the species was also recorded at three sites in the granular material borrow area south of the mine site and at a site along a rocky ridge between Litchfield Park Road and Rum Jungle Road – see Figure 14-25. All these areas contain remnant woodland that is not infested with Gamba Grass. It is likely that Black-footed Tree-rats occur in any such habitat within the project footprint. The regrowth on the previously-disturbed land within the granular material borrow area is a low open woodland with coloniser species such as Turkey Bush (*C. exstipulata*), Wattle (*Acacia oncinocarpa*) and Sand Palm (*Livistona humilis*) beneath a (low) overstorey of *E. phoenicea.* The paucity of food trees and hollows in that vegetation community suggest there is a low likelihood that Black-footed Tree-rats use it for foraging or roosting.

The Black-footed Tree-rat is listed as Endangered under the EPBC Act and Vulnerable under the TPWC Act. The occurrence of this Endangered species within the project footprint is considered an 'important' population. Potential impacts to the Black-footed Tree-rat are further discussed in Section 14.3.6.

14.2.3. Summary

The likelihood of threatened species occurring within each section of the project footprint and whether a population would be an *important population* (as defined in *EPBC Significant Impact Guidelines 1.1*) are summarised in Table 14-7.

Table 14-7: Summary assessment of significance of terrestrial threatened species within the project footprint

Species	**Status**		**Important population**	**Likelihood of occurrence**				
	Cth	NT		Mine site	Mt Burton and Mt Fitch	Granular material borrow area	Low permeability material borrow area	Finniss branches
Darwin Cycad	-	VU	No	High	Low	High	Low	Low
Partridge Pigeon	VU	VU	No	High	Low	High	Low	Low
Black-footed Tree-rat	EN	VU	Yes	High	Med	High	Low	High

14.3. Potential Impacts and Risks

The *Risk Register* (GHD, 2019f – see Appendix) identifies 26 potential impacts that project activities detailed in Chapter 2 – Proposal Description could have on the biodiversity values detailed above.

Some of these potential impacts were rated as being of Low inherent risk to biodiversity and therefore do not require specific mitigation measures. These are summarised and presented in Table 14-8 below for completeness but are not addressed any further in this EIS. Project activities will only occur during daylight hours therefore there are no potential impacts associated with night works. Impacts associated with loss of habitat or reduction in habitat quality, leading to a decrease in the diversity and/or abundance of species, rated as a Medium or High risk are discussed below. Risk to specific threatened species are addressed in Section 14.5.

Table 14-8: Potential impacts to biodiversity that have a Low inherent risk

Description of impact	Potential event
Terrestrial biodiversity	
Mortality of individual plants and animals due to…	Interactions with machinery and vehicles between sites and onsite during operations
	Interactions with machinery and vehicles servicing the project and during land clearing
	Inhabiting areas with high radiation levels
	Ongoing radionuclide exposure from dust emissions, contaminated water or remnant radioactive material
	Floodwaters causing loss of vegetation
Reduction in habitat quality due to…	The creation of an edge or barrier effect[7] because of vegetation clearing
	Noise and vibration from vehicles, mobile plant, excavation and material movements
	Habitat fragmentation[8] because of the construction of linear infrastructure (*e.g.* access tracks, haul roads *etc*)
	Floodwaters causing soil contamination

14.3.1. Impacts due to Land Clearing

The purpose of this project is to rehabilitate previously disturbed land. However, to achieve this, some remnant bushland will be cleared – primarily as part of the two WSF footprints, but also to access low permeability material and granular borrow materials. The borrow areas will prioritise clearing of previously-disturbed vegetation and should be able to limit disturbance of remnant bushland to approximately 5% of the total clearance area at each site.

Therefore, the maximum areas of remnant bushland that will be cleared – based on a 4 m cut approach at both borrow areas – are presented in Table 14-9. These are small areas and will be rehabilitated afterwards. As stages are completed disturbed areas will be revegetated with native species.

Table 14-9: Areas of remnant bushland that will be cleared

Note: Based on percentage of previously/heavily disturbed land in Chapter 2

Component of footprint	Area (ha)	Vegetation Unit
WSF	7.1	*E. tetradonta, E. miniata, E. clorostahys* woodland to open forest
Granular material borrow pits and haul road	2.0	*Eucalyptus* low open woodland
Low permeability material borrow area*	2.0**	*Corymbia* open woodland
Mt Fitch	-	
Mt Burton	-	

* *Highly impacted by Gamba* Grass infestation
**A small portion of what is within the total mapped potential footprint

Most of the cleared land is savanna woodland – the dominant vegetation type across northern Australia. The quality of the woodland that will be cleared varies; the low permeability material borrow area is heavily infested with Gamba Grass (and consequently transitioning to a grassland), the WSF areas have patches of Gamba Grass and is burnt almost annually, and the granular material borrow areas are mostly weed-free but are also burnt annually.

Because this project requires large amounts of borrow materials extracted from off-site sources, there is an inherent risk of net loss of biodiversity by disturbing borrow areas that are in good ecological condition to rehabilitate previously

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[7] Whereby because of the disturbance of intact vegetation, the newly-created edges between the intact and disturbed areas become lower quality habitat for species occurring in that vegetation – see, *e.g.*, Murcia (1995). This is often due to increased exposure to sunlight, wind, fire and/or weeds.

[8] Habitat fragmentation is the permanent process by which habitat loss results in the division of large, continuous habitats into smaller, more isolated remnants. These remnants are then subject to the complex processes of habitat degradation and island biogeography, leading to loss of species' diversity – initially locally, but ultimately at the landscape scale.

disturbed areas. This is not relevant to the low permeability material borrow area because of the very poor habitat quality present. Within the broader granular material borrow area there is intact woodland that could support two threatened species – Black-footed Tree-rat and Partridge Pigeon; however, as mentioned above, the borrow areas will prioritise clearing of previously disturbed vegetation and should be able to limit disturbance of remnant bushland to approximately 5% of the total clearance area at each site. The final land use of the borrow areas is yet to be determined; however the intention is that the granular material borrow area will be revegetated.

The disturbance of significant vegetation types – as defined in the *Land Clearing Guidelines* (DENR, 2019) – will be limited to that required to establish creek crossings for earthmoving access. No monsoon vine thicket will be cleared. There is a risk, however, that in removing the WRD at Mt Burton, the adjacent wet rainforest, which is currently sheltered by the WRD from fire, wind and weeds, will be exposed and experience an *edge effect*. That patch of rainforest is approximately 20 ha and in good condition. This risk is addressed in Chapter 7 – Rehabilitation Strategy.

To facilitate movement within the former mine site, very small areas of riparian vegetation that fringes the EBFR will be temporarily removed. Likewise within the granular material borrow area, the construction of a temporary haul road necessitates removal of small areas of riparian vegetation along the ephemeral watercourses bisecting that area.

Some areas of remnant woodland within the WSF disturbance footprint may contain hollow-bearing trees which are also considered a significant vegetation type. Vegetation mapping indicates that these are at low densities and only small areas of such habitat will be cleared.

14.3.2. Impacts due to Weeds

The proliferation of weeds on rehabilitated areas – to the detriment of revegetation success – and the introduction of weeds into adjacent remnant bushland during construction are the two greatest potential impacts that project activities could have on biodiversity values. Weed infestations in weed-free areas has the potential to displace native vegetation, reduce habitat quality, reduce food sources and shelter for fauna, and increase the frequency and intensity of bushfires. Furthermore, should rehabilitated areas – particularly the WSF – become infested with weeds, the stability of soil cover may be compromised, affecting the integrity of the rehabilitated landforms. Even if the structural integrity of rehabilitated sites is not affected, replacement of native flora (planted for revegetation) by weeds could revert the site to a landscape dominated by Gamba Grass, like it currently is, with low biodiversity values.

The species and abundances of weeds across the project footprint are detailed in Section 14.1.5. Most of the areas slated for land disturbance for this project are already subject to weed infestation – particularly by Gamba Grass. That species is able to form very dense thickets which dramatically alter the structure of native communities and decrease biodiversity (NT, 2018a). It also threatens native vegetation as it can rapidly grow bigger and taller than native grasses, and creates high fuel loads that promote late and intense fires – 11 tonnes *per* ha, compared to 3.6 tonnes *per* ha for native grasses (Setterfield *et al.*, 2013). Such fires are capable of killing most trees, even fire-tolerant Eucalypts. Mature trees that had been killed in fires were observed in woodland in the north-west corner of Rum Jungle (see photograph at Figure 14-15) where Gamba Grass densities are up to or greater than 50% (see Figure 14-18).

The clearing of native vegetation for the WSF and granular material borrow pits has the potential to facilitate the invasion of weeds – particularly Gamba Grass into relatively weed-free areas. Movement of personnel and vehicles throughout the project footprint – particularly along public roads – also has the potential to increase the likelihood of weed species being introduced into areas currently not infested.

14.3.3. Impacts due to Dust

The generation of dust at the project area could come from:

- Transportation of material along haul roads and access tracks
- Construction and excavation activities
- Wind erosion of exposed surfaces (*e.g.* pits, WRDs, laydown areas, stockpiles and roads).

Both plants and animals may be affected by the deposition and/or the inhalation of the dust. Dust may affect photosynthesis, respiration, transpiration and allow the penetration of phytotoxic gaseous pollutants on plants. Visible injury symptoms could occur, as well as decreased productivity. Because most of the plant communities can be affected by dust deposition, it is possible that community structure is altered. In the Top End, these effects are more pronounced in the Dry season when there is no rain to wash the dust from vegetation. However, as detailed in Chapter 9 – Terrestrial Environmental Quality, dust control is a standard and effective mitigation measures for this potential impact.

14.3.4. Impacts due to Bushfire

The threat of bushfire is ever present across the Top End in the Dry season. It is possible that project activities could create a bushfire. As mentioned in Section 14.1.3, the project area and surrounds is currently subject to annual burns; it also contains large areas of Gamba Grass, a species with a very high fuel load. There are also vegetation types within the project footprint that are especially sensitive and vulnerable to fire; namely riparian vegetation, monsoon vine thicket and rainforest. As detailed in Chapter 15 – Human Health and Safety and Chapter 7 – Rehabilitation Strategy, many measures will be put in place to; a) ensure there is a very low chance that project activities result in a bushfire and b) minimise the extent and severity of a fire if one does occur.

14.3.5. Impacts due to Groundwater Extraction

As detailed in Chapter 2- Proposal Description, one project activity is the extraction of groundwater from aquifers in the vicinity of the existing pits for remediation purposes. Additionally, it is required to partially draw down Intermediate Pit for the purpose of treated water storage. A potential consequence of these activities is reducing groundwater availability for GDEs, most pertinently the vine thicket to the north/east of Intermediate Pit. The location of the bores that will be used are to the south of the pits. Temporary drawdown of groundwater as a consequence of this activity has been modelled – see Chapter 10 – Inland Environmental Water Quality. The model indicates that the extraction rates will be too low to cause a substantial cone of depression. Drawdown in the vicinity of the vine ticket is unlikely to affect the vine thicket to the north of Intermediate Pit.

14.3.6. Threatened Species

There is a separate, prescribed process for determining whether a project is likely to have a significant impact upon any threatened species. As detailed in Section 14.2.2, a detailed and thorough assessment process led to the conclusion that only the presence of Black-footed Tree-rat (*M. gouldii gouldii*) within the project footprint constitutes an 'important population', as defined in the *EPBC Significant Impact Guidelines 1.1*.

The likelihood of the local population of Black-footed Tree-rat being significantly impacted by this project is assessed in Table 14-10 against the criteria contained within the abovementioned guidelines.

Table 14-10: Significant impact assessment for Black-footed Tree-rat

Note: The table below refers to 'inherent likelihood'. This is the likelihood that, in the absence of any mitigation measures, a significant impact for that particular criterion would occur.

Criterion	Inherent likelihood	Summary of mitigation measures and significant impact assessment	Residual likelihood
Lead to a long-term decrease in the size of the population	Low	One of the intended outcomes of this project is a net gain in the area of native bushland within the project footprint which could (if rehabilitation is successful) lead to a long-term increase in the local Black-footed Tree-rat population. Nevertheless, there remains the potential for a long-term decrease in the local population of Black-footed Tree-rat's occurring because of loss of habitat (if rehabilitation is unsuccessful) and/or mortality of individuals. Habitat loss is addressed in the next criterion and mortality is addressed below. The potential for mortality of individual Black-footed Tree-rat during land clearing and construction will be minimised by the small area of habitat that will be cleared (reducing the chance that a roosting individual will occur within the clearance footprint) and by the Vegetation Clearing Procedure – detailed in Section 14.4.1 – which includes employing a fauna spotter-catcher onsite during all vegetation clearing activities.	Low
Reduce the area of occupancy	Low	One of the intended outcomes of this project is a net gain in the area of native bushland within the project footprint which would increase the area of occupancy for Black-footed Tree-rats. Following rehabilitation, areas that are currently so disturbed as to not support the Black-footed Tree-rat should, assuming revegetation transitions successfully, become suitable foraging and, eventually, breeding habitat for the species. In 2019, the species was located at three disparate sites – all with different habitat characteristics – within the large survey area. This result, as well as those from other recent surveys for Black-footed Tree-rats at sites such as Middle Arm, suggest that the large areas of bushland to the north, east and south of the mine site and granular material borrow area represent suitable habitat for this species. During works, there will the unavoidable loss of 7.1 ha of potential Black-footed Tree-rat habitat in the WSF	Low

Criterion	Inherent likelihood	Summary of mitigation measures and significant impact assessment	Residual likelihood
		footprint and 2 ha in the granular material borrow area. Black-footed Tree-rats have a large home range (~67 ha) and are capable of travelling over 2 km in a night (Rankmore and Friend, 2008). Therefore a negligible percentage of existing habitat will be temporarily lost. The potential for reduced Black-footed Tree-rat habitat area and quality due to dust from construction activities will be minimised through the dust suppression measures outlined in Chapter 9 – Terrestrial Environmental Quality.	
Fragment the existing population	Low	The mine site is already a fragmented habitat and the small area of remnant bushland that will be temporarily lost for the WSF is unlikely to further fragment the population that persists in that area, given that most of the WSF footprint will be centred on previously disturbed land. The granular material borrow area is more intact; however the small patches that will be temporarily cleared for borrow pits and the dirt road that will be temporarily installed to connect these areas to the mine site, would not be expected to fragment such a mobile species as the Black-footed Tree-rat.	Low
Disrupt the breeding cycle of a population	Low	The Black-footed Tree-rat is thought to live for approximately 3-5 years, and reach reproductive maturity at about 3 months (Woinarksi *et al.*, 2014). Breeding may occur throughout the year but studied populations peaked in August-September (Rankmore, 2006). It is therefore possible that land clearing of a patch of remnant bushland coincides with the breeding of a pair of Black-footed Tree-rat for one season. If so, that could disrupt that pair's breeding success for that particular year. However, that pair may relocate to another site and successfully breed that year or in future years. As such, the worst-case scenario is a pair not being able to breed in one season. This does not constitute a disruption to the breeding cycle <u>of a local population</u>.	Low
Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent the species is likely to decline	Low	As mentioned above, an intended outcome of this project is a net improvement in the amount and quality of Black-footed Tree-rat habitat within the project footprint. Assuming revegetation transitions successfully, this bushland should, over the following decade, become suitable foraging and, eventually, breeding habitat for the species. Some Black-footed Tree-rat habitat within the project footprint will be temporarily cleared during works. This table presents a number of arguments as to why that area of clearing is not large enough to affect this species to such an extent that it is likely to decline.	Low
Adversely affect critical habitat	Low	Critical habitat for the Black-footed Tree-rat is a mosaic of different vegetation types that offer food resources across the seasons and provide secure roosting sites. Given the species has a large home range, those resources do not have to all occur within a small area. At Rum Jungle, because of the very high fire frequency, it is likely that riparian vegetation is critical habitat because it provides a haven and food source, during and after burns. The area of riparian vegetation in proximity to the Black-footed Tree-rat records for this site that will be disturbed is negligible – a fraction of a ha *per* home range area. The small areas of this species' habitat that will be disturbed represent one of the most abundant vegetation types that occur in the region. Critical habitat for this species will not be adversely affected.	Low
Result in invasive species, that are harmful to the species, becoming established in the species' habitat	High	Predation by Feral Cats is considered a plausible, but not demonstrated, threat to Black-footed Tree-rat (DoE, 2015). Surveys indicate that Feral Cats are already present within the project site. The inherent risk of a significant increase in this species because of project activities is minimal. As such, no specific mitigation measures are proposed for this development Weeds are also considered a plausible, but not demonstrated, threat to Black-footed Tree-rat (DoE, 2015). Invasive grasses – especially dense stands of Gamba Grass – change the ability of this species to forage effectively on the ground and result in fires that are far more intense and destructive of Black-footed Tree-rat habitat. As discussed in Section 14.3.2, the management of weeds is considered a critical factor influencing the success of this project. The weed management strategy presented in Section 14.4.2 is designed to minimise the proliferation of Gamba Grass within the granular material borrow area and surrounds.	Low

Criterion	Inherent likelihood	Summary of mitigation measures and significant impact assessment	Residual likelihood
		Successful implementation of this plan, and post-works weed control, is critical to minimising this potential impact to the species.	
Introduce disease that may cause the species to decline	Low	Disease is not listed as a threatening process for Black-footed Tree- rat. DPIR are not aware of any literature on diseases that could be introduced by the project and that would detrimentally affect this species.	Low
Interfere with the recovery of a species	Low	The Conservation Advice (DoE, 2015) provided to support this species' nomination for federal listing as an Endangered species is considered to provide sufficient direction to implement priority actions and militate against key threats. That document contains a large number of conservation and management actions, none of which will be interfered with by this development. In fact – as discussed in previous sections above – the rehabilitation and management actions should reduce fire frequency and intensity, constrain invasive grasses, and increase habitat patch integrity and connectivity.	Low

For most criteria, the inherent risk is Low. In the bushland there are very large areas of suitable habitat available to support the local Black-footed Tree-rat population. A negligible proportion of this habitat will be disturbed (temporarily) during construction works. A few individuals may be impacted upon directly or indirectly during construction activities or all individuals that were potentially impacted upon may temporarily relocate to adjacent suitable habitat. None of these consequences constitute a significant impact to this species and no offsets are required.

However, Black-footed Tree-rats seldom occur in areas infested with Gamba Grass and so, in the absence of weed management measures, there is an inherently High risk that Black-footed Tree-rat habitat could be lost to Gamba Grass invasion. It is therefore imperative that Gamba Grass management is successful to avoid a significant impact to Black-footed Tree-rats.

Assuming weed management and rehabilitation is effective in reintroducing native species, the project could be of net benefit to this species and other threatened species such as Partridge Pigeon and Darwin Cycad.

14.4. Mitigation and Management

This section focusses on mitigation measures that are specifically designed to minimise impacts to biodiversity values. The mitigation measures for potential impacts that may affect multiple environmental factors are detailed elsewhere in this EIS, namely:

- Dust deposition in Chapter 9 – Terrestrial Environmental Quality
- Groundwater extraction in Chapter 11 – Hydrological Processes
- Bushfire response in Chapter 15 – Human Health and Safety.

14.4.1. Vegetation Clearing

Potential impacts on flora and fauna because of land clearing have been minimised through project design and will be mitigated during clearing activities.

Vegetation buffers

The *Land Clearing Guidelines* (DENR, 2019) recommend a buffer around significant vegetation types to minimise the impact on them from development. Some areas requiring rehabilitation are adjacent to significant vegetation types – *e.g.* the vine thicket and riparian vegetation within the mine site, and the rainforest at Mt Burton – and so buffers cannot be applied without severely compromising rehabilitation outcomes. Within the granular material borrow area, however, first-order drainage lines are buffered by 25 m, as shown in Figure 14-28.

The third-order Meneling Creek is buffered from activities at the low permeability material borrow area by 100 m.

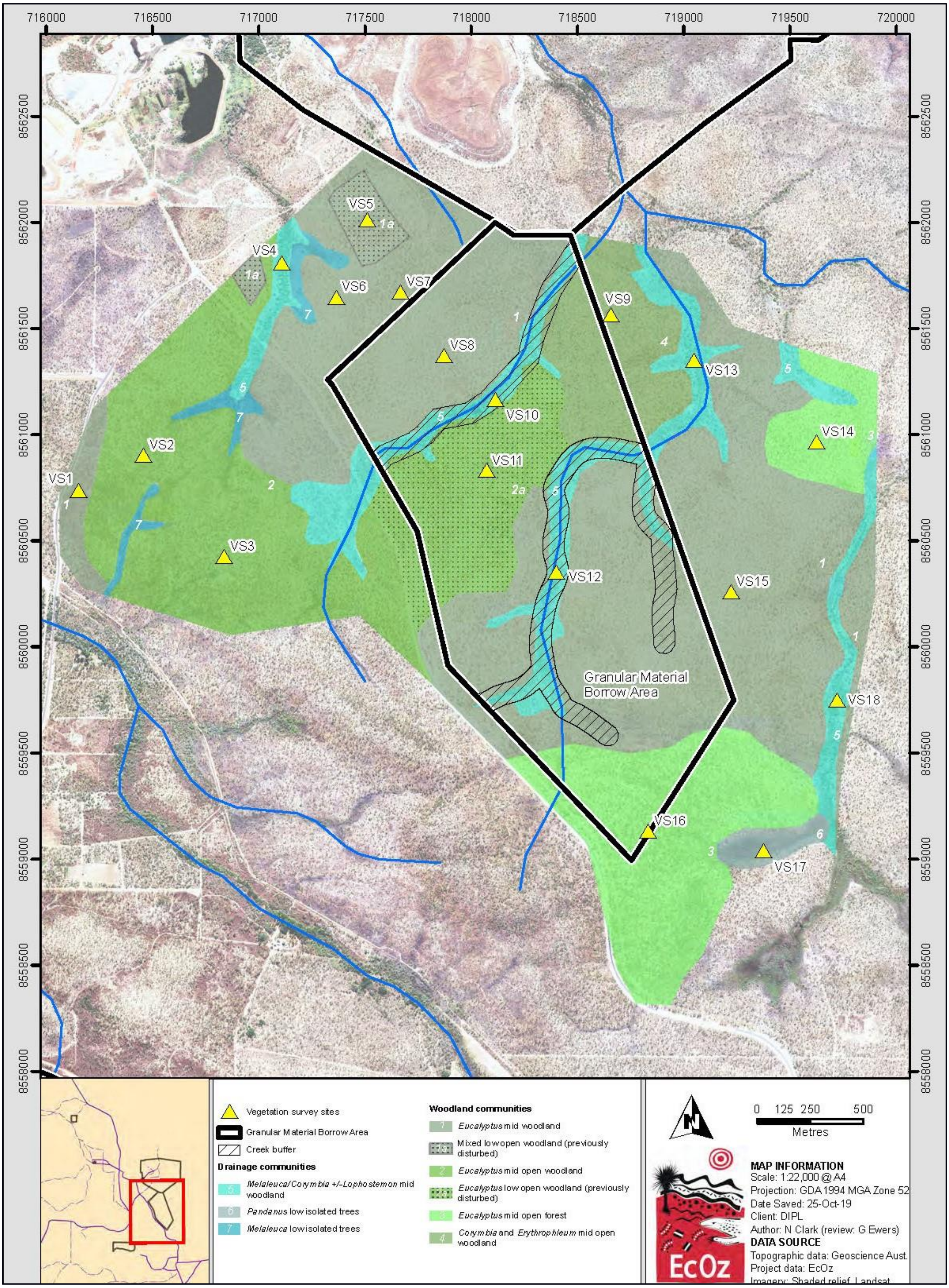

Figure 14-28: Buffers within the granular material borrow area

Vegetation Clearing Procedure

A Vegetation Clearing Procedure will be developed to detail the process involved in the removal of vegetation in preparation for works, including guidance to a fauna spotter-catcher (FSC) to minimise the risk of injury or death to fauna during vegetation clearing activities. The procedure will contain measures that ensure that clearing is only undertaken within clearly designated areas and in accordance with the schedule. The procedure will be followed in conjunction with the Cycad Salvaging Procedure discussed below.

The FSC will:

- Identify and assess potential habitat prior to any clearing works onsite.
- Undertake pre-clearing surveys, including habitat tree identification.
- Determine with project engineers if habitat trees at WSF toe areas and within borrows can be worked around and left in place. There is flexibility in design and construction and this adjustment should be the first preference.
- Assess the suitability of habitat within the project area for the relocation of fauna.
- Ensure the supervisor of clearing activities is made aware of the location of significant habitat features – including trees with hollows, active nests, burrows, hollow ground logs, potential dens and debris piles.
- Ensure that hollow-bearing trees will be left overnight to allow fauna to self-relocate prior to felling. Where possible, prior to felling, the FSC will inspect hollows with a torch or burrow scope and remove fauna. Otherwise, where possible, hollow-bearing trees should be gently lowered to the ground or moved to one side with an excavator using a grab attachment for inspection by the FSC. That hollow tree will then be immediately relocated to a nominated restoration area.
- Inspect cleared areas immediately afterwards to locate and capture any wildlife affected by clearing.
- Assess the health of captured wildlife and determine appropriate action – *i.e.* relocate, euthanise or prepare a voucher specimen.

Initial clearing will only be done using the ‘raised blade’ technique so that the vegetation layer is removed and the FSC can see any fauna in the area. Cleared vegetation will be pushed into windrows for use in rehabilitation works. In instances where windrow piles present an obstacle to fauna, breaks will be periodically left between piles to allow fauna passage. Moreover, as cleared vegetation that is left in windrows for more extended periods can become potential refuge habitat for fauna affected by clearing operations, a FSC will be present for when this vegetation is disturbed.

If any threatened fauna or flora species are observed within the project area, the FSC will mark the location with a GPS and immediately contact the Environment Manager. That person will notify DENR and, with that Department’s advice, review existing management measures to determine whether any additional actions or controls are required. Construction activities will not continue in the area until this process has been followed.

Cycad Salvaging Procedure

The translocation of Darwin Cycads is routinely undertaken for developments in the greater Darwin region. The NT *Management Plan for Cycads* (Liddle, 2009) states in Section 3.3 that:

> *Areas where cycads are likely to be destroyed in the pursuit of other legitimate purposes such as construction of roads or fire breaks or under a clearing permit, will be eligible for the issue of permits for utilisation by salvage… All permits for the removal of cycads will include the condition that all plants must be labelled with a Parks and Wildlife Commission approved tag prior to removal from the salvage site.*

Translocation of cycads has a good chance of success provided it is done correctly. There are cycad species threatened under Commonwealth legislation that are regularly translocated if disturbance cannot be avoided. According to Forster (2004):

> *If the translocation is based on good landscape horticultural practises, it should have a high rate of success when care and a sensible methodology are followed.*

Because Darwin Cycads are a threatened species, and because of their significance to the Traditional Owners, the granular material pits and WSF have been located such as to minimise the number of cycads that will be disturbed by project activities. Ecologists surveyed for cycads ~100 m either side of the proposed WSF boundaries (because the area had recently been burnt, re-sprouting cycads were highly visible). The boundaries were then re-designed to avoid as many cycads as possible.

Nevertheless, multi-stem cycads will be salvaged prior to works and replanted in a rehabilitated area that has stabilised soil and weeds controlled.

Prior to land clearing within the WSF sites and the granular material borrow area, identified Traditional Owners for whom the species has cultural significance will survey the area to be disturbed and flag any significant plants. Those plants will then be extracted using the following Cycad Salvaging Procedure adapted from Forster (2004):

1. Mark each plant on one side with marker paint or fluorescent dye to ensure that the plants are replanted with a north-south orientation similar to their original one.
2. Assign an identification number to the plant, and attach a filled-out Parks and Wildlife Commission approved tag.
3. Clean around individuals by hand or with machinery.
4. Trim excess or badly damaged foliage back to where the rachis is attached to the stems.
5. Spray trunks and foliage with an anti-transpirant.
6. Loosen soil around each individual using a trenching pattern (either by hand, or ideally with an excavator, backhoe or chain digger).
7. Remove each individual whilst attempting to maintain a root ball of soil (ideally this should be done by hand (small plants) or with an excavator or backhoe bucket).
8. Trim damaged roots with secateurs, apply fungicide powder.
9. Wrap and secure root ball and roots with dry hessian sacking.
10. Transport to new locality, taking care to avoid bruising of plant stems. Heavy plants should be loaded using a soft sling that is slung on a backhoe or excavator bucket and packed using rolls of hessian sacking or similar.

The replanting process will be:

1. Dig holes at the translocation locality by hand or with an excavator or back hoe. The soil should be loosened and the hole should not be much deeper than the root ball of the plants being transplanted.
2. Position plants in new hole, remove hessian sacking and trim any further damaged roots. Ensure that the north-south orientation from the old locality is maintained.
3. Pack washed river sand around the roots and root ball. This will provide a suitable substrate for new roots.
4. Backfill with the original topsoil removed from the hole.
5. Spray the trunks and foliage a second time with anti-transpirant.
6. Water thoroughly around each with ordinary water.
7. Water (5-9 L) around each root ball with a systemic fungicide.
8. Water each plant about once a month (10-20 L) depending on rainfall for the next six months or as appropriate.
9. When plants show sign of growth, water and spray thoroughly with a systemic insecticide to avert insect attack. These systemic insecticides should be applied at a high concentration.
10. Monitor plants for new growth, death, insect attack, reproduction, gender *etc* (see Section 14.4.1).

Although clearing and revegetation will be undertaken progressively, during the first year of works there may not be rehabilitated sites available for translocation. Any cycads removed will be translocated to a suitable bushland location chosen by Traditional Owners.

14.4.2. Weed Management

Context

Under the Weeds Management Act, landowners and occupiers are required to control the growth and spread of declared weeds. It is also an offence under the Act to move or transport any declared weed on a public road by itself or as a contaminant (*i.e.* in soil/cleared vegetation). Two of the weeds recorded within the project footprint have statutory management plans under the Act – Gamba Grass and Mimosa. Under the *Weed Management Plan for Gamba Grass* (WMB, 2018a), the project footprint is best categorised as a Part 6 – Class B zone (area greater than 20 ha). The requirements of landowners and occupiers for that category are presented in Table 14-11.

Table 14-11: Gamba Grass management requirements for Part 6 – Class B zone (> 20 ha)

All land owners and occupiers with Gamba Grass on their land of parcels this size must:	
6.1	Establish and maintain by chemical, mechanical or physical means, a Gamba Grass free buffer zone on all land parcels > 20 - 200 hectares, that is a distance of 15 m in width around property boundaries, infrastructure, flammable materials and along tracks and roads, within one year of commencement of this plan.
6.2	Establish and maintain by chemical, mechanical or physical means, a Gamba Grass free buffer zone on all land parcels > 200 hectares, that is a distance of minimum 15 m in width along existing firebreaks, river corridors, infrastructure such as roads and tracks and fence lines or other natural land formations to prevent spread into clean areas or into neighbouring land within five years of commencement of this plan.
6.3	For properties > 200 hectares, develop a Property Weed Management Plan as per the "Planning for better weed management" guide and identify buffer zones in the property plan. Submit to the Weed Management Branch upon request.
6.4	Actively control, contain and reduce all Gamba Grass infestations by minimum 50% of infestation size on land parcels > 20 - 200 hectares within five years of commencement of this plan and demonstrably reduce infestations over the life of this plan (for properties not utilising Gamba Grass as a pasture).
6.5	Relevant to pastoral activities only.
6.6	Relevant to pastoral activities only.
6.7	For development/construction areas: design and implement a weed spread prevention program including quarantine and/or hygiene procedures, which will ensure no new infestations establish as a result of the development process/activities, or off-property.
6.8	Control Gamba Grass in areas scheduled for construction works prior to flowering. No earthworks to occur through seeding Gamba Grass.
6.9	Not allow Gamba Grass to establish on soil stockpiles.
6.10	Not use Gamba Grass contaminated soil stockpiles as clean fill or topsoil.
6.11	Not cut Gamba Grass for the purpose of use as fodder or mulch for sale.

There is also a *Weed Management Plan for Mimosa* (WMB, 2018b) under which the project footprint is categorised as a Part 2– Class B zone. The requirements of landowners and occupiers for that category are presented in Table 14-11.

Table 14-12: Mimosa management requirements for Part 2 – Class B zone

All land owners and occupiers with Mimosa on their land in this zone must:	
2.1	Destroy all outlier Mimosa plants and infestations as a priority.
2.2	Control, contain and demonstrably reduce all Mimosa infestations within ten years of commencement of this plan.
2.3	Prevent Mimosa spreading into clean areas or adjoining land.
2.4	Minimise seed production by controlling Mimosa prior to flowering and seeding.
2.5	Monitor areas under active control for new infestations and control annually.
2.6	Commence annual control of all Mimosa within 80m of all boundaries and within 1 km upstream of a wetland within ten years over the life of this plan.
2.7	For all lots located in Zone T (Township) or Rural Activity Centres (Darwin, Coolalinga and Palmerston municipal boundaries), including all urban and peri-urban developments (residential and industrial): Control any Mimosa plants annually.
2.8	For properties >200 ha: Develop a property weed management plan which identifies buffer zones as priority control areas and areas for containment and submit to the Weed Management Branch upon request.
2.10	For development and construction areas: Control Mimosa in areas scheduled for construction works prior to flowering and seeding and before any works commence.
2.11	For development and construction areas: Dispose of weed contaminated topsoils by deep burial on site. Weed contaminated soil must be buried greater than 1 m deep under construction material (including roads and buildings) or in areas that will not be exposed in the future. No material is to be transported off site.
2.12	Not use Mimosa contaminated soil as clean fill or topsoil.
2.13	Notify the Weed Management Branch of the presence of Mimosa within 14 days when identified in areas which it has not been observed previously.

The project footprint falls within the *Darwin Regional Weed Management Plan 2015-2020* (DLRM, 2015). That plans presents three regional weed management priorities:

1. Priority weeds, of which Gamba Grass, Mimosa, Olive Hymenachne, Mission Grass and Grader Grass have been recorded in the project footprint.
2. Priority landscapes, of which sites with no/low incursions of weeds is the most relevant to this project
3. Priority pathways of spread, the most relevant of which are mining areas and river corridors.

As discussed in Section 14.1.5, the proliferation of Gamba Grass is arguably the most serious environmental problem in the region.

Objectives

In light of the management plans discussed above, and after discussions with the Flora and Fauna Branch, and the Weed Management Branch of DENR, it has been decided that weed management for this project will have two primary focuses:

1. Controlling weed species that present the highest risk to rehabilitation success
2. Maintaining areas within or adjacent to the project footprint that currently have low/no weed infestations.

The key species of concern is Gamba Grass (which is widespread and prolific both regionally and within much of the project footprint, and has the capacity to completely alter the ecological landscape). The other species of most concern are Olive Hymenachne (an aquatic weed discussed in Chapter 12 – Aquatic Ecosystems) and Mimosa (which, fortunately, only occurs in small patches within the project footprint). Those species are also the three WoNS recorded within the project footprint.

Relevant sites within the project footprint that are relatively weed-free are:

- Areas within the granular material borrow area away from watercourses and historically-disturbed sites
- Remnant bushland surrounding the WSF
- The verges of public roads between the low permeability material borrow area and the mine site
- The rainforest at Mt Burton.

It is also imperative that, during works, there is no proliferation of weeds on rehabilitated sites. Such an event could severely curtail the stability of surface cover at those sites and even impact upon the integrity of the WSF.

Control methods

Control of small infestations of Mimosa – such as are present within the Rum Jungle and Mt Fitch sites – is best undertaken through chemical control. Chemical control is also the best approach for the localised occurrences of Gamba Grass present within the Mt Burton site and the granular material borrow areas. The Weed Management Handbook (WMB, 2018c) details the optimum chemicals, concentrations, rates and timing for these species.

For controlling the widespread infestations of Gamba Grass present within much of the Rum Jungle site and the granular material borrow areas, the Gamba Grass residual herbicide treatment trial undertaken by the Research Institute for Environment and Livelihoods (RIEL) at Charles Darwin University within Rum Jungle in 2016 provides some direction (Luck *et al.*, 2019). Gamba Grass produces large quantities of seeds, but these seeds rapidly lose viability after 12 months (Bebawi *et al.*, 2018). However sufficient seed stock can persist in soil for up to two years, allowing re-establishment of the species (Setterfield *et al.*, 2004) and thwarting management efforts. Luck *et al.* (2019) noticed that the current management plan for Gamba Grass does not address this aspect of the problem and undertook herbicide trials targeting the Gamba Grass soil seed bank. The trial found that applying certain herbicides to the soil at a site recently cleared of Gamba Grass plants resulted in a 90% reduction in re-growth density compared with untreated sites. Notably, the survivorship of tube stock Acacias planted in the soil approximately three months later was not compromised by the prior application of herbicides. However, it is probable that any seed banks of other species within the treated soil were affected by the herbicides.

It is understood that the Weed Management Branch are also undertaking trials with the aim of improving Gamba Grass control, particularly in relation to increasing uptake of herbicides by the species.

Control strategy

Mindful of the requirements of the abovementioned statutory plans, the recommendations within the Weed Management Handbook and the findings of the residual herbicide trial, the following weed management approach is proposed. It is recommended that this strategy is further refined in collaboration with the Weed Management Branch and RIEL.

Pre-construction

- Create and maintain a 15 m wide weed buffer around the perimeter of the mine site land parcel. This may be through a combination of a graded firebreak along the fence line with topical weed control in adjacent bushland.
- Aerial spray existing Gamba Grass infestations on previously disturbed areas within the mine site for two years prior to works commencing. For any areas that will be disturbed in later years, maintain annual aerial spraying until they are disturbed. The best month for such treatment is April/May (*i.e.* prior to seed fall). This approach should kill the seed bank prior to works. Because the areas to be disturbed are essentially Gamba Grass monocultures, carefully undertaken aerial spraying should not significantly impact on native flora.
- Aerial spray the low permeability material borrow area in April/May. Once dead, burn the Gamba Grass and remove the topsoil into piles. Apply residual herbicide to the stockpiles as *per* Luck *et al.* (2018) around October/November. Keep soil in stockpiles with gaps between them to allow for follow-up spraying if required. This is to reduce the likelihood of bringing contaminated soil into the mine site.
- Undertake topical spraying in April/May of occurrences of Gamba Grass within the sections of the granular material borrow area that will be disturbed (with a ~50 m buffer). This is to reduce the likelihood of bringing contaminated soil into the mine site or spreading Gamba Grass into surrounding bushland.

Construction

- Require all machinery upon first arrival to present a declaration that they are weed-free.
- After topsoil has been stripped, quarantine the topsoil stockpiles from all machinery except that used to re-apply the soil for rehabilitation purposes (noting below that the stockpiles will be treated for weeds).
- The stripped surfaces will be, by nature, weed-free and so no weed hygiene measures are required for machinery working them.
- Establish in each quarantine area, a weed hygiene facility for cleaning all machinery used in that area prior to that machinery leaving that area. If that area is dry, weed hygiene will be in the form of blow-downs and the use of brooms and other tools to remove soil and seeds. In the event of wet weather, or where vehicles and machinery are wet, wash-downs will be used.
- No soil can be moved from a quarantine area unless it is fill that will be buried or material accompanied by a form declaring it to be weed-free. If it is the former, the material will be carried in covered trucks if it is being moved between project sites (e.g. from the low permeability material borrow area to the mine site).
- Apply residual herbicide to any soil stockpiles within the mine site as per Luck et al. (2018) around October/November, prior to placement on rehabilitated areas or the WSF. This is to reduce the likelihood of placing contaminated soil into these areas. It is important to choose herbicide that does not persist in the soil for too long and thereby reduce native flora seeding as part of the revegetation program.
- At the mine site, ground spray Gamba Grass within surrounding bushland that is adjacent to areas that will be disturbed the following year or adjacent to areas that have had topsoil reapplied. This is to occur in April/May for the purpose of creating a buffer to minimise spread of Gamba Grass from undisturbed areas into newly disturbed/rehabilitated areas.
- Undertake topical spraying of Gamba Grass on rehabilitated sites in April/May where needed.
- Avoid movement of soil/material that contains visible Gamba Grass.

Post-construction

- Undertake topical spraying of Gamba Grass on rehabilitated sites in April/May where needed.
- Undertake topical spraying of Gamba Grass in April/May within surrounding bushland at the mine site and granular material borrow area to maintain a buffer from surrounding infestations.

Aside from weed hygiene measures for vehicles and equipment, no weed management is proposed for Mt Fitch because of its small area and its location within a pastoral property that already has many weed issues.

Post-construction weed management actions for the borrow areas will be developed once the post-works land uses have been determined.

Supplementary actions

There are many other weed species present within the project footprint that under the Weeds Management Act the land owner/occupier is required to control. If the abovementioned strategy for controlling Gamba Grass is successful, there remains the risk that other weed species such as Hyptis and Mission Grass will invade. The ability of many of these species to invade should be reduced by the aerial spraying of Gamba Grass because the herbicides likely to be used also control many other grass and herb weeds. Nevertheless, topical spraying of local infestations of other weeds species will likely be required throughout the project, as guided by the Weed Management Handbook.

14.5. Monitoring and Reporting

This section provides an overview of the monitoring and reporting that will be undertaken to ensure that management actions are effective or else ensure a prompt review of them and corrective action.

14.5.1. Vegetation Clearing

For each clearing event, the FSC will prepare a:

- Pre-clearance Report documenting:
  - Vegetation type
  - Habitat features requiring special attention during clearing
  - Suitable fauna relocation sites
  - Clearing plan to establish access for processing hollow-bearing trees
- Post-clearance Report documenting:
  - Area cleared
  - Number and species of fauna relocated or deceased
  - Locations in which release occurred
  - Any recommendations for future clearing events.

To monitor the salvaging of cycads, a database will be maintained detailing when and where each was removed, potted and replaced. The health of reinstated plants will be monitored periodically.

14.5.2. Weeds

Weed monitoring will be undertaken during both the Construction and Post-construction phase of this project. A Construction Weed Monitoring Plan will be developed based on the following:

- As soon as possible prior to construction works, a baseline weed survey will be undertaken of:
  - The haul route between the low permeability material borrow area and the mine site
  - The proposed granular material borrow pit/s and surrounding bushland
  - The weed hygiene station sites and immediate surrounds
  - The proposed haul route between the granular material borrow pits and the mine site.

  The data from this survey will be the benchmark against which the success of weed management in these areas of the project footprint is measured.
- During construction monitoring will focus on:
  - The haul route between the low permeability material borrow area and the mine site
  - The granular material borrow pit/s and surrounding bushland
  - The weed hygiene station sites and immediate surrounds
  - The haul route between the granular material borrow pits and the mine site
  - Areas within the project footprint that have been subject to weed control the previous year.

- Topsoil stockpiles will be inspected for weeds prior to placement on rehabilitated areas.
- Monitoring will occur in February, which is early enough for weeds to be identifiable and controlled (potentially simultaneously).
- A database will be developed to record all weed monitoring and control events.

The Stabilisation and Monitoring Phase Plan will include weed monitoring of all land that was disturbed by project activities.

For both stages of the project, the monitoring results will be used to trigger and inform any corrective actions that are required. Such actions will likely be a combination of responsive control of new infestations/re-infestations and a review of the adequacy of the existing weed hygiene and control regime.

14.6. Statement of Residual Impact

The project footprint is predominantly a highly disturbed landscape because of historical mining activity and/or infestation by Gamba Grass. This has had a negative impact on the terrestrial flora and fauna values of the footprint and surrounds. The goal of the project is to rehabilitate previously disturbed land in such a way that environmental values and habitat condition are significantly improved. If successful, the result should be net increase in terrestrial flora and fauna values – namely improved vegetation health and habitat condition, reduced landscape fragmentation and increased fauna diversity and abundance.

However, before the situation improves, works need to be undertaken that carry with them the potential to have a negative impact on terrestrial flora and fauna values. Because of the nature of the project and the already reduced habitat quality within most of the footprint, most project activities present a low risk to those values. Unavoidably, some relatively weed-free, remnant bushland will have to be cleared for the WSF and granular material borrow area. The vegetation communities that will be cleared are forms of *Eucalyptus* woodland – the dominant vegetation type in the region. The maximum area of remnant bushland that will be temporarily cleared, and then revegetated, is less than 12 ha. The residual impact of this loss of habitat is low.

The biggest existing risk to terrestrial flora and fauna values, and one that could be exacerbated by project activities, is the scale and density of Gamba Grass infestations within the footprint and the concomitant increase in bushfire intensity. Mitigation of that risk is possible, but will require unwaveringly following the weed management strategy and a dedicated commitment of resources (personnel, equipment and chemicals) for an indefinite period. The residual impact will only be low if that occurs. If this commitment does occur during rehabilitation and carry on post-rehabilitation there is a significant risk that weed infestations will jeopardise revegetation efforts and site will return to a reflection of what is currently experienced on site.

Dust and bushfire – both risks to occupational health and safety, as well as terrestrial biodiversity – will be managed using a suite of standard industry mitigation and control measures. Consequently, the residual impact of these will be low.

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15. Human Health and Safety

Tables

15.1. Introduction

The project will require the delivery of earthworks, water treatment, land management and other activities in a brownfields work environment having existing hazards. Some of these hazards are inherent to tropical environments and in a significant earthmoving project, but many hazards are unique to the former Rum Jungle Mine site. The unique hazards are due to historic uranium and polymetallic mining and processing practices, such as radiological soils. This chapter describes the Stage 3 Human Health and Safety impacts and addresses worker safety. Potential impacts to surrounding land users, including surrounding residents, are detailed in Chapter 13 – Social and Economic Impact.

The impacts have been identified over several Qualitative Risk Assessment (QRA) workshops which have included the majority of the project's technical specialists, lead engineers and earthworks contractors. These workshops were facilitated by risk specialists from GHD to improve the quality of the assessment process and the results of these workshops are documented in the *EIS Risk Register* (GHD, 2019f – see Appendix). Importantly, the findings of the risk workshops over the progressive development of the project have informed the design and project delivery plans. For the purpose of the EIS, a risk assessment framework was developed as described in Chapter 3 – Compliance and Risk.

15.2. Stage 3 Delivery Health and Safety Framework

15.2.1. Applicable Legislation

NT work health and safety laws are administered by NT WorkSafe and are based on the Safe Work Australia Model Work Health and Safety Act and Regulations (Northern Territory, 2017). The applicable NT legislation is described in Chapter 3 – Compliance and Risk. The Proponent will comply with the listed legislation and applicable codes of practice for all activities associated with the Rum Jungle Rehabilitation Project.

15.2.2. Management Framework

As the Rum Jungle Rehabilitation Project is proposed to consist of up to five years of construction and five years of intensive maintenance and monitoring, DPIR will develop and implement a Health, Safety and Environment Management System. The structure of the Management System will use guidance provided by WorkSafe Australia, AS/NZS 45001:2018 - Occupational health and safety management systems (Standards Australia, 2018) and ISO 14001*:2015* - Environmental Management Systems (ISO, 2015); and will include the following elements:

- Policies
- Leadership, management, accountability and commitment
- Hazard and risk management
- Information and documentation
- Incident management
- Management of change
- Contractor management
- Emergency preparedness and response
- Systems of work / operations and maintenance
- Personnel roles and responsibilities
- Health and fitness for work
- Monitoring, auditing, review and continuous improvement.

As part of the Management System, the Proponent's risk management procedures will require the development and maintenance of an operational Risk Register to identify, assess, mitigate and eliminate risks to human health and safety throughout the project lifecycle. The Risk Register will be a live document, formally reviewed on a regular basis, to assess the operations and put in place appropriate control measures to prevent and/or mitigate the risks. The frequency of the review will be dependent on the hazard likelihood and consequences as well as the effectiveness of controls.

The *EIS Risk Register* (GHD, 2019f – see Appendix) will form the foundation for future iterations into the aforementioned operational Risk Register. The lead engineers were present at the QRA workshops held in November 2018 and August 2019 to assist in designing out risk and to advise on practical implementation of proposed engineering and process controls.

Developing the contracting and procurement strategy, which complements the project delivery model, will be an important step in assigning roles and responsibilities within the management framework. As a result, it is proposed that prior to rehabilitation works, all project documentation is reviewed by the implementation teams.

15.2.3. Hierarchy of Control

The hierarchy of controls is a commonly used principle applied across the industry in the management of safety hazards. It involves a prioritised order of control strategies from the most effective strategies to the least effective strategies.

The aim of applying the hierarchy of control is to have a combination of control strategies to manage a specific risk and to use the hierarchy to reduce the risk so far as is reasonably practicable. Where applicable a combination of controls within the hierarchy can be used.

The hierarchy of control and basic examples are included below:

- Elimination: remove or avoid the hazard completely (for example: project design that eliminates need to handle historic tailings materials).
- Substitution: replacing with a safer alternative (for example: arranging one bus rather than multiple light vehicles to travel to site).
- Isolation: separating the hazard from the person, environment or process at risk by isolation, guarding or barricading.
- Engineering controls: constructing new devices or methodology to reduce the risk (for example: adapting the liming process to reduce the potential impact of lime dust).
- Administrative controls: promote awareness of hazards (for example: signage, updating risk registers, toolbox focus topic and training).
- Personal protective equipment (PPE): considered only when other controls are not practical or to increase protection (for example: wearing gloves to prevent contact with contaminated soils).

By undertaking a risk assessment of human health and safety during the early stages of the Rum Jungle Rehabilitation Project, the Proponent has had the opportunity to implement the hierarchy of controls more effectively. As the design progresses, consistent assessment and revision will occur which should allow for overall reduction of hazards, using the hierarchy of controls. Several potential risks have been designed out of the Stage 3 scope including the elimination of:

- Handling of historic tailings material from within the Main or Dyson's (backfilled) Pits as this material presents a radiological hazard to workers that can be avoided with insitu capping methodologies
- Main Pit dewatering to access submerged tailings as the Main Pit geotechnical stability under dewatering activities is likely to be low.

15.2.4. Incident Management

The prompt and accurate reporting of incidents will be a responsibility of all employees and supervisors/management will be held accountable for compliance with this requirement. An incident register will be maintained and key incidents will be widely shared to reduce the likelihood of incident reoccurrence.

Each incident will be investigated to determine the root cause and how controls can be adjusted to prevent reoccurrence. Actions will be developed, assigned and tracked using the incident management system. Regular check and audits, with timeframes, will be undertaken following an incident to ensure that corrective actions are in place.

15.2.5. Emergency Management

An important element of the management system is the emergency response systems, procedures and resources. The emergency response process will be managed by the site Emergency Response Team and supplemented by local volunteers if required. All personnel within the Emergency Response Team will undergo regular training and participate in regular simulation exercises.

A Fire and Emergency Response Group (FERG) is located in Batchelor. This volunteer group consists of approximately ten members who are trained in road crash rescue, first aid, search and rescue, and flood boat operation. The project Emergency Response Team may form a component of the FERG to assist in sharing resources, skills and training across the area. In addition, Batchelor Health Clinic has a resident doctor and nurses, and an ambulance is stationed at Batchelor. The Batchelor Police Station is located within the town centre with 24 hr operation (NT Police Fire and Emergency Services, 2019).

As part of the emergency management system, scenario specific emergency response plans will be developed based on the potential emergencies that may arise at the operations. Credible emergencies include bushfire, traffic accident and bulk chemical spill. The support and co-operation with the FERG will be another positive benefit resulting from the project.

Existing local emergency services will need to be supplemented with additional project resources including an operational first aid station, fire response equipment, potentially road accident rescue equipment and fully trained personnel. In all cases, the project will establish links with existing services to supplement response capabilities locally and support existing services. This includes links with Browns Oxide Mine located adjacent to the Rum Jungle Mine site.

15.2.6. Reporting and Audits

An effective management system includes regular monitoring, auditing, review and improvement.

The Proponent’s monitoring, auditing, review and improvement process will include:

- Routine inspections of assets
- Routine monitoring of control implementation (for example: peer audits, audits by more senior staff, external audits)
- Routine management review of the effectiveness of all standards, procedures and work instructions/job safety environmental analysis (JSEAs)
- A document control system to enable update of all standards, procedures and work instructions/JSEAs following management review
- A training and qualifications management system to identify and track training requirements of all personnel and qualifications held by personnel
- A permit to work process to monitor and control higher risk activities (for example: excavation permits, hot work permits, vegetation clearance permits)
- A communication strategy to notify all relevant personnel of changes made (for example: toolboxes, regular training and notice boards).

The Proponent will implement a regular audit program to confirm compliance with the health and safety legislative requirements and company/operations specific processes and procedures. This will also include independent external authorities conducting audits as necessary.

15.2.7. Interface with the Detailed Engineering Design

Integration of risk mitigation into engineering design has allowed for the elimination of multiple risks from the Stage 3 Project. Continuing integration of risk and value engineering processes as the detailed project design progresses is critical to further reduce the project risk profile. Experienced design and delivery personnel are critical in ensuring risk mitigation measures are practical and achievable and do not introduce further risks.

The risk of loss of knowledge and continuity is significant in transition from the current Stage 2A planning phase into the Stage 3 delivery phase. To counter this, the designer should continue to remain involved in project planning. This should include developing and auditing construction quality assurance and quality control, and assisting in managing deviations from the engineering design.

15.3. Potential Impacts and Risks

The *EIS Risk Register* (GHD, 2019f – see Appendix) identifies 19 potential impacts that project activities detailed in Chapter 2 – Proposal Description could have on Stage 3 employee human health and safety. Of these 19 potential impacts one was ranked as a Low initial risk (general slips, trips and falls); two are related to the general public (addressed in Chapter 13 – Social and Economic Impact); and one is related to radiation (addressed in Chapter 16 – Radiation).

An additional potential impact is related to the likely increase in traffic movement on public roads for the purposes of the project. As noted in Chapter 13 – Social and Economic Impact, the road authority (DIPL) will set the traffic management requirements that the Proponent must comply with on major arterial roads. The Proponent has commenced discussions with DIPL in order to ensure that the correct approvals and processes are followed. Once detailed design and detailed scheduling are complete the Proponent will be well placed to complete the required processes for approval to safely operate within the public road network.

For each of the 19 Human Health and Safety potential impacts identified with inherent risk greater than Low, the effective timeframe of potential impact was defined. There were three defined classifications for the effective time periods of which identified risks could occur:

- Stage 3 (the construction period – up to 15 years)
- Stage 4 (post-rehabilitation short-term – up to 20 years)
- Stage 5 (post-rehabilitation long-term – > 20 years)

The expected effective timeframes for each risk *EIS Risk Register* (GHD, 2019f – see Appendix). The potential impacts are summarised into seven impact categories as shown in Table 15-1.

Table 15-1: Potential impacts to human health and safety

Description of impact	Potential event
Human Health and Safety	
Flooding and open water bodies may result in injury or death…	During Pit backfilling
	Stage 3 rainfall exceeds limitations of waterways flooding other work areas
	Personnel drowning when working around and within open water bodies
Respirable dusts and gases cause injury	Emissions of dust from exposed working areas
	Emission of noxious gases from mobile plant
	Emissions of dust from contaminated soils (heavy metal – particularly lead, lime and asbestos) during decontamination works
	Emissions of asbestos dust during decontamination works
Fire causing injury or death	Uncontrolled bushfire onsite due to heavy weed infestation
	External bushfire encroaches onto site and into work area including bulk fuel farm
	Fire from work area (particularly bulk fuel farm and hydrocarbon storage) escalates and spreads through site/offsite
Climate extremes cause injury or death	Tropical work environment causes dehydration or heat stroke, lightning strike on elevated work areas, sunburn and other factors
Workplace hazards cause injury or death	Exposure to workplace hazards - general
Hazardous fauna cause injury	Workers exposed to hazardous fauna such as snakes, biting insects, crocodiles, buffalo and pigs
Unauthorised site access causes injury	Member of public intentionally or inadvertently accesses site - this may cause injury to that person or to workers

15.3.1. Flooding and Drowning

Three events relating to flooding and drowning were identified due to the presence of existing pit lakes and the EBFR within an area where work is to take place. The inherent risk rating for all three risks was classified as High. The drowning hazard onsite is present year-round with substantial standing water bodies at both existing pits. The Main Pit is to be backfilled and will require a floating conveyor delivery system. There is potential for personnel to be exposed if the operation is poorly managed. The hazard at Intermediate Pit is less likely as there is less planned work for that area. Additionally, several bridges and culvert crossings will be in operation and there is a risk that vehicles may inadvertently enter flowing or standing water bodies.

The Wet season hazards include flooding of the work site – particularly in high intensity rainfall events such as cyclones. The risk of flooding causing impact is higher during the pit backfilling stage as people and equipment will be accessing the Main Pit.

15.3.2. Respirable Dust and Gases

Four events relating to respirable dust and gases were identified due to earthworks taking place. The inherent risk rating for all four risks was classified as Medium. Loading, hauling and material placement activities can cause dust, the nature of which may be radiological. All risks associated with radiological sources are covered in Chapter 16 - Radiation.

In addition to operational activities, dust may be generated in future from the constructed WSF in the event that revegetation is not sufficient. The nitrous and sulphurous oxides produced by the operational equipment may also prove hazardous to sensitive receptors.

15.3.3. Fire

Three events relating to fire were identified due to the bushland setting of the project and the storage and handling of hydrocarbons throughout the Stage 3 works. The inherent risk rating for all three risks was classified as Medium. The risk of bushfire on the project site is exacerbated, especially during the fire season, by the high level of Gamba Grass infestation in areas across site and on adjacent properties. As the frequency of fires in the area is high, it is likely that Stage 3 works may be impacted by bushfire. Bulk fuel will be stored onsite, as will oil and grease and waste products of these from the maintenance workshop. Additionally, operating equipment if poorly maintained presents a potential ignition source.

15.3.4. Climatic Extremes

One event specifically relating to climatic extremes was identified due to the challenging outdoor working climate posed by the project location. The inherent risk rating for this risk was classified as High. Adverse weather conditions, commonly experienced in the Top End, include high heat and humidity, lightning storms, high wind events, high rainfall events and UV radiation. Exposure to such conditions will have varying consequences to personnel depending on the type of exposure - effects may range from dehydration, sunburn and injuries through to fatality due to heat stroke or lightning strike.

15.3.5. General Hazards

One event related to general hazards was identified as an acknowledgement of the complex nature of working on a brownfields site with several work teams in an area with unique mineralogy, hydrology and history of contamination. The inherent risk rating for this risk was classified as High.

15.3.6. Hazardous Fauna

One event specifically relating to hazardous fauna was identified due to fauna that may be encountered within the work area. The inherent risk rating for this risk was classified as High. The EBFR is known to have resident salt and freshwater crocodiles – despite there being no recent verified sightings onsite, it is possible that at some time during the Stage 3 works crocodiles may be present within the workplace. Despite other larger animals, such as wild pig and buffalo, regularly frequenting the area, they are unlikely to continue to occupy the work area during higher intensity activity periods such as Stage 3 works. Smaller fauna hazards include snakes, spiders and biting insects, all of which are likely to be within Stage 3 work areas.

15.3.7. Unauthorised Site Access

One event specifically relating to unauthorised site access was identified due to the presence of hazards such as moving equipment. The inherent risk rating for this risk was classified as High. Unauthorised site access may occur as an intended event or may be inadvertent. In both circumstances those entering site may be at risk and may also pose a hazard to site personnel. Consequences may vary depending on the location of unauthorised access and the reason for access (for example, if they are deliberately intending to cause harm).

15.4. Mitigation and Management

Through the application of planned controls, the residual risk ranking for all human health and safety risks has been reduced to either Low or Medium. Planned controls generally follow the hierarchy of control with the majority of controls focussing on elimination, substitution or engineering controls and very few focussing on administrative controls or PPE.

Prior to commencement of the Stage 3 works additional workshops with the relevant contractors and project team will be carried out in order to update and add operational details into the project Risk Register. This will form the foundation for the Project Health, Safety and Environment Management System.

15.4.1. Flooding and Drowning

Following application of planned controls, all three risks were re-assessed as having a Low residual risk rating.

These controls include design and construction considerations such as ensuring that all designs are to Australian Standards where applicable (and Australian Rainfall & Runoff 2016) for hydrology, the WSF construction site is located out of the 1,000 ARI flood modelled area, and commencing construction works during the Dry season in order to establish work systems in the lowest risk part of the seasonal cycle.

In addition to design and construction considerations, appropriate project planning will be completed, including development and implementation of:

- an adverse weather action procedure;
- inspection process for post flood events and Wet season to ensure integrity of structures;
- a *Water Management Plan*;
- an Emergency Response Plan; and
- a procedure for working in and around water bodies.

Other mitigation and management activities to further reduce risks during construction include implementing appropriate weather monitoring, appropriate use of fixed and portable edge protection, appropriate use of personal flotation device, and availability of Emergency Services and equipment.

15.4.2. Respirable Dust and Gases

Following the application of planned controls, all four risks were re-assessed as having either a Low or Medium residual risk rating.

Appropriate project planning including placing lime in the tipping area as a slurry, progressively undertaking stripping and revegetation of work areas to limit exposed surfaces as far as possible, and ensuring that air-conditioned cabins are present on mobile plant and light vehicles will all control the dust hazard.

Construction control measures which will lower the risk of dust evolution include dust suppression on haul roads and material placement surfaces, applying primer sealer to unsealed road surfaces (where risk warrants this), enforcing speed limits on unsealed work surfaces, inspection and maintenance measures for running surfaces, and standing down operational equipment when required by the Superintendent due to dust hazards.

Mitigation and management measures to reduce gas hazards include scheduled vehicle and heavy equipment maintenance as *per* Original Equipment Manufacturer, procuring diesel fuel to Australian standards (for S content), use of solar powered infrastructure where possible, optimisation of haul routes to decrease run distances, and optimisation of machinery operation to minimise operating times.

To prevent potential failure of the WSF which may result in distribution of contaminated dust, mitigation and management measures are focussed on appropriate and considered designs in combination with the development of a Quality Assurance/Quality Control Plan to be included in technical specifications. Design mitigation and management measures include appropriately engineered cover design by a suitably qualified engineer with oxygen and water infiltration reduction controls, surface water control design, minimising the WSF surface area through effective designing, completing the WSF to ensure adequate erosion mitigation structures over the facility, ensuring controlled shedding drainage of excess surface water, and undertaking detailed material investigation to ensure material suitability.

Following construction, progressive revegetation, maintenance and monitoring will be completed and a Bushfire and Weed Management Plan (to include tree removal) will also be implemented.

15.4.3. Fire

Following application of planned controls all three risks were re-assessed as having a Low residual risk rating.

Mitigation and management measures focus on prevention and planning. Activities to manage the fuel load around the project will be documented in the Weed Management Plan and Bushfire Management Plan. Preparation for responding to a fire event is to be supported by the development of an Emergency Response Team which interfaces with locally available service providers and adjacent land holders. The team would be managed under the Emergency Response Plan and require adequate training and resourcing to deal with documented credible emergencies. The analysis of credible emergencies would aid in the appropriate development of response preparedness.

15.4.4. Climatic Extremes

Following application of planned controls, the single risk was re-assessed as having a Medium residual risk rating.

Mitigation and management measures include development and implementation of:

- a fitness for work management system including hours of work, drug and alcohol policy, medicals and fatigue management;
- stop work and refuge procedures underpinned by appropriate use of lightning tracking;
- an adverse weather procedure;
- an Emergency Response Plan;
- a lone and isolated workers procedure;
- a heat stress/hydration monitoring program; and
- a site induction.

Additional controls during construction include weather monitoring, appropriate use of communication protocols, good site housekeeping, appropriate use of PPE and availability of Emergency Services and equipment.

15.4.5. General Hazards

Planned controls for this risk is the development of appropriate risk management systems prior to delivery of Stage 3 works in order to capture newly emerging hazards and risks that cannot be foreseen at this stage of project planning.

15.4.6. Hazardous Fauna

Following implementation of planned controls, the single risk was re-assessed as having a Medium residual risk rating. Planned mitigation and management measures include compulsory site induction and the development and implementation of a vegetation management program and a lone and isolated worker procedure. Crocodile awareness training will be built into the induction program.

To further lower this risk, control measures such as appropriate use of communication protocol, appropriate pest control program (insects, spiders *etc*), appropriate use of PPE, ensuring availability of Emergency Services and equipment, development of fauna awareness training and ensuring qualified snake handlers are onsite will also be implemented.

15.4.7. Unauthorised Site Access

Following implementation of planned controls, the single risk was re-assessed as having a Medium residual risk rating. Planned controls that will be implemented include site security and access restrictions with signage and fencing, ensuring that emergency services and equipment are available, and development and implementation of:

- site access control procedures;
- a contractor management system;

- media communication protocols/plan; and
- a Stakeholder Engagement and Communications Plan.

15.5. Statement of Residual Impact

The Stage 3 project is relatively high risk due to being a bulk earthmoving and water treatment activity, undertaken on a relatively remote brownfield site with a challenging climate. Unmitigated, select project activities have a high likelihood of having a significant impact on the health and safety of site personnel and possibly the general public. All of these potential impacts, however, can be controlled through the mitigation measures detailed within this chapter and the *EIS Risk Register* (GHD, 2019f – see Appendix).

Assuming proper adoption of the mitigation measures, the residual risk ranking for all human health and safety has been assessed as Medium or Low.

15.6. References

AS ISO 31000:2018 - Risk management – Guidelines (Standards Australia, 2018).

Safe Work Australia, Model Work Health and Safety Act and Regulations (Northern Territory, 2017).

AS/NZS 45001:2018 - Occupational health and safety management systems – Requirements with guidance for use (Standards Australia, 2018).

GHD (2019f) *Rum Jungle Stage 3 EIS Risk Register* – Rum Jungle Project Team.

ISO 14001:2015 - Environmental Management Systems – Requirements with Guidance for Use (ISO, 2015).

NT Police Fire and Emergency Services (2019) *NT Police Force - Batchelor*. [Online] Available at: https://pfes.nt.gov.au/police/police-station-profiles/batchelor [Accessed 21 September 2019].

15.7. References included in Appendix

GHD (2019f) *Rum Jungle Stage 3 EIS Risk Register* – Rum Jungle Project Team.

16. Radiation

Figures

Tables

16.1. Context

Rum Jungle was mined for copper and uranium between 1953 and 1971. Mt Burton was mined for uranium and copper in 1958. The orebody at Mt Fitch was exposed between 1968 and 1969 for evaluation, but was not mined due to its low grade. Therefore, some of the material present at these sites is the by-product of uranium mining. Uranium is the ‘parent’ of a series of radioactive elements that emit alpha, beta and gamma radiation. As such, its presence represents a radiological hazard during rehabilitation works.

In the Land Use Plan (see Figure 6-8 or Figure 7-2) discussions mentioned in Chapter 7 – Rehabilitation Strategy, some Traditional Owners shared their beliefs that the land has always been considered as ‘sickness country’. In other parts of Australia, this term is associated with land that has naturally high background radiation levels. Given its geology, this was likely the case at Rum Jungle before mining occurred.

16.1.1. Exposure Scenario

There are two types of radiation exposure scenarios – *practices* and *interventions*. These are defined in detail by the International Commission for Radiological Protection (ICRP 60, 1991) – the premier international body for radiation protection. Put simply, a *practice* is an intentional activity in which the practitioner is routinely at risk of exposure – *e.g.* workers who are exposed to radiation during the course of their duties (such as at Ranger Mine). An *intervention* is an action that one takes to reduce a radiation exposure (often to other individuals or groups) from specific radiation sources. It is an important distinction to make, as each scenario type has its own dose guideline levels.

One of the purposes for rehabilitating Rum Jungle is to reduce public health hazards, including from radiation exposure. Therefore, it is more appropriate to consider the rehabilitation action as an *intervention*. The sources of exposure and exposure pathways are already present due to earlier practices that precede regulatory control; it is an existing exposure situation.

For these existing exposure situations, it is recommended that doses be optimised below a dose constraint. In ICRP 103 (2007), paragraph 240, it is recommended that *'existing exposure situations are exposure situations that already exist when a decision on control has to be taken'* and thus calculated annual doses can be compared to the dose constraint of 1 to 20 mSv *per* year. Although that is the published intervention range, reasonable caution should be exercised in adopting the upper end of this range without suitable justification, because the principle of *as low as reasonably achievable* (ALARA) must also be considered. The *Guide for Radiation Protection in Existing Exposure Situations – Radiation Protection Series G-2* (ARPANSA, 2017) recommends a 10 mSv *per* year reference level as a suitable starting point in an Australian context. That reference level has therefore been adopted for this project.

The Land Use Plan which has been developed includes future access to the site for cultural practices, land management activities across the broader FRALT, teaching younger generations bush skills and culture, practicing caring for country and for potential cultural tourism ventures. It is a primary objective of the Stage 3 Rehabilitation Project to improve site condition to support the proposed future Land Use Plan.

16.1.2. Units

Radiation activity is measured in an international (SI) unit called a Becquerel (Bq). The Becquerel counts how many particles or photons (in the case of wave radiation) are emitted *per* second by a source.

Radiation exposure is expressed in several ways to account for the different levels of harm caused by different forms of radiation and the different sensitivity of body tissues. It is measured in an SI unit called the Gray (Gy). The radiation exposure is equivalent to the energy "deposited" in a kilogram of a substance by the radiation. Exposure is also referred to as absorbed dose.

A quantity called the equivalent dose relates the absorbed dose in human tissue to the effective biological damage of the radiation. Not all radiation has the same biological effect, even for the same amount of absorbed dose. Equivalent dose is measured in an SI unit called the Sievert (Sv).

The probability of a harmful effect from radiation exposure depends on what part or parts of the body are exposed. Some organs are more sensitive to radiation than others. A tissue weighting factor is used to take this into account. When an equivalent dose to an organ is multiplied by the tissue weighting factor for that organ the result is the effective dose to that organ. The unit of effective dose is also the Sievert (Sv).

16.1.3. Information Sources

There was minimal historical characterisation of the radiological conditions of the area since mining ceased in 1971. Sporadic studies were conducted in the 1970s to the 1990s, but little data on radiation issues was collected. Post-rehabilitation, several studies (1990s to present) have been completed and provide characterisation of the mine site. These more recent studies form the basis of information for the Radiological Hazard Assessment and are detailed in that report (EcOz, 2019b – see Appendix). This section provides an overview of those studies.

Rum Jungle Mine site

Information about the radiological hazards at the Rum Jungle Mine site has been obtained from the following surveys:

- Bollhöfer *et al.* (2007) undertook an airborne gamma radiation survey.
- Tropical Water Solutions (2008) conducted a study on radionuclides in the water within Main Pit and Intermediate Pit.
- CSA Global (2011) characterised parts of the Rum Jungle Mine site to determine metal levels in surface and near surface soils and sediments across previously-rehabilitated areas and un-rehabilitated areas. Uranium was one of the metals analysed in the survey.
- Hughes and Bollhöfer (2010) undertook further investigations to characterise the source and vertical extent of the radiological anomalies at Rum Jungle.
- SRK (2012) conducted a geochemical characterisation – including uranium – on the Main, Intermediate and Dyson's WRDs and Dyson's (backfilled) Pit.
- Hydrobiology (2016) analysed radionuclides in fish, mussel and plant tissues in the EBFR and downstream of the East Branch.
- Radiation Advice and Solutions (2014) undertook a small study aimed towards providing radiological information on the drilling and digging activities performed by workers onsite.
- EcOz (2019) assessed the data from the Bollhöfer study, ranked sites with elevated high radiation levels by the amount of radon emanation and ^{226}Ra soil activity concentrations, and then undertook additional field investigations on the top nine of those. This assessment is contained within the *Radiological Hazard Assessment Report* (EcOz, 2019b – see Appendix).

Mt Burton and Mt Fitch

Information about the radiological hazards at Mt Burton and Mt Fitch has been obtained from the following surveys:

- Commonwealth Department of Administrative Services (1988) which studied some legacy mines in the NT, including both Mt Burton and Mt Fitch.
- Hughes and Bollhöfer (2010) undertook further investigations downstream of the EBFR and Finniss River confluence in the vicinity of Mt Fitch.
- Department of Mines and Energy (2016) carried out a survey to assess radiation levels emanating from the mined area and stockpiled materials at Mt Burton.

16.1.4. Hazard Assessment

***Rum Jungle* Mine site**

The radiation residual risks associated with this project are Low to Medium as much of the material encountered is of low radioactivity. In summary:

- **Gamma radiation.** Bollhöfer *et al.* (2007) determined that the average external gamma dose rate over the mine site amounts to 0.2 µGy/h. Average dose rates of approximately 0.6 µGy/h were measured at three 'hot' areas: an area west of Dyson's (backfilled) Pit (Dump area); an area close to the Acid Dam; and an area close to the Old Tailings Dam. The averaged whole-body effective dose rate across the entire site from terrestrial gamma radiation is 0.14 µSv/h, which is approximately twice as high as background effective dose rates. EcOz (2019) identified nine areas with particularly high radiation levels and these are the focus of rehabilitation efforts. The area to the west of Dyson's WRD is the most radiologically-contaminated area, with > 30 µSv/h readings measured for some of the large rocks strewn across the area. That area may have been used to stockpile large boulders for later processing.
- **Radon.** The average radon activity concentration in the air at Rum Jungle during the Dry season was calculated by Bollhöfer *et al.* (2007) to be 80 Bq/m^3. The average Australian radon exposure is ~25 Bq/m^3 (ARPANSA, 2019). During the Dry season, approximately 5 % of the area investigated was above the Australian reference level of 200 Bq/m^3 for indoor airborne radon activity concentration in new or existing dwellings (this is the only Australian reference level for radon available). Annual averages will be lower because a reduction of radon levels by one order of magnitude can be expected during the Wet season.
- **Dust.** Doses received via the dust inhalation pathway are low; less than 0.005 µSv/h across the site (Bollhöfer *et al.*, 2007). However, this pathway may play a more prominent role in the unlikely event that the site was inhabited permanently or in the likely event that workers are engaged in activities such as digging, drilling or heavy traffic movements during the rehabilitation of the site.
- **Water.** In the deep, dense, high-conductivity waters of Main Pit, two samples by Tropical Water Solutions (2008) had alpha activity of 100 Bq/L and 59 Bq/L, and beta activity of 120 Bq/L and 72 Bq/L. While the 2008 activities are lower than those found in 1996, they remain elevated compared to those in the surface mixed layer of Main Pit – alpha activity of 0.1 Bq/L and beta activity of 0.9 Bq/L. The *Australian Drinking Water Guidelines* (NHRMC, 2004) and the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC, 2000) for irrigation and livestock waters provide guideline values of 0.5 Bq/L for both gross alpha and beta activities.[9] According to Tropical Water Solutions (2008), radionuclide activity in the upper levels of Intermediate Pit are well below recommended guideline values, while levels in the deeper portion are above guideline values, but substantially less than the deep water in Main Pit.
- **Soil.** From CSA Global (2011) it can be concluded that there is a total area of 116.26 ha and a volume of 259,316 m^3 of material greater than the trigger value of 100 ppm of uranium present on the Rum Jungle Mine site. These measurements of uranium are only to a depth of 1.3 m and an exact measurement of uranium content has not been measured. These levels need to be measured and confirmed with other radioisotopes measured to calculate dose measurements for the area and to measure against ARPANSA (2005) guideline limits for soil wastes. Interestingly, much of the area identified as above 100 ppm uranium lies over undisturbed bushland. This may indicate the presence of the zone of mineralisation.

It was calculated by Bollhöfer *et al.* (2007) that workers simply accessing the site during working hours (2000 hours *per* year) would receive a total above background dose of about 0.3 mSv *per* year. Radiation Advice and Solutions (2014) concurred in their study of excavation workers that the maximum dose received by the workers was negligible and, even in the hypothetical case of full year exposure, would remain well below the 'member of public' limit.

Traditional Owners may choose to access the Rum Jungle area for customary harvesting purposes post-rehabilitation, although the process for handing over of the site is not yet established and the timeframe for this is unknown. Radiation doses received by Traditional Owners accessing the site would depend onsite use and duration of occupancy. This is discussed in more detail in Section 16.3.3.

[9] The proponent understands that the current guidelines are under review. In future, there will be 'trigger' or action levels beyond which further analysis is required, as opposed to 'guideline values'. The radium isotope concentrations are the trigger levels with ^{226}Ra at 5 Bq/L, ^{228}Ra at 2 Bq/L, and gross alpha and beta each remaining at 0.5 Bq/L. The uranium trigger for irrigation / livestock watering is 0.2 Bq/L. If the trigger levels are exceeded, then radionuclide/isotope analysis is required and dose calculations are then determined using dose conversion factors. The 'trigger' levels should never be used as guideline values, as the guidelines relate to dose only – i.e. 1 mSv for potable water.

Mt Burton and Mt Fitch

The Department of Administrative Services (1988) found that the water in the open pit at Mt Burton was deemed by the (then) Australian Radiation Laboratory to be below the annual dose limits for consuming 1 litre of water per day (Reference Person, IAEA 2008, gives consumption of 4 litres per day in a tropical environment per person).

DME (2016) determined, at Mt Burton, that average background gamma radiation across four sampling areas (each containing multiple sampling sites) was 0.07 (+/- 0.01) µSv/h. The survey found that the area with the highest gamma radiation – 4.3 (+/- 0.2) µSv/h above background – was the stockpile in Area C at the south-west corner of the laydown area (see Figure 16-1). Generally, the remainder of the site had low levels of radiation. It was concluded that, using ICRP criteria, there is no significant human health hazard at the Mt Burton site.

At Mt Fitch, water assays in 1988 showed uranium levels at 124 µg/L, which is above the current ANZECC water quality guideline of 0.5 µg/L. Assessment of the water by (then) Australian Radiation Laboratory was deemed below the then annual dose limits for consuming 1 litre of water *per* day (as *per* discussion above). Gamma radiation levels around the waste heap and the access to the mine were less than 0.5 µGy/h, with the exception of a few spots along the access to the open pit where levels of 2 µGy/h were recorded.

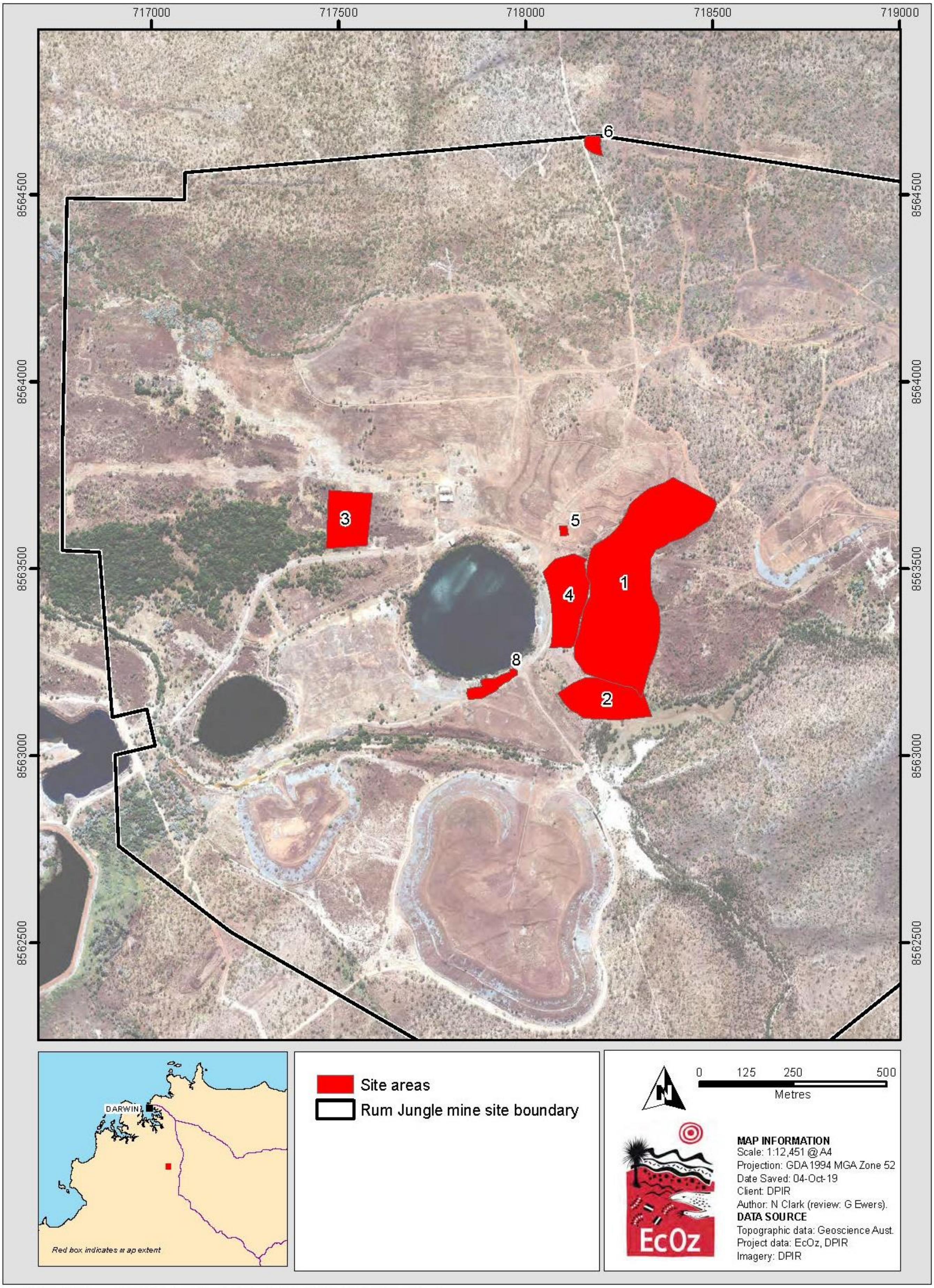

Figure 16-1: Extent of elevated gamma radiation after an on-ground survey, Rum Jungle Mine site (EcOz, 2019)

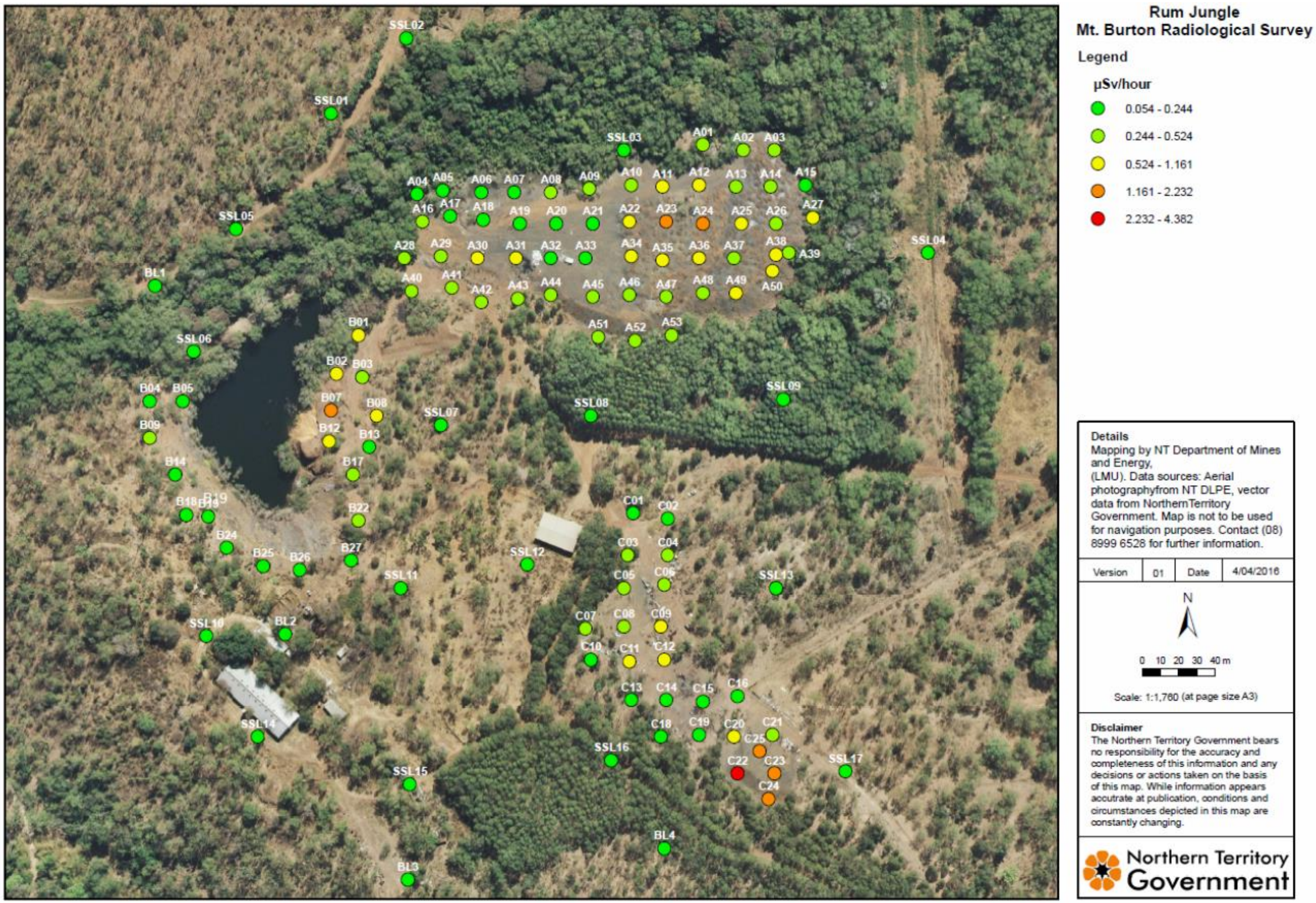

Figure 16-2: Mt Burton radiation survey area (DME, 2016)

16.1.5. Health Impacts from Radiation

Radiation exposure only occurs when there is a pathway or exposure route between the radioactive material and the person. There are two general types of exposure:

- **External exposure** occurs when the source of radiation is outside of the body. An example is the exposure received during a medical x-ray.
- **Internal exposure** arises from radioactive material inside the body. The most common ways that radioactive materials enter the body are by inhalation (breathing) or ingestion (swallowing).

These are depicted in Figure 16-3.

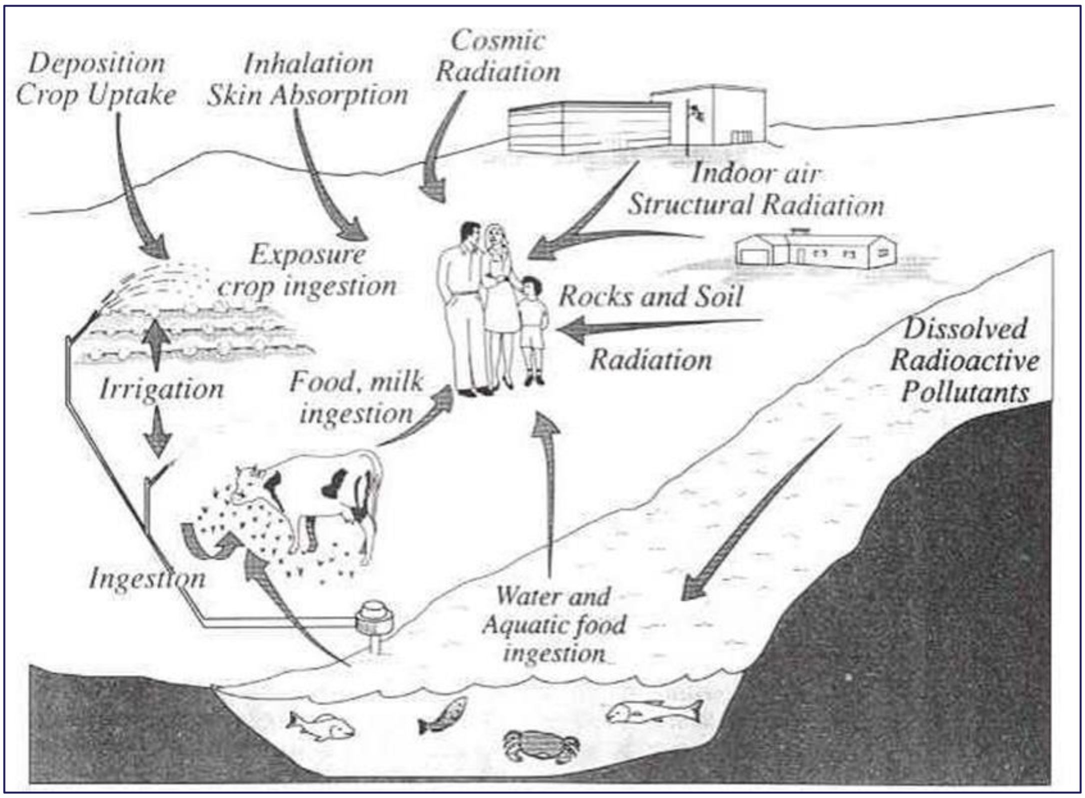

Figure 16-3: Simplified diagram of the primary pathways leading to dose (source unknown)

The mechanisms that lead to adverse health effects after ionising radiation exposure are not fully understood. Ionising radiation has sufficient energy to change the structure of molecules, including DNA, within the cells of the body. Some of these molecular changes are so complex that it may be difficult for the body's repair mechanisms to mend them correctly. However, the evidence is that only a small fraction of such changes would be expected to result in cancer or other health effects, and depends on the radiation dose, and also on sex and age at exposure.

16.2. Potential Impacts and Risks

There are three sites within the project footprint that have elevated radiation levels – the Rum Jungle Mine site, Mt Burton and Mt Fitch. At these sites, there are four potential pathways for delivery of radiation doses to the human body that should be considered for this project:

- External irradiation by gamma radiation from radionuclides in soils, rocks and mining residues
- Inhalation of airborne dust

- Inhalation of radon daughters[10]
- Ingestion through food and water.

The *Risk Register* (GHD, 2019f – see Appendix) identifies 17 potential impacts that project activities detailed in Chapter 2 – Project Description could have on human health because of increased exposure to radiation. This section describes the aspects of the project – during works and post-works – that have the potential to deliver radiation doses to humans via one or more of the abovementioned pathways.

Impacts have been assessed to four critical groups:

a. Critical Group 1 – Occupational: construction workers onsite for the duration of the Stage 3 construction period

b. Critical Group 2 – Traditional Owners taking into account all potential future land uses

c. Critical Group 3 – People living downstream of the Rum Jungle site on the EBFR

d. Critical Group 4 – General members of the public (closest are employees at Browns Oxide Mine).

16.2.1. During Works

One of the primary objectives of the project is to reduce the onsite risks of radiation exposure. This necessitates the excavation, handling, movement and interment of radioactive materials. Such activities carry with them an inherently high risk to the workers undertaking them. Table 16-1 outlines the possible sources and pathways for radiation exposure to workers at the Rum Jungle Mine site. These are addressed in more detail below.

During works, these activities also have the potential to increase the exposure of members of the public to radon. However, due to the large distance between the mine site and sensitive receptors, this is a Low risk.

The international limit for designated radiation workers is 20 mSv *per* year averaged over 5 years, and not more than 50 mSv received in any one year for effective dose (ARPANSA, 2016). For the planning of a rehabilitation practice the aim is for less than the 20 mSv annual limit, with a common constraint being 5 mSv *per* year. The dosage for members of the public and non-designated workers is 1 mSv *per* year.

Table 16-1: Summary of sources/pathways of radiation exposure

Source	Pathway	Exposure type
Surface exposure of radioactive material	Working on top of, or with, exposed elevated radiological material	External gamma
Radioactive material brought to surface during excavation *etc.*	Airborne material from disturbance	Inhalation of dust
	Handling of radioactive waste material	Ingestion
	Working near excavations	External gamma Inhalation of dust
Handling of radioactive waste material	General handling of radioactive waste material or stockpiled material	Inhalation of dust
		Ingestion
		External gamma
Airborne radon gas and its decay products	Radon decay product build-up in confined spaces near material	Inhalation of RDP

Impacts due to exposure to gamma radiation

Whilst undertaking rehabilitation works at the Rum Jungle site, workers will be exposed to gamma radiation – especially in the first few years of works which is when most of the identified radioactive waste will be excavated, moved and encapsulated in the WSF.

[10] Radon gas emanates as radium decays. It then decays itself to (solid) radon daughters, which are energetic alpha-emitters. Radon occurs in most rocks, soils. water and as traces in normal air. The inhalation of radon itself does not impose a major health risk as the majority of radon inhaled is exhaled again after a short period. However, at high concentrations it is a health hazard since its short half-life means that disintegrations giving off alpha particles are occurring relatively frequently. Radon's alpha-emitting radioactive decay products are strongly and causally linked to lung cancer in humans.

Impacts due to ingestion of contaminated material

Radioactive contamination can be transferred from hands to mouth when eating, drinking, smoking, or through poor personal hygiene.

Impacts due to inhalation of particulates and dust

With the presence of radioactive material at the site and the nature of the rehabilitation to take place, there will be areas of elevated radiation being disturbed. Dust may be generated by project activities:

1) Through the excavation, handling and transporting of material.
2) By the action of wind over surfaces exposed during remediation works.
3) By spills when transporting the radiological waste material onsite to different areas.

In all cases, the dust may be contaminated with radiation. Such dust may not be contained within the mine site boundary. That dust could contain radionuclides that, if inhaled or ingested, could result in an increased exposure to radiation for workers onsite and/or members of the public offsite. The airborne uranium ore dust associated with this work will contain long-lived alpha emitters of the natural uranium decay chain. Depending on size, these particles can get deep into the lungs and cause serious health problems. Larger particles may irritate the nose, throat and eyes.

Impacts due to contaminated vehicles or equipment leaving the project site

With the movement and handling of radioactive contaminated material as part of this operation, surfaces of vehicles and plant material will become contaminated with radioactive material. Sometimes, this radioactive contamination will become embedded into the surface of equipment and will require specialised treatment to remove it. This contamination will not be easily detected, as the metal surrounding the radioactive material will shield it from detection especially if the material enters cracks in a vehicle's chassis. If these vehicles are not checked properly, there is a risk of this radioactive material leaving the site, with the potential for health impacts to members of the public from exposure to radiation.

Impacts due to the disturbance of unidentified areas with elevated levels of radionuclides

There is a risk that not all areas within the project area with elevated radionuclide content were identified by the studies that have been completed to date. This being the case, due to the nature of radiation, there is a risk that higher than expected exposure levels may occur to workers. If this is the case, those workers potentially could be exposed to a dose that is higher than is acceptable.

Impacts due to contaminated runoff from rainfall events during earthworks

With the disturbance of contaminated material during the rehabilitation works, there is the risk of runoff material being affected by radioactive matter. This could either end up in the waterways surrounding the project or be deposited in areas downstream of the rehabilitated site in the EBFR. It has the potential to bio-accumulate in terrestrial and aquatic plants and animals, and increase the dose potential to Aboriginal people and members of the public *via* the ingestion pathway.

16.2.2. Post-works

Impacts due to elevated concentrations of radionuclides in waste storage facilities

The project design is such that radioactive material that is currently spread across the site is collected and contained within the WSF. As a consequence, there will be a local build-up of radionuclides within the WSF.

In the potential event of WSF failure – due to insufficient neutralant (*i.e.* lime), damage to capping and/or poor design, construction and/or material selection – radionuclides could be released as radon daughters or leachate contaminated by radioactive material. This could be a major source of groundwater impact in the future if the WSF is not designed, constructed and managed properly.

Impacts due to elevated residual radiation doses

The Traditional Owners desire that residual radioactivity in the environment after rehabilitation will not make it unsafe for them to access or use the Rum Jungle Mine site. If not all radioactive-contaminated areas are identified by the *Radiological Hazard Assessment* and therefore rehabilitated or a spill of contaminated material is not remediated, there is a risk that the post-rehabilitation dose limits will be exceeded – with potential implications for ongoing land use.

Impacts due to ingestion through food and water

Plants and animals present within the project area could be contaminated by radiation. Notwithstanding the Land Use Plan for the mine site is yet to be finalised, there is the potential for post-rehabilitation consumption by Traditional Owners of these animals and plants leading to an increased radiological dose that may lead to detrimental health effects. There are many potential ways by which long-lived alpha emitting radionuclide may enter the ingestion pathway. These include direct ingestion of material (*e.g.* soil by children, campfire cooking), bushfood consumption and use of groundwater or surface water (*e.g.* drinking, crops, livestock, consumption of livestock or wild animals that have been on the operational area). Higher dose rates to humans will be received from the consumption of foods from the vicinity of the contamination source. The recommended dose limits in ARPANSA (2016) is 1 mSv *per* year.

The lack of research information on ingestion pathway factors contributes to a knowledge gap regarding potential exposure pathways for people using the Rum Jungle site for traditional purposes. Currently the site is NT Crown land and access to site is restricted. There is no known access to site for traditional purposes and no site occupation either temporary or permanent. This ingestion pathway information is an important component of any dose assessment for people who may use the site in the future, whether it be for traditional ceremonies or customary harvesting practices. Access will remain restricted until rehabilitation works are complete and a radiological dose assessment is undertaken. This is discussed further in Section 16.3.3.

16.3. Proposed Mitigation and Management

This section details the mitigation measures that will be used to minimise the impacts described above. Many of these are prescribed by legislation and/or guidelines. The importance of establishing requirements for the protection of worker health, public health and the environment from the effects of radioactive waste cannot be understated.

The radiation residual risks associated with this excavation and construction project are Low to Medium; this is because much of the material encountered is of low radioactivity. The management measures presented below have been developed according to this Low risk.

16.3.1. Pre-works

A key risk associated with the remediation of a radioactive site is that not all areas within the project area with elevated radionuclide content are identified prior to works commencing. Consequently, a *Radiological Hazard Assessment* (EcOz, 2019b – see Appendix) was undertaken that covered all three sites where exploration or mining activities had occurred.

16.3.2. During Works

Project activities have been informed by the *Radiological Hazard Assessment Report* of this EIS. That assessment informed the location, extent and depths of radioactive material to be included within the Excavation Plan for the Rehabilitation Strategy.

Project Design

In the first year of rehabilitation earthworks, radiological soils will be excavated, placed over existing radiological soils and covered with a low permeability barrier blanket. A new waste rock storage will then be constructed over this radiological 'cell'. The relocation and burial of these materials early in the first year of the earthworks schedule will reduce overall worker exposure risks.

The project design has been adapted to eliminate any exposure or handling of uranium tailings previously disposed of in Main Pit; tailings previously disposed of in Dyson's (backfilled) Pit will similarly remain undisturbed.

Radiation Management Plan

The *Radiation Management Plan* (RMP) (EcOz, 2019 – see Appendix) addresses the potential radiological risks and necessary mitigation measures associated with the excavation, transport and placement of radiologically-contaminated materials at the Rum Jungle Mine site. The RMP provides mechanisms for the safe management and control of radiological exposures likely to impact humans, non-human biota and the environment during all activities. It outlines the systems and processes that will be put in place to ensure compliance with standards (guidelines and codes) and regulatory requirements relating to radiation protection. The RMP will be updated prior to commencement of the Stage 3 works.

Supervision

A Radiation Safety Officer will be present for the entire duration of the works. A Senior Radiation Advisor will visit the site weekly to:

- Attend initial personnel inductions to ensure that safe working procedures have been adequately discussed with workers.
- Implement and maintain the Radiation Monitoring Plan.
- Conduct inspections to ensure that safe working practices and records are being maintained.
- Be available for discussion of any issues and potential safety concerns that arise.
- Brief the management on appropriate radiation safety oversight matters.
- Conduct and oversee the close of the project radiological schedule including all equipment clearances.

Throughout works there will be tracking of material placement to record the mass of inert waste, radioactive waste and other material with geochemical risks delivered to the WSF, and to ensure waste is placed as required in WSF designs from site planning. That data will inform a regular review of the Material Movement Plan.

Safety of workers

The following precautions will be taken at the rehabilitated area to protect the health of workers:

- Induction *re* radiation for all employees and visitors to site.
- Management of radiological material by sectioning into clearly defined and signposted areas. Areas identified as having elevated levels will be excavated and placed first into the WSF, minimising worker exposure.
- If workers are unsure whether material they are working with is radioactive, the Radiation Safety Officer will test it using a radiation contamination meter.
- Access restrictions to areas of higher radiation levels.
- Good hygiene practices including personnel wash facilities and mobile equipment wash bays.
- PPE including disposable dust masks, gloves for handling radioactive material and work clothing that will be removed and washed at the end of the day at an onsite laundry area by an employee.

Safety of members of the public

Because of site access limitations and the distance to sensitive receptors, there is a very low risk that the total effective dose equivalent to individual members of the public would exceed the recommended level. The exception could be the landowners of Mt Burton, whose residence is near to the site. To minimise the risk of exposure, it is recommended that no members of the public – including the landowners – are present during the short period that waste rock is being excavated and hauled from Mt Burton to the Rum Jungle Mine site.

Dust management

The general management of dust – primarily through wetting of work areas – is detailed in Chapter 9 – Terrestrial Environmental Quality and Chapter 15 – Human Health and Safety. Additional measures that relate specifically to the threat posed by radioactive dust are:

- Radioactive material will be moved only during times of low wind.
- Machinery will have air-conditioned cabins with high-efficiency particulate air filters to limit occupational exposure during loading.
- Whenever possible workers will be positioned up-wind from any dust generating activities.
- Dust masks will be provided to all workers and required to be used during dusty conditions.

Spill management

The RMP and Chapter 9 – Terrestrial Environmental Quality details management measures to minimise the likelihood of a spill occurring and to ensure that the response to any spills is rapid and thorough.

Decontamination of vehicles and equipment

All equipment that has potentially been exposed to contaminated material (including plant air-conditioner filters and engine air filters) will be cleaned and checked for contamination before being allowed to leave the project area at the completion of the works program. The equipment will be decontaminated on a wash-down pad which drains into an onsite approved sump.

No piece of equipment shall be allowed to leave the site without a completed Radiation Clearance Certificate and written approval from the Project Manager.

Run-off management

As detailed in Chapter 9 – Terrestrial Environmental Quality, Chapter 11 – Hydrological Processes and the *Water Management Plan* (DPIR, 2019 – see Appendix), the development and implementation of an Erosion and Sediment Control Plan (ESCP) will help ensure that runoff is controlled and contained within the site. A further strategy for limiting surface runoff of radioactive material is limiting movement of high risk radioactive materials to only in the Dry season, having them sealed in the WSF by the Wet season.

16.3.3. Post-works

Minimising ingestion of radiation

The controls for minimising post-rehabilitation consumption by Traditional Owners of contaminated animals and plants include:

- A minimum cover thickness of 2 m over all stored waste rock onsite.
- Further studies of the ingestion pathway, in particular the aquatic pathway, with the collection and analysis of food samples prior to the reduction of restrictions set out in the Land Use Plan (see the *Radiological Hazard Assessment Report* for detail).
- Rehabilitation planning that excludes the use of native food plants during the rehabilitation process (see Chapter 7 – Rehabilitation Strategy) on the WSF. This should ensure that the risk is reduced for the bioaccumulation of radionuclides into plant materials.
- A Stakeholder Engagement and Communications Strategy that ensures people are aware of the risks (see Chapter 13 – Social and Economic Impact).

Maintenance of the integrity of the WSF

A suite of management measures are proposed to minimise the likelihood that the WSF fails in the future. These are detailed in other Chapters.

Minimising exposure to people spending extended periods on the rehabilitated site

In the event that high radiation areas are identified during site excavations, the areas will to be sign-posted and control of access will be maintained to prevent inadvertent access. In addition, the Stakeholder Engagement and Communications Plan (see Chapter 13 – Social and Economic Impacts) will ensure people are aware of the risks relating to spending extended period onsite.

Future land use of Rum Jungle depends on the Traditional Owners expectations, but could include some ceremonial uses, customary harvesting activities including hunting, stock grazing and tourism ventures.

The final Land Use Plan will be endorsed by a Contaminated Sites Auditor (see Chapter 7 – Rehabilitation Strategy) to confirm that land condition is safe for any of the proposed uses. Consequently, that Plan may include land use restrictions. It will be an important facet of future work to ensure that full dose assessments are performed on all designated critical groups. All of these dose assessments will rely on a positive reduction of dose at the project's conclusion, with the first critical group being able to estimate their dose assessment with real time data from the first year of construction.

16.4. Monitoring and Reporting

The RMP (EcOz, 2019 – see Appendix) details the radiation monitoring and reporting to be undertaken during construction works. Broadly, this will take the form of:

- **Area monitoring (routine and task-related)** which involves the collection of dose rate conditions onsite, and the subsequent assessment, interpretation and evaluation of this information.
- **Individual monitoring** collects information on exposures to individuals using personal electronic dosimeters.

- **Dust monitoring** using an air sampler to determine the concentration of long-lived, dust-borne, alpha emitters.
- **Radon monitoring** at the working sites using long-term passive radon/thoron gas monitors (RGMs).
- **Water monitoring** of both ground and surface waters.
- **Clearance monitoring** of haul routes, temporary laydowns and equipment that has potentially been exposed to radioactive material. Baseline surveys will be conducted on all haul routes.

Radiological close-out surveys will be conducted at Mt Burton, Mt Fitch and the Rum Jungle Mine site after remediation has taken place. This should be completed as part of the check monitoring program to ensure that both areas are within the acceptable radiation levels set prior to the remediation works taking place.

Ongoing monitoring to determine rehabilitation success and inform the residual human health risk (if any) will also be required post-construction as part of the Rehabilitation Monitoring Plan.

16.5. Statement of Residual Impact

Previous studies – summarised in the *Radiological Hazard Assessment Report* (EcOz, 2019b – see Appendix) – have informed the extent of radiological contamination at Mt Burton, Mt Fitch and Rum Jungle that requires remediation. That contaminated material will be excavated, moved and encapsulated within the WSF as detailed in Chapter 7 – Rehabilitation Strategy. There will be monitoring procedure in place to ensure all material above a certain radiological level is treated in that way. By the end of works, there should not be any areas with unacceptable radiation levels.

Working with radioactive materials is a heavily-regulated activity. The Proponent's objective is best practice – *i.e.* to not just be below reference levels for dose limits, but to further reduce exposure to *as low as reasonably achievable*. The RMP (EcOz, 2019 – see Appendix) details procedures and measures that will ensure that no workers on this project will receive unacceptable doses of radiation. Because of site access limitations and the distance to sensitive receptors, there is a very low risk that the total effective dose equivalent to individual members of the public would exceed the recommended level.

Post-works, some additional studies may be needed to inform potential impacts to certain critical groups – particularly regarding ingestion pathways. Those studies, and the interpretation of their results, will be informed by the Land Use Plan which has only just recently been developed. Certain land use activities may be restricted or modified depending on the outcomes of those studies

On the basis of the assessment of potential impacts and the recommended mitigation measures in this chapter of the EIS, overall, the proposed rehabilitation of the site is not likely to impose significant adverse radiological effects on the environment or humans.

16.6. References

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ARPANSA (2016) *Radiation Protection Series C-1 – Code for Radiation Protection in Planned Exposure Situations*.

ARPANSA (2017) *Guide for Radiation Protection in Existing Exposure Situations*. Radiation Protection Series G-2.

Bollhöfer A.., Pfitzner K., Ryan B., Esparon A. and Brazier J. (2007) *Radiological Assessment of Rum Jungle Mine, Northern Territory*, The Environmental Research Institute of the Supervising Scientist, Supervising Scientist Division, Department of Environment and Water Resources. Report to the NT Department of Natural Resources, Environment and the Arts and Commonwealth Department of Industry, Tourism and Resources.

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Hughes A. and Bollhöfer A. (2010) *Radiological investigations in the Rum Jungle and East Finniss River areas 2009*. Internal report 584 by the Supervising Scientist to the Department of Primary Industry and Resources, Northern Territory.

Hydrobiology (2016) *Rum Jungle Impact Assessment Final Report.* Report to the Department of Mines and Energy, Northern Territory Government.

IAEA (2018) *Safety Standards Series no. ssr-6 (rev. 1) Regulations for the Safe Transport of Radioactive Material*, Specific Safety Requirements. International Atomic Energy Agency, Vienna.

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Radiation Advice and Solutions Pty Ltd (2014) *Rum Jungle Radiation Monitoring Report*. Report to the Department of Mines and Energy, Northern Territory.

SRK (2012) *Geochemical Characterisation of Waste at the Former Rum Jungle Mine Site.* Report to the Department of Resources, Northern Territory.

Tropical Water Solutions (2008) *Water Quality Profile & Bathymetric of White's and Intermediate Open Cuts*. Rum Jungle. Unpublished report

16.7. References included in Appendix

Department of Primary Industry and Resources (2019) *Draft Water Management Plan, Stage 3 Rum Jungle Rehabilitation Project*.

EcOz (2019*) Radiation Management Plan, Rum Jungle mine rehabilitation.* Prepared for the Department of Primary Industry and Resources, Northern Territory.

EcOz (2019b) *Rum Jungle radiological hazard assessment report*. Prepared for Department of Primary Industry and Resources, Northern Territory.

GHD (2019f) *Rum Jungle Stage 3 EIS Risk Register* – Rum Jungle Project Team.

Radiation Advice and Solutions Pty Ltd (2014) *Rum Jungle Radiation Monitoring Report*. Report to the Department of Mines and Energy, Northern Territory.

17. EPBC Matters

Tables

17.1. Introduction

Under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act), an action that will have, or is likely to have, a significant impact on a matters of national environmental significance (MNES) is considered to be 'controlled action' and requires approval by the Australian Government Minister for the Environment.

The EIS ToR requires an assessment of matters that are protected under Part 3 of the EPBC Act (MNES). This chapter outlines the risks to MNES and provides guidance to the specific EIS Chapters in which the relevant EPBC Act matters, including the significance of the residual impact of the proposal to identified values, are addressed.

Section 17.4 of this chapter addresses matters of ecologically sustainable development (ESD) as required under the *General Guidance for Proponents Preparing an Environmental Impact Statement* (NT EPA, 2019b) and EPBC Act.

For the context of discussion of MNES, the Stage 3 Rum Jungle Rehabilitation Project, as described in this EIS, provides for a project with planned net environmental and social benefit as it is the proposed rehabilitation of a mining legacy.

17.2. EPBC Act Referral

The EPBC Act objectives, relevant to this project, are:

- provide for the protection of the environment, especially those aspects that are MNES
- conserve Australian biodiversity
- protect and conserve of important natural and cultural places
- promote ecologically sustainable development (ESD) through the conservation and ecological sustainable use of natural resources
- recognise the role of Indigenous people in the conservation and ecologically sustainable use of Australia's biodiversity
- promote the use of Indigenous peoples' knowledge of biodiversity with the involvement of, and in cooperation with, the owners of the knowledge.

The Former Rum Jungle Mine Rehabilitation Project (Ref: EPBC 2016/7730) was referred to the Australian Government Minister for the Environment for consideration under the EPBC Act. On 4 August 2016, a delegate for the Minister determined that the proposed action is a 'controlled action' and would require assessment and approval under the EPBC Act before it can proceed. The controlling provisions protected under Part 3 of the EPBC Act are:

1. Listed threatened species and communities (sections 18 & 18A).
2. Protection of the environment from nuclear actions (sections 21 & 22A).

The Proponent submitted a variation to the Department of the Environment and Energy on 23 September 2019. On 24 October 2019, a delegate for the Minister accepted the variation to the proposal in accordance with section 156B of the EPBC Act.

The project is being assessed under the bilateral agreement between the Australian and Territory Governments made under section 45 of the EPBC Act.

17.3. Protected Matters Search

A Commonwealth Department of the Environment and Energy Protected Matters Search was conducted by the Proponent in preparation for this EIS (Rum Jungle Mine site and a 100 km buffer). The results of the search supported and directed the subsequent surveys onsite, the results of which have informed project design to ensure any and all potential impacts on MNES have been reduced to acceptable levels through design, schedule or other controls.

The outcomes of the Protected Matters Search, relevant to the project's controlling provisions, are presented in Table 17-1. There are no World Heritage areas, no National Heritage places, no Ramsar wetlands of international importance and no Threatened Ecological Communities within a 10km radius of the project area.

Table 17-1: Summary of protected matters (100 km buffer)

Protected matter	Number	Comment
World Heritage Properties	1	Kakadu National Park
National Heritage Places	1	Kakadu National Park
Wetlands of International Importance	1	Kakadu National Park
Commonwealth Marine Area	1	EEZ and Territorial Sea
Listed threatened ecological communities	0	-
Listed threatened species	50	8 flora species 34 fauna species 8 estuarine/marine species
Listed migratory species[11]	69	23 Marine Species 6 Marine Birds 6 Terrestrial Species 34 Wetland Species

Other matters protected by the EPBC Act of note include the Finniss Floodplain SoCS which is listed as a Nationally Important Wetland. The SoCS forms a component downstream receiving environment.

Not all MNES identified in the Protected Matters Search as potentially occurring within the project area require assessment - however a full search result list is provide in EcOz (2019a) *Review of terrestrial ecology surveys relevant to the Rum Jungle EIS* (see Appendix). In updated project ecological survey works, EcOz (2019a) conducted a 'likelihood of occurrence' assessment for threatened species based on all the information available regarding the current state of the environment within the project footprint. The assessment considered the habitats present, historic regional records of threatened species, new threatening processes, any changes in the conservation status of species and changes in surrounding habitat availability and quality.

A list of 59 threatened species that have potential to occur in the terrestrial ecosystems within the Pine Creek Bioregion was generated (EcOz, 2019a) from desktop analysis of databases including a Protected Matters Search. For each of these species, the likelihood of it occurring within the project footprint was then assessed based on any desktop and field information relating to habitat requirements, distribution and the number and dates of proximate records (including those from past surveys). Species having a high or medium likelihood of occurrence are list in Table 17-2. These species have a reasonable likelihood of occurring within the project footprint and have therefore been assessed for project impact within this EIS (Chapter 12 – Aquatic Ecosystems and Chapter 14 – Terrestrial Flora and Fauna).

[11] Not a controlling provision on Notification of Referral Decision dated 4 August 2016.

Table 17-2: Threatened Species Likelihood of Occurrence (High and Medium Only) (EcOz, 2019a)

Likelihood	Scientific Name	Common Name	Class	Status	
				NT	Cth
High	*Cycas armstrongii*	Darwin Cycad	Plant	VU	-
	Geophaps smithii smithii	Partridge Pigeon	Bird	VU	VU
	Mesembriomys gouldii gouldii	Black-footed Tree-rat (Kimberly and mainland NT subspecies)	Mammal	VU	EN
	Varanus mitchelli	Mitchell's Water Monitor	Reptile	VU	-
	Varanus mertensi	Mertens' Water Monitor		VU	-
Medium	*Tyto novaehollandiae kimberli*	Masked Owl (mainland Top End subspecies)	Bird	VU	VU
	Erythrotriorchis radiatus	Red Goshawk	Bird	VU	VU

VU = Vulnerable: EN = Endangered

This list generated by EcOz (2019a) does not contain some species for which there are proximate historic records as the environmental conditions have changed in such a way that the likelihood of these species being extant in the project footprint has been significantly reduced. A summary of findings (EcOz, 2019) includes:

- **Fawn Antechinus** has been recorded several times in earlier surveys onsite and at the Browns Oxide site over 2005 - 2009. The more recent small mammal surveys by Eco Logical (2014) and EcOz (2019) failed to record the species, despite having survey sites in the same habitat types proximate to the previous records. The limits of its range are poorly known, but it is suggested that there has been a range contraction as recent surveys have failed to locate any individuals across central and east Arnhem Land (referenced in Woinarski *et al.*, 2014), where it was historically known to occur.
- The **Northern Quoll** was recorded within the Browns Oxide site and Rum Jungle site (2002 – 2009) however, it has not been recorded since. More recent small mammal surveys across the extent of the mine site (Eco Logical, 2014; EcOz, 2019) did not record the species. This species now has a very low likelihood of persisting within the project footprint. The mortality of Northern Quolls due to Cane Toad ingestion has been very high wherever these two species co-occur and there are few post-Cane Toad records of Northern Quoll anywhere.
- The **Pale Field-rat** was recorded twice in the Browns Oxide Project prior to development (EMS, 2005) and numerous times within the Yarram site (Low Ecological Services, 2012). Low Ecological Services found that the species occurred in the tall *Mnesithea rottboellioides* grasslands and, to a lesser extent, in the monsoon vine thickets within the centre of the Yarram site, most likely due to its proximity to the grasslands. EMS trapped the species in *Melaleuca* woodland and recorded characteristic burrow systems throughout *E. miniata, E. tetrodonta* and *E. chlorostachys* open forest. The recent small mammal surveys mentioned above did not record the species.
- **Northern Brush-tailed Phascogale** was recorded in 2002 when spotlighting within the Browns Oxide site (pre-development) (EMS 2005). Although this species probably occurs naturally in low densities, it has only been recorded in Kakadu National Park, Coburg Peninsula and the Tiwi Islands throughout the last 10 years, despite many extensive general wildlife surveys across broad regions during that time (Woinarski *et al.*, 2014). There has likely been a significant recent decline in range and/or population size (Woinarski *et al.*, 2014). The recent small mammal surveys mentioned above did not record the species.
- There are nine historic records for **Gouldian Finch** all assigned to a waypoint in the south-east corner of the Browns Oxide site (just to the south-west of the Rum Jungle site). These range from 1897 to 1995, and each of them has within its metadata the note: Gay Crowley/Riikka Hokkanen clean-up of Gouldian Records 2009. When Gay Crowley was contacted by the EcOz (2019a) she could not recall the provenance of these records. It is suspected that these are regional records that were, at some stage, clumped together and given a generalised geo-reference of latitude -13o, longitude 130o. Despite being a conspicuous species, none of the surveys recorded Gouldian Finch and there is no breeding habitat (wooded hills of Snappy/Salmon Gums) for this species present within the project footprint. It is possible that this species occurs, from time to time, within the project footprint, but there is a low likelihood that it is resident.
- **Floodplain Monitor** was recorded by EMS in 2002 at a drainage area along Rum Jungle Creek (immediately west of Browns Oxide project area), but has not been observed in the region since. This species has undergone extensive decline due to Cane Toad ingestion and there are few records of the monitor persisting where the two species co-occur (Doody *et al.*, 2009). The Floodplain Monitor now has a very low likelihood of persisting within the project footprint.

17.4. Relevant Matters of National Environmental Significance (MNES)

The existing environment has been described previously in Chapter 5 – Regional Setting and Chapter 6 – Regional Setting. Table 17-3 indicates the EIS Chapters where EPBC Act controlling provisions – in terms of potential impact, mitigation measures and likelihood of significant impact - are addressed in detail.

Table 17-3: EIS Chapters addressing the project's EPBC Act controlling provisions

EPBC Act Controlling Provisions	EIS Chapter
Listed threatened species and communities	**12** Aquatic Ecosystems **14** Terrestrial Flora and Fauna
Protection of the environment from nuclear actions	**6** Existing Environmental Condition **7** Regional Setting **8** Historic and Cultural Heritage **9** Terrestrial Environmental Quality **10** Inland Water Environmental Quality **11** Hydrological Processes **12** Aquatic Ecosystems **13** Social and Economic Impact **14** Terrestrial Flora and Fauna **15** Human Health and Safety **16** Radiation

17.4.1. MNES Residual Impacts

The residual impacts are explored in detail within each relevant EIS Chapter listed in Table 17-3 and are summarised below.

Listed threatened species and communities

The project footprint is predominantly a highly disturbed landscape because of historical mining activity and/or infestation by Gamba Grass which has also caused altered fire regimes. This has had a negative impact on the terrestrial flora and fauna values of the footprint and surrounds. The goal of the project is to rehabilitate previously disturbed land in such a way that environmental values and habitat condition are significantly improved. Because of the nature of the project and the already reduced habitat quality within most of the footprint, most project activities present a low risk to those values. If successful, the result should be net increase in terrestrial flora and fauna values – namely improved vegetation health and habitat condition, reduced landscape fragmentation and increased fauna diversity and abundance.

Active steps in the project design phase have been taken to reduce the need to further disturb currently undisturbed footprint. The new WSF to be constructed onsite is to be placed in an area that is by majority, already disturbed. Additionally, clean cover borrow materials are to be sourced from historically disturbed footprints thus reducing the impact to intact ecological communities.

The footprint that will be disturbed by land clearing is unlikely to represent important habitat for the Masked Owl and Red Goshawk. Masked Owls and Red Goshawks forage across a broad range of Top End habitats, but have more specific breeding and roosting habitat requirements. Breeding habitat for the Masked Owl is not found at Mt Burton, Mt Fitch and the low permeability and granular material borrow areas; possible breeding habitat is located at Rum Jungle in the tall, dense Eucalypt woodlands (unit 10) which will not be disturbed. No nesting habitat for the Red Goshawk was found in the project footprint; riparian vegetation along the East and West Branches of the Finniss River likely represent suitable nesting habitat.

The occurrence of the Partridge Pigeon in the project footprint is <u>not</u> considered an 'important' population (as defined in *EPBC Significant Impact Guidelines 1.1* (DoE, 2013)). The project footprint is located well within the known distribution of this species and habitat is generally not suitable to its presence due high Gamba Grass (and other weed) invasion.

The Black-footed Tree-rat, however, is considered to be an important population (see Chapter 14 – Terrestrial Flora and Fauna, Section 14.2.2). Further impact assessment concluded that the likelihood of the local population of Black-footed Tree-rat as being significantly impacted by this project as Low as a negligible proportion of suitable habitat will be disturbed (temporarily) during construction works (Section 14.3.6). Gamba Grass management, which is an issue for the entire Top End, is imperative to ensure suitable habitat is not lost.

Protection of the environment from nuclear actions.

The EIS has assessed the potential risks associated with the relocation of waste rock and radiologically contaminated soils to either Main Pit or the new WSF, and mitigation measures to reduce those potential risks. It can be concluded:

- predicted radiological doses to workers is minimal as the design has reduced the need to handle radiological materials across the project and retained existing below surface storage for the majority of the historic mine tailings (Chapter 16 – Radiation). The *Radiation Management Plan* (EcOz, 2019 - see Appendix) addresses the necessary mitigation measures associated with excavation, transport and placement of radiologically contaminated materials during Stage 3 works.
- the project is not expected to adversely impact downstream water quality or hydrology; rather an improvement to water quality supporting Finniss River system beneficial uses is expected. This is achieved through –
  - hydrological assessment and modelling to inform river crossing designs
  - development of an ESCP and Water Management Plan (see Appendix), and installation and maintenance of appropriate sediment control measures where required
  - potential WSF seepage management *via* monitored natural attenuation processes (Chapter 10 – Inland Water Environmental Quality). The primary Contaminants of Concern (copper and other heavy metals) are predicted to remain attenuated within the waste rock mass, however saline drainage may form from within the WSF. The volume of saline drainage will be reduced as far as possible through the methodologies of surface capping and stored rock mass density increase by compaction. Modelling indicates very low loading due to the low anticipated volume.
- vegetation clearing, especially of sensitive or significant (high quality) vegetation, has been reduced as enabling works, the WSF and borrow areas are proposed to be located in highly disturbed areas, and through recommended native vegetation buffer widths (DENR, 2019) and the Cycad Salvaging Procedure (Chapter 14 – Terrestrial Flora and Fauna).
- the Ecological Restoration Strategy takes into account analogue land and vegetation information to target appropriate vegetation types and framework species for each domain to promote effective vegetation (Chapter 7 – Rehabilitation Strategy).
- Weed and Feral Animal Management Plans will be assist to manage (especially in respect of weeds species established throughout the Coomalie region) or minimise invasive species impact to threatened species.
- disturbance footprints have taken into account historic and cultural heritage sites, to the extent known (Chapter 8 – Historic and Cultural Heritage). A CHMP will be developed and implemented to protect known sites and unknown sites if identified during excavation works or land management activities.
- the predicted noise level increase associated with the project at the nearest residential and public receptors will be insignificant.
- that ambient air quality values can be maintained through the successful implementation of the Vegetation Clearing Procedure and an Air and Dust Management Plan to minimise dust emissions.
- the project provides an opportunity for delivering business opportunities for existing local businesses, and employment and training opportunities for Traditional Owners and locals, in addition to landowners of the two proposed borrow areas – FRALT and CCGC – identifying an innovative land use for those areas.

Summary

The assessment of risks to MNES and mitigation measures described to protect biodiversity, surface and ground water, and cultural heritage values will minimise risks to the environment within (and beyond) the project area. The project therefore is unlikely to cause significant impacts to MNES.

17.4.2. Environmental Offsets

Under the EPBC Act, projects that consist of negative residual environmental impacts are required to outline measures in the project proposal to offset adverse actions on the environment. The *Environment Protection and Biodiversity*

Conservation Act 1999 Environmental Offsets Policy (SEWPaC, 2012) outlines the Australian Government's approach to the use of environmental offsets. It is designed to:

- provide improved certainty on how offsets are determined, including the appropriate nature and scale of those offsets; and
- ensure the efficient, effective, timely, transparent, proportionate, scientifically robust and reasonable use of offsets under the EPBC Act.

Suitable offsets must deliver an overall conservation outcome that maintains or improves the viability of the aspect of the environment that will be affected by the project proposal and is protected by national environmental law.

The development of an EIS for this project proposal is unique in that while the proposal will directly impact MNES, the purpose of the project is to deliver a net positive outcome for currently impacted MNES and the environment as a whole by improving long-term environmental condition onsite and in the downstream EBFR.

During Stage 3 of the project there will be some impact to MNES which cannot be avoided such as vegetation clearing or extraction of materials for the WSF cover system as detailed in pervious EIS Chapters. However the negative impact of these activities has been minimised or mitigated as far as possible and are inherently offset by the project's long-term rehabilitation goals thus resulting in the goal of minimal to no net negative residual impacts. The impact assessment, as described in this EIS, predicts that the residual impacts on the environment will be a net positive outcome alongside a positive social and economic impact.

Despite the local Black-footed Tree-rat population being an important population (see Chapter 14 – Terrestrial Flora and Fauna, Section 14.2.2) under the EPBC Act, the likelihood of it being significantly impacted by this project is Low as a negligible proportion of suitable habitat will be disturbed (temporarily) during construction works (Section 14.3.6).

The objective of restoring site conditions that will support a post-rehabilitation Land Use Plan is critical for the cultural rehabilitation of the site and for productive steps towards Warai and Kungarakan reconnection to this impacted country. The Rum Jungle site is home to several sacred sites and cultural heritage places therefore preservation of existing assets and restoration of the EBFR elements is crucial to healing landscape and healing spiritual connection to site.

Taking in to account that there are no significant residual environmental impacts, offsetting is not required. This project predicts environmental gain and, additionally, the project has been designed to deliver social and economic co-benefits, such as seeking to engage Traditional Owners to undertake management actions and restoring poorly vegetated land parcels (*e.g.* Old Tailings Dam area, vine thicket stand) where no rehabilitation activities to address contaminating processes are proposed.

17.5. Ecologically Sustainable Development (ESD)

Sustainable development is defined as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (WCED, 1987). In 1992, COAG endorsed the National Strategy for Ecologically Sustainable Development to facilitate a coordinated and cooperative approach to ESD which it defined as 'ESD means using, conserving and enhancing a community's resources so that ecological processes, on which life depends, are maintained and the total quality of life, now and in the future, can be increased'.

17.5.1. Legislative Context

The guiding principles of ESD are incorporated into many Acts of parliament including the EPBC Act, the *Northern Territory Environment Protection Authority Act 2012* (NT) (NT EPA Act) and the *Environment Protection Act 2019* (NT) (EP Act).

<u>Environment Protection and Biodiversity Conservation Act 1999</u>

The EPBC Act provides for the environmental protection of matters of national significance and the promotion of sustainable development. The Act includes the guiding principles for ESD.

<u>Northern Territory Environment Protection Authority Act 2012</u>

This Act establishes the NT EPA as a body that undertakes environmental assessments. When providing advice or a report to the Minister, the NT EPA must have regards to the principles of ESD.

<u>Environment Protection Act 2019</u>

The relevant objects of this Act are to promote ESD and recognise the role of environmental impact assessment in protecting and managing the environment of the NT. It also provides guidance on the principles of ESD.

17.5.2. Principles of Ecologically Sustainable Development

The guiding principles of ESD as stated in the EPBC Act, and referenced in the EIS ToR, are:

- Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations.
- If there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.
- The principle of inter-generational equity – that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations.
- The conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making.
- Improved valuation, pricing and incentive mechanisms should be promoted.

Provisions in the NT EPA Act and EP Act similarly reflect the guiding ESD principles above.

17.5.3. Application

The guiding principles of ESD have been considered throughout the design and planning process for the project. This section describes the application of each of the guiding principles into the assessment of impacts and proposed avoidance, mitigation and management measures, as demonstrated throughout the EIS. It is important to note that this project, as described, is planned to deliver a net environmental and socio-economic gain to the existing condition at Rum Jungle. This is a unique frame of reference for an EIS.

Integration of Economic, Social and Environmental Considerations

The Proponent notes that the project must be considered based on its potential impacts to not only the environment, but also to social and economic development. ESD requires a mutual consideration of impacts across all components that make up sustainable development.

The Proponent has adopted an iterative and consultative approach to the development and design of the project. This includes research, site investigation, consultation with stakeholders and the consideration of expert technical advice in developing the project.

Specialists across a range of technical disciplines have completed studies to determine the potential environmental and social impacts that could be associated with the project (Table 17-4). These studies were based on a detailed understanding of the Rum Jungle environment and past experience with similar projects.

Table 17-4: Specialist technical studies

Air Quality, Noise and Vibration	Surface Water	Roads and Transport (commitment)
Contaminated land	Terrestrial and Aquatic Ecology	Social
Geology	Radiation	Indigenous and Non-Indigenous Cultural Heritage
Geochemistry	Tenure and Land use	Preliminary Hazard and Risk
Groundwater	Landscape and Visual Amenity	Rehabilitation

The outputs of each study detailing the potential impacts and proposed mitigation, management and avoidance measures are summarised in the relevant EIS Chapters and Appendices.

Precautionary Principle

The precautionary principle states that scientific uncertainty should not be used as a reason for postponing measures to prevent environmental degradation. The purpose of the EIS itself is precautionary, as the document engages with the potential for the Stage 3 Rehabilitation project to impact the environment.

In order to fulfil the requirements of the precautionary principle, the Proponent has considered the following measures:

- Significant technical studies to improve understanding of key risks such as AMD sources. Key assumptions where assessed for technical risk and additional work was carried out to improve certainty where required.

- Avoidance of disturbance of existing ecological values wherever possible such as site selection for permanent landforms (*e.g.* borrow pits and WSF)
- Ground and surface water modelling work has incorporated conservative assumptions wherever an absence of data exists.
- Project delivery flexibility in acknowledgement of the unknowns inherent in brownfield site operations (*e.g.* location of unmarked landfill)
- A risk-based approach was used to determine significant project risks. These were assessed through a qualitative process to consider the likelihood and consequence of individual risks. Where possible significant risks were then quantified to further evaluate their specific impacts.
- Use of statutory guidelines was applied to protect relevant environmental values (*e.g.* those associated with air quality, and noise and vibration parameters).
- Avoidance, mitigation and management measures will be implemented (and monitored) to ensure that the potential for serious or irreversible damage to the environment is minimised.

Intergenerational Equity

This is a value concept that ensures planning considers the long-term consequences of actions and the rights of future generations. Any activity undertaken today should not prejudice the standard of life or environment available to present and/or future generations. The project has considered intergenerational equity through comprehensive analysis of project impacts and proposing management techniques that address any identified issues.

The principle objectives of this project to restore onsite and downstream environmental values (to the extent practicable) can be expected to restore a multi-generational impact. Project delivery to support Traditional Owner participation in Stage 3 works and future stewardship activities can provide:

- (Increased) Opportunity to work on country and forge a new connection to this disturbed landscape.
- Containment of hazardous materials (*e.g.* ACMs, radiologically contaminated soils, AMD generating waste rock) to the WSF and Main Pit.
- Opportunity for a sustainable, long-term onsite land use at Rum Jungle that combines traditional knowledge, current practices and aspirations of Traditional Owners for their future.
- Opportunistic development of the CCGC low permeability borrow site into a facility that encourages greater community of the adjacent RJCS recreational area.

In addition to restoring the existing environment, the project may provide other benefits to current and future generations. Increased economic growth through the stimulation of the local and regional economy through:

- Skills development and employment opportunities for Traditional Owners and local residents.
- Business development or improved outcomes.

The ongoing contamination issues arising from the Rum Jungle site has caused impact to the EBFR for over 60 years. The Stage 3 Rehabilitation Project has an estimated 10 year duration; however, subsequent Stage 4 works may require up to 20 additional years of monitoring to confirm successful performance. Although the proposed actions taken during Stage 3 should have an immediate improvement on the EBFR, ecosystem recovery may take a generation. The Stage 3 works are intended for the long-term improvement of water, land and ecological values for future generations.

Conservation of Biological Diversity and Ecological Integrity

The environment surrounding the project, and that which could be impacted by activities, has important ecological values. This includes flora and fauna, vegetation communities and habitat features which are currently impacted due to historic mining practices and current day AMD impacted waters. This is a rehabilitation project with the primary objective being to restore EBFR water quality and thus ecological condition.

The Proponent’s preferred approach is:

- Avoid areas of high environmental value and site new rehabilitation domains or enabling services to avoid or minimise vegetation clearance wherever practicable.
- Select potential borrow material pits within land that is already disturbed wherever practicable.

The Ecological Rehabilitation Strategy set out in Chapter 7 – Rehabilitation Strategy of this EIS details the planned methodology and target ecosystems to be incorporated into the project landforms. The threatening processes of weed infestation and altered bushfire regimes present the greatest risk to ecological values outside of the ongoing AMD processes and are discussed in Chapter 14 – Terrestrial Flora and Fauna.

Improved Valuation, Pricing and Incentive Mechanisms

It is important to note that in the traditional sense of 'development' that this project falls outside this definition. This is a rehabilitation project where there is no net economic gain to the Proponent whilst seeking to minimise existing environmental impact and improve cultural values. As this proposal would be a publicly funded project it is critical that sound cost-benefit analysis is carried out for all elements of the project.

The development of this EIS was carried out in consideration of both the cost of activities, as well as the social and environmental benefit that could be achieved.

The Proponent's preferred approach includes:

- Proposed recovery of WSF foundation material and its use as cover material to reduce imported material volumes.
- Investigation into the opportunity to lease the existing site facilities at the adjacent Browns Oxide Mine to reduce the cost, materials and other resources needed to develop, decontaminate and decommission these facilities should they be built on the Rum Jungle site.
- Recycling of generated waste materials wherever practicable.

17.5.4. Commitment to Ecologically Sustainable Development

The Proponent is committed to sustainable development and will ensure all activities balance the social, environmental and economic aspects to deliver sustainable results. Progress of the project will be monitored and evaluated over time to ensure that the guiding principles of ESD continue to be considered and adhered to throughout project execution.

17.6. References

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18. Project Alternatives

Figures

Tables

18.1. Introduction

The EIS ToR require the Proponent to describe feasible alternatives to carrying out the proposal. This chapter describes and reviews all feasible alternatives for the project that were considered during Stages 1 through 2A of the Rum Jungle Rehabilitation Project.

18.2. Alternative Rehabilitation Scenarios

In Chapter 7 of the Conceptual Rehabilitation Plan (DME, 2013), a number of potential rehabilitation scenarios were considered:

- Undertake no further rehabilitation works.
- Re-cover the existing WRDs and Dyson's (backfilled) Pit (*in situ*).
- Backfill the Intermediate and Main Pits, and consolidate the remaining waste rock to either Main or Dyson's WRD.
- Backfill Main Pit only (Intermediate Pit remains water filled) and recover remaining 1980s structures (*in situ*).
- Backfill the Intermediate and Main Pits, and relocate the remaining waste rock for consolidation into a new WRD located within the Rum Jungle Mine site.

Rehabilitation works at Mt Burton and/or Mt Fitch were not considered.

These scenarios were evaluated using Multiple Accounts Analysis (MAA) – a tool for evaluating different options or alternatives for a project by weighing the relative benefits and costs of a variety of independent factors (Shaw *et al.*, 2001). The evaluation was undertaken in 2013 with input from the (then) Rum Jungle Working Group and Traditional Owners. The evaluation process focused on four key categories: environmental, technical, cultural and financial.

A summary of the results is presented in Table 18-1. The preferred scenario was to backfill both pits and relocate remaining material into a new WRD. It is important to note that six years have transpired since that MMA was undertaken. In that time, there have many more studies, meetings and consultations undertaken, and modelling completed. As result, the rehabilitation strategy detailed in this EIS is an improvement on the abovementioned preferred scenario, but is more closely aligned to that scenario than any of the others evaluated in the MMA process.

Table 18-1: Summary of MMA results (DME, 2013)

Category	No rehab.	Re-cover WRDs and Dyson's (backfilled) Pit	Backfill pits & consolidate to an existing WRD		Backfill Main Pit only and recover	Backfill pits & develop new WRD
			Main	Dyson's		
Environmental	3.3	4.3	6.6	4.4	6.9	8.0
Cultural	1.3	2.3	4.6	5.0	3.9	8.1
Technical	4.3	3.9	5.4	3.3	5.7	7.3
Total cost (millions $)	-	$64	$100	$113	$79	$109
Overall score	2.9	3.5	5.5	4.3	5.5	7.8
Overall rating	**6**	**5**	**3**	**4**	**2**	**1**

18.2.1. No Rehabilitation Works

The *no rehabilitation works* scenario assumes that no further improvement works would be undertaken on the Rum Jungle site, at Mt Burton or at Mt Fitch. Under this scenario, the contamination levels on the site, and the downstream impacts to the EBFR and Finniss River (described in Hydrobiology, 2016), would, at best, remain similar to current conditions. It is highly likely that further degradation to the existing WRD cover systems could occur, increasing the contaminant load to the EBFR.

Under the alternative to not proceed with the proposal, the intended future Land Use Plan could not be supported with the current site contamination profile.

When evaluated using MAA, this scenario was, by far, the least favourable option. As already detailed in this EIS, the performance of the WRD covers constructed during the 1980s has declined substantially over time. This decline in performance is primarily the result of inadequacies in the original design. Without intervention, performance of the existing covers will continue to decline over time. As a minimum, the covers need to be repaired or replaced.

18.2.2. Re-cover Existing WRDs

This scenario focused on constructing new cover systems over the existing waste landforms, and did not involve any major relocation of waste materials. It included other improvements, *e.g.*, the shape of the WRDs, some WRD consolidation and a clean-up of residual contaminated soils onsite.

This scenario scored poorly for environmental performance. It had a significantly higher likelihood of ongoing contamination to surface water and groundwater because the WRD would still be unlined and would remain located close to watercourses – two factors that create substantial opportunities for ongoing AMD to the East Branch.

18.2.3. Backfill Pits and consolidate to an Existing WRD

Two scenarios were evaluated that involved backfilling the Intermediate and Main Pits, and consolidating remaining waste rock to one of the remaining WRDs – Main or Dyson's. These scenarios scored lower than the scenario presented in Section 18.2.5 because of the likelihood of ongoing, albeit significantly reduced, contamination of groundwater and surface water.

18.2.4. Backfill Main Pit only and recover Remaining WRDs

This scenario considered backfilling Main Pit only and recovering remaining historic rehabilitation structures (part of Main WRD, Dyson's (backfilled) Pit and Dyson's WRD) in place. This scenario scored lower than the scenario presented in Section 18.2.5 because of the likelihood of ongoing, albeit significantly reduced, contamination of groundwater and surface. It scored higher that than previously mentioned scenarios involving backfilling of both pits as Intermediate Pit was could act as a buffer for diluting first flush contaminants.

18.2.5. Backfill Pits and develop a New WRD

The final scenario considered involved backfilling the Intermediate and Main Pits, and consolidating all remaining waste rock into a new WRD somewhere within the Rum Jungle Mine site. This was ranked the highest of the proposed scenarios. It was considered particularly effective for improving surface water quality in the East Branch, limiting further generation of AMD and minimising further groundwater contamination. This scenario achieves these environmental outcomes by consolidating waste rock further away from the watercourses than existing WRDs in a lined facility, and by treating seepage collected by the liner system.

The rehabilitation strategy presented in this EIS is a variation on the preferred scenario within the Conceptual Rehabilitation Plan (DME, 2013).

18.2.6. Groundwater Recovery and Treatment Only

A more recent proposed alternative, and one not evaluated in 2013, is to proceed only with the installation of the groundwater SIS system for the Intermediate and Main WRD existing AMD-impacted groundwater plumes (as detailed in Chapter 10 – Inland Water Environmental Quality). This would provide an improvement to the EBFR quality (by reducing the load of copper and other Contaminants of Concern to the EBFR) which would, in turn, expedite recovery of the downstream aquatic ecosystem. However, the installation of this system would not address the root cause of AMD production on the Rum Jungle site.

This alternative would be a considerable cost-saving option; however, it would not support the intended future Land Use Plan.

18.3. Alternatives within the Rehabilitation Strategy

Once the preferred rehabilitation strategy had been chosen there were, for some components of that strategy, different methodologies from which to choose. These are discussed in this section.

18.3.1. Tailings Storage Methodology

Several iterations of tailings storage methodology have been investigated over the course of the Rehabilitation Project Stages 1 to 2A. Historic tailings are currently stored at depth (*i.e.* well below natural surface elevation) within the Main Pit and Dyson's (backfilled) Pit. These tailings are both radiological and potentially acid forming.

Initial proposals for Main Pit tailings treatment involved:

1. Dewatering the Main Pit.
2. Pushing back of Main Pit western wall to establish ramp access into the Pit.
3. Removing tailings media from the Main Pit.
4. Filter pressing to dewater the tailings media.
5. Transporting the de-watered tailings to the new WSF for lime treatment, compaction and storage within the WSF.
6. Retaining the tailings stored within Main Pit.

An assessment of the risk associated with this Main Pit tailings relocation methodology found that it presented the following hazards:

- Geotechnical stability of Main Pit walls over the duration of the methodology would be difficult to manage.
- Workers would be exposed to radiological tailings materials (although the exposure could be managed).
- Removal of tailings offered no direct improvement to EBFR water quality as the tailings do not appear to be a significant source of contamination to the EBFR.

A review of the above led to the development of the methodology proposed within this EIS. The driving need to remove the tailings can be overcome with the Main Pit Lake capping methodology and the potential risk to Stage 3 worker safety from the radiological and geotechnical hazards are avoided.

18.3.2. Main Pit Rehabilitated Landform

The Stage 2 methodology for development of the Main Pit rehabilitated landform proposed the removal of currently stored tailings, followed by placement of PAF-I waste rock within the pit void. The waste rock was to be capped with a domed surface that was designed to stand approximately 10 m above the surrounding natural surface. The EBFR was to be diverted to the north of the backfilled dome where it would have reconnected with its original course to the west of Main Pit. Figure 18-1 shows the configuration of the Main Pit backfilled landform with the EBFR diverted to the north of the landform.

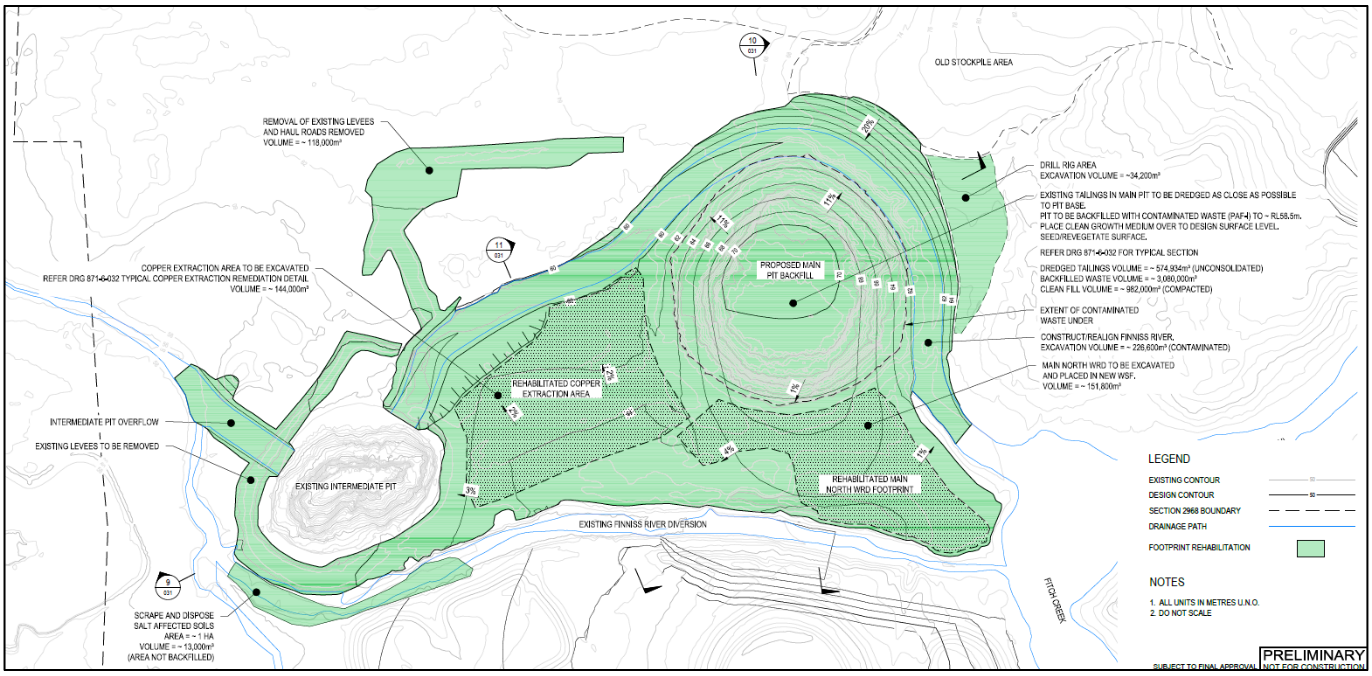

Figure 18-1: Stage 2 proposed Main Pit rehabilitated surface design (O'Kane Consultants, 2016a)

This design and methodology presented radiological and geotechnical risk to workers as mentioned above. Additionally, this Stage 2 design required a significant volume of imported clean fill earthen materials to be extracted from an offsite borrow – approximately 4.8 Mm³.

The Stage 2A review of these risks led to the development of the methodology that is presented within this EIS. The proposed retaining of tailings within Main Pit, PAF-I backfilling and water cap methodology reduces worker exposure to radiological and geotechnical hazards, and reduces the imported clean fill cover demand for the project to 3.7 Mm³.

The water cap methodology also allows for further improvement of alignment of the EBFR to its original course. Additionally, the water cap ensures that the highest risk PAF materials remain submerged, thus reducing the AMD risk posed by this material as far as is possible.

18.3.3. WSF Location

Throughout the development of the Rum Jungle Rehabilitation Project, several iterations of storage location for the new WSF have been investigated. Early Stage 1 designs placed the WSF close to the existing WRDs in order to reduce material haulage costs. Early Stage 2 designs placed the WSF at the Old Tailings Dam area which was subsequently ruled out due to flooding and stability concerns. Two examples of the Stage 2 iterations of WSF location are shown in Figure 18-2 and Figure 18-3.

A review during Stage 2A found that the proposed northern location impacted vegetation units onsite that were relatively undisturbed. Additionally, the geology at this location is Coomalie Dolostone which, though providing some heavy metal attenuation qualities within the Dolostone, is also known to have underground karst formations that cannot always be easily identified (RGC, 2016). Geotechnical advice was that the drainage and foundation system for the northern location would need to be robust enough to tolerate subsidence of any potential karst features. Finally, there were potential impacts relating to the effect of flooding on the batter toe.

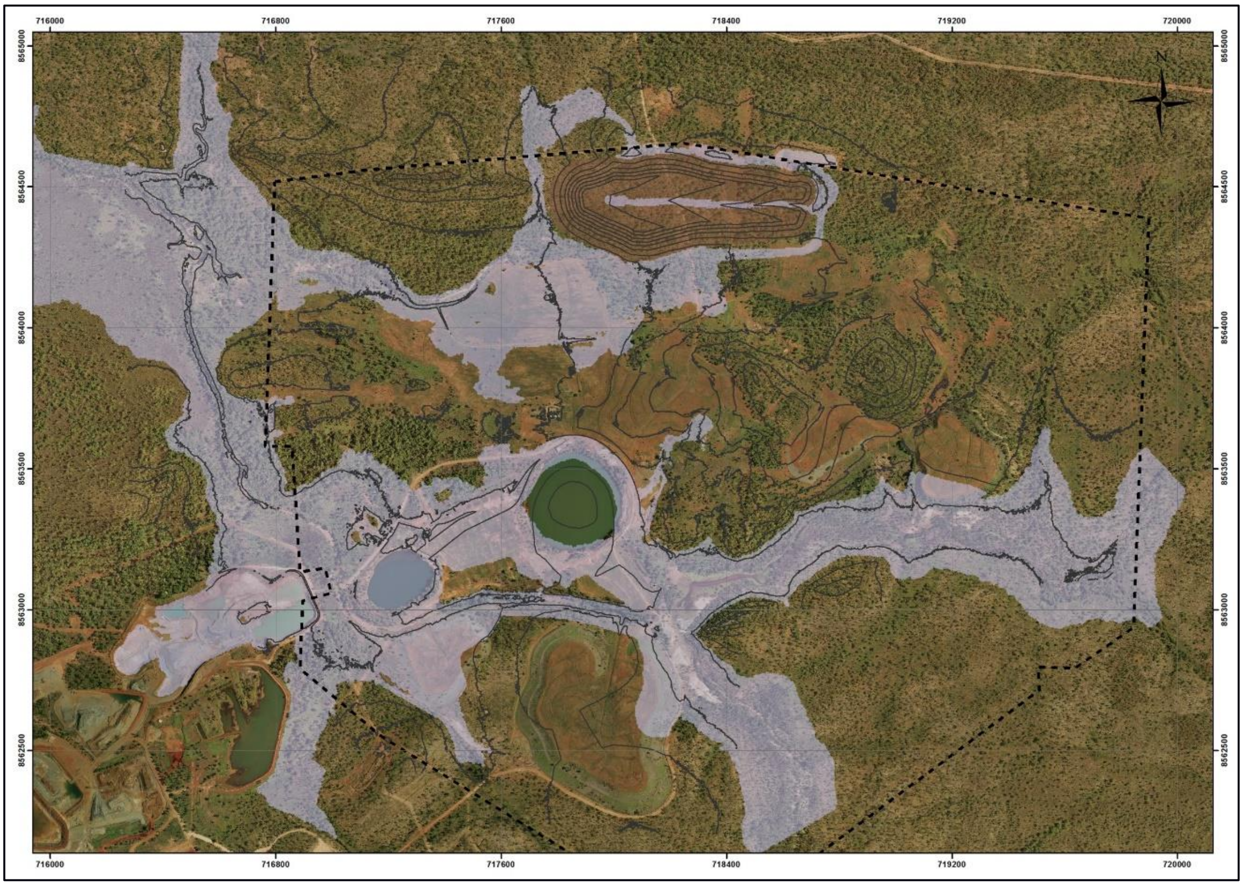

Figure 18-2: Stage 2 proposed WSF location and 100 yr ARI Flood Map

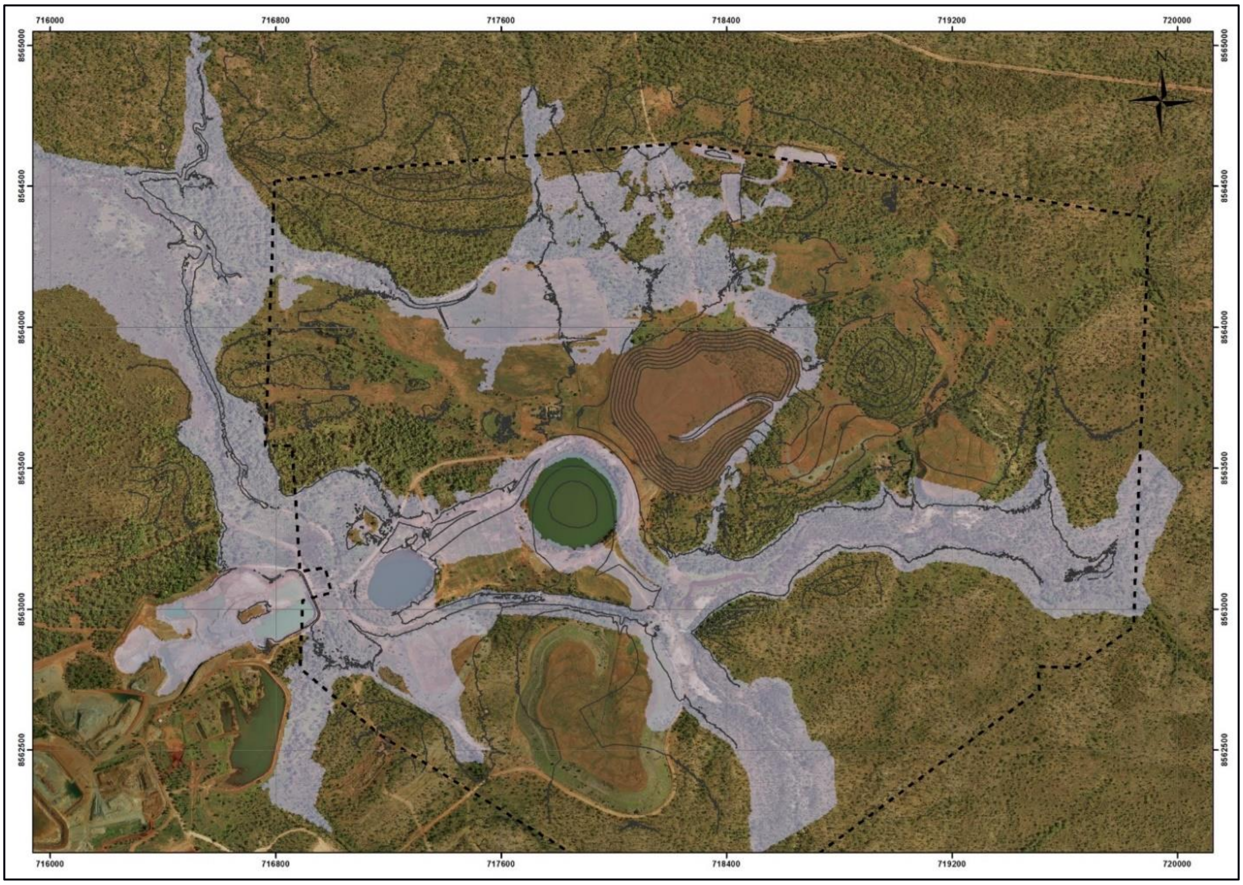

Figure 18-3: Stage 2 investigated Central WRD location and 100yr ARI Flood Map

The location of the WSF presented within this EIS reduces the risk of geotechnical instability. The majority of the WSF is located over Geolsec, White's Formation and Coomalie Dolostone thus reducing the risk of loading over potential karst features. Figure 18-4 shows the location of the Old Tailings Dam and proposed northern WSF in relation to geological units. The EIS proposed WSF footprint also maximises the use of already cleared or disturbed land, thus protecting an additional 26 ha of relatively undisturbed open woodland that would have been cleared for the proposed northern WSF site in Figure 18-5.

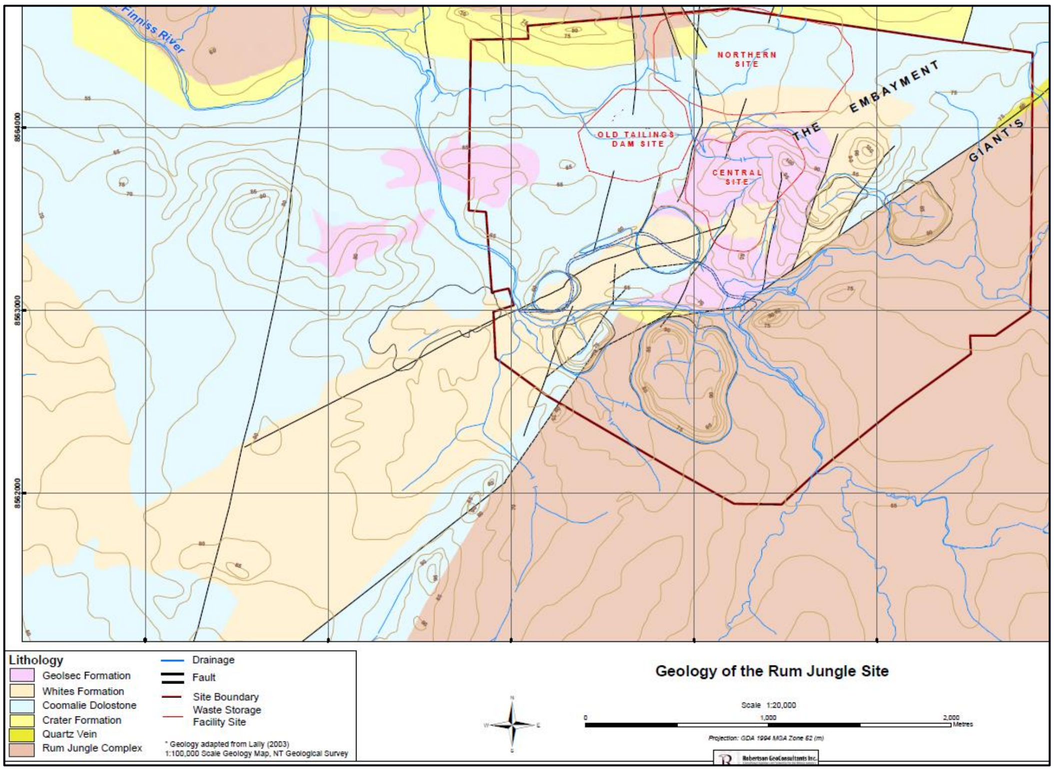

Figure 18-4: Stage 2 WSF options and geological units

Figure 18-5: Stage 2 WSF location options review (Robertson GeoConsultants, 2016a)

18.3.4. Borrow Pit Locations

Over the development of the project, several investigations have been carried out across the area to identify clean borrow materials suitable for the construction of the cover systems on the new landforms at Rum Jungle. The Stage 2 borrow location is shown here in Figure 18-6. The vegetation map for this proposed borrow location is shown in Figure 18-7.

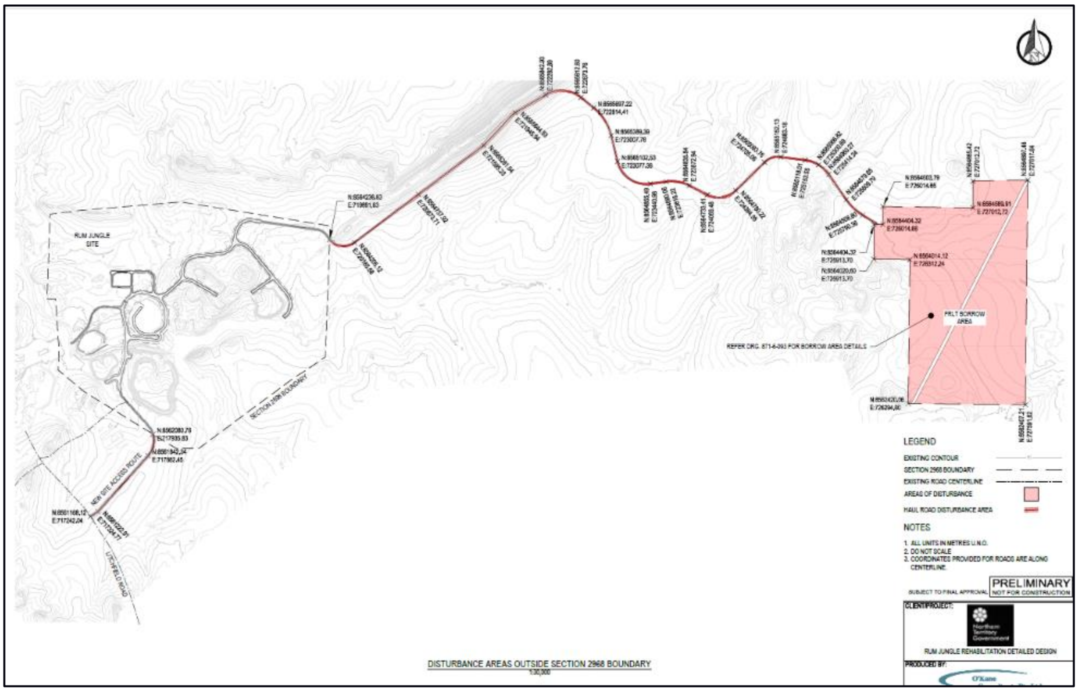

Figure 18-6: Stage 2 proposed borrow location (O'Kane Consultants, 2016a)

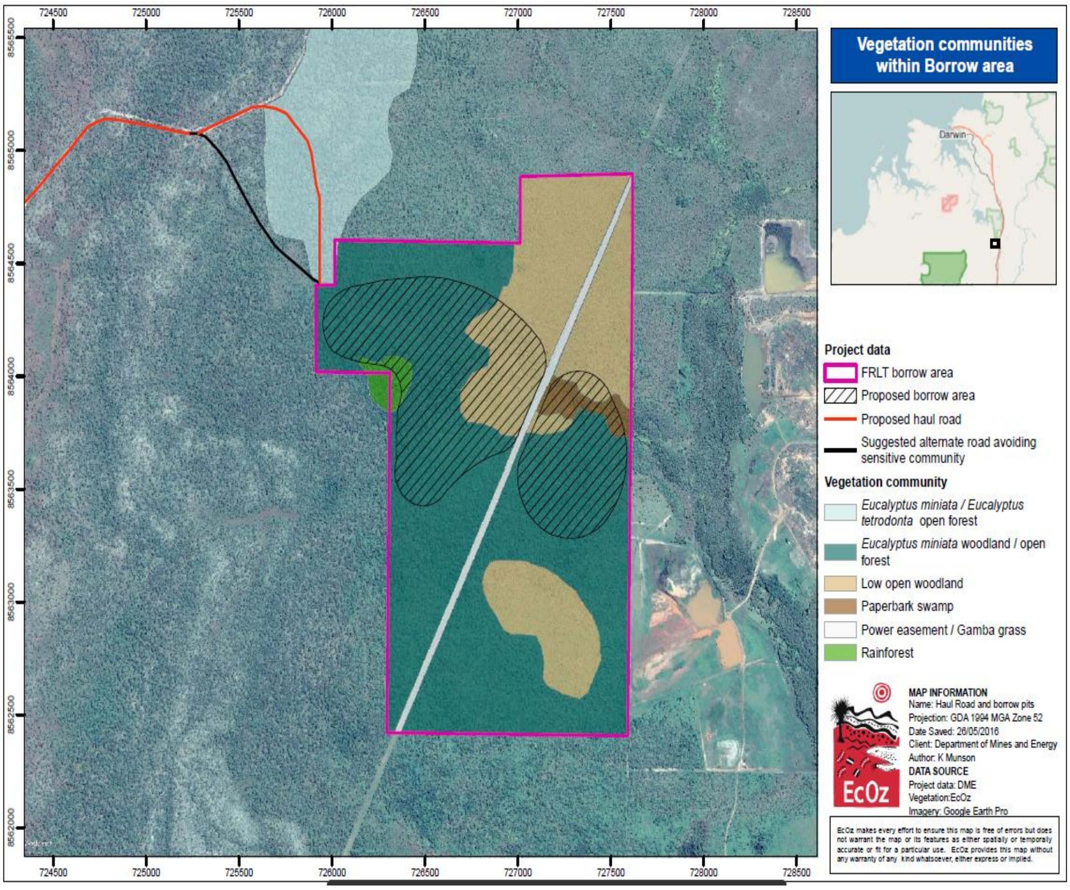

Figure 18-7: Stage 2 proposed borrow location vegetation map (EcOz, 2016)

A review of the total borrow material demand due to the design changes associated with the Main Pit rehabilitated landform identified that alternative borrow sources were available. The Stage 2 borrow location contains sufficient borrow material of sufficient quality to supply the Stage 3 works; however, the haul road traverses adjacent to sacred sites, and the borrow area itself contains relatively undisturbed vegetation units of rainforest, open woodland, open forest and low open woodland.

Further Stage 2A development work identified a nearby source of granular materials on adjacent FRALT property and low permeability materials from nearby CCGC property. The ecological value of these areas is described in Chapter 14 – Terrestrial Flora and Fauna. The advantage of utilising these proposed new sources is that the ecological impact is significantly reduced for borrow demand due to both footprints already being substantially disturbed. The shorter haul route from the FRALT proposed borrow is an additional ecological and cost saving advantage.

Overall, the reduction in impact by relocating to new proposed borrow pits is an estimated 50 ha less clearing of good quality vegetation.

18.4. Other Alternatives

18.4.1. Water Management

In addition to the water management strategies outlined within this EIS and attached *Water Management Plan*, the alternatives investigated to reduce the proposed three years of Dry season discharge to the EBFR include:

- Irrigation of the vine thicket to the north of Intermediate Pit to reduce impacts to this GDE.
- Irrigation of the revegetation areas.
- Evaporators to lose this water volume.

These options are considered to have relatively high capital cost for this publically-funded project that is difficult to justify because, as discussed in Chapter 11 – Hydrological Processes, the impacts to EBFR aquatic ecosystems is considered to be low for the short period of Dry season discharge. In the unlikely event that the vine thicket shows sign of impact due to the Main Pit backfilling water management strategy, irrigation may be warranted.

18.4.2. AMD Technologies

Management of AMD onsite is the highest priority for the rehabilitation project. Options that were considered for AMD management included:

- Storage of all waste rock above natural surface within the new WSF.
- WSF cover design that did not incorporate a low permeability barrier layer.
- Alternative neutralant options for the WSF and backfilled PAF materials.
- Thicker placed waste rock layers within the new WSF (2 m compared to proposed 0.5 m).
- Storage of waste rock within Intermediate Pit.

These alternatives were considered to not provide high enough risk mitigation for the site AMD risks. The storage of waste rock in Intermediate Pit was considered likely to cause impact to the EBFR due to hydraulic conductivity in this area.

Guidelines referenced in the establishment of the AMD methodology include the Leading Practice Sustainable Development in Mining Series AMD Handbook (DIIS, 2016) and the International Network for Acid Prevention (2019) *Global Acid Rock Drainage Guide*.

18.4.3. WSF Cover Design

During Stage 2, several WSF cover design options were explored by O'Kane Consultants (2015). Modelling was completed to understand predicted oxygen influx and water infiltration rates for each cover system. From this study, a recommended cover system was developed by O'Kane Consultants (2016b) and this has been adopted as part of the Stage 2A work presented in this EIS.

The cover system selected provides adequate reduction of oxygen influx and infiltration in order to reduce AMD production rates within the WSF.

18.4.4. Main Pit Backfilling Methodology

During Stage 2, a study (RGC, 2016b) investigated conceptual approaches to backfilling waste rock into Main Pit. This study investigated five approaches:

- Dewatering and dry placement
- Crest dumping
- Overwater dumping
- Pit crest stacker dumping
- Floating conveyor dumping.

From this study, the option to backfill waste rock using the floating conveyor dumping methodology was selected because it provides for a safe working environment for Stage 3 workers, allows for efficient lime neutralant dosing and meets project timeframes.

18.4.5. Browns Oxide Mine Facilities

Adjacent to the Rum Jungle Mine site, the Browns Oxide Mine is currently in care and maintenance. The site has fully-functioning assets that could be utilised for the Rum Jungle Rehabilitation Project. Additional assets requiring little upgrade also exist on this site. These include:

- Bulk fuel storage and delivery
- Waste treatment plant and reagent storage
- Ablutions and offices
- Potable water supply
- Emergency response facilities
- Laboratory facilities
- Power supply.

Utilisation of these facilities by the Rum Jungle Rehabilitation Project would greatly reduce construction time and costs, and eliminate the need for decommissioning of any built assets for the Rum Jungle site (apart from the heavy plant workshop). This option will be further explored as the Rum Jungle Rehabilitation Project progresses as it may provide a win-win solution for both parties.

18.5. Conclusion

The alternatives noted above were explored by the Proponent over the development of the proposed rehabilitation strategy. Several of these alternatives have not been entirely ruled out. These provide a safety net in the event of change in circumstances or an opportunity yet to be realised. For example, the option to utilise the existing facilities at Browns Oxide Mine would have significant Ecological Sustainable Development gains for the project as this would reduce capital expenditure of public funds, reduce the total resources required to install new temporary facilities for the 5 year Construction phase and reduce demolition and disposal resources. Additionally, the alternative borrow location may be revisited in the event that formal agreements for the proposed borrow locations cannot be reached.

The rehabilitation project has been in development for several years and comprehensive studies of the site and current available technologies have been carried out. The Proponent considers that the proposed strategy outlined within this EIS includes the best fit of iterated alternative elements for the existing site conditions and planned rehabilitation outcomes.

18.6. References

Department of Industry, Innovation and Science (2016) *Preventing Acid and Metalliferous Drainage, Leading Practice Sustainable Development Program for the Mining Industry*. Commonwealth of Australia. [Online] Available at: https://www.industry.gov.au/sites/default/files/2019-04/lpsdp-preventing-acid-and-metalliferous-drainage-handbook-english.pdf.

Department of Mines and Energy (2013) *Former Rum Jungle Mine Site Conceptual Rehabilitation Plan*, Northern Territory Government. [Online] Available at: https://dpir.nt.gov.au/__data/assets/pdf_file/0007/261493/Rum_Jungle_Conceptual_Rehabilitation_Plan.pdf.

EcOz (2016) *Rum Jungle Borrow Pit and Haul Road*. Prepared for Department of Mines and Energy, Northern Territory. [Online] Available at: https://dpir.nt.gov.au/__data/assets/pdf_file/0007/362608/Borrow-pit-and-haul-road-investigation-EZ16052-C0301-EST-R-0002.pdf.

International Network for Acid Prevention (2019) *Global Acid Rock Drainage Guide*. [Online] Available at: http://www.gardguide.com/index.php?title=Main_Page.

O'Kane Consultants Pty Ltd (2015) *Batchelor Region (Former Rum Jungle Mine Site) Conceptual Cover System and Landform Design*. Unpublished.

O'Kane Consultants Pty Ltd (2016a) *Northern Territory Government, Rum Jungle Mine, Rehabilitation Project Engineering Design Drawings*. Unpublished.

O'Kane Consultants Pty Ltd. (2016b) *Former Rum Jungle Mine Site; Detailed Civil Works Design for Rehabilitation – Design Report*. Prepared for Department of Mines and Energy, Northern Territory. [Online] Available at: https://ntepa.nt.gov.au/__data/assets/pdf_file/0011/398162/rum_jungle_noi_attachQ_civil_works_design_report.PDF

Robertson GeoConsultants (2016a) *Waste Storage Facility Investigations, Rum Jungle*. Prepared for Department of Mines and Energy, Northern Territory. [Online] Available at: https://ntepa.nt.gov.au/__data/assets/pdf_file/0008/398177/rum_jungle_noi_attachZ_waste_storage_facility_investigations.pdf.

Robertson GeoConsultants (2016b) *Main Pit Backfilling Concept Approaches, Rum Jungle*. Prepared for Department of Mines and Energy, Northern Territory. [Online] Available at: https://ntepa.nt.gov.au/__data/assets/pdf_file/0008/398177/rum_jungle_noi_attachZ_waste_storage_facility_investigations.pdf.

Shaw S.C., Maehl W.C., Kuipers J. and Haight S. (2001) *Review of the Multiple Accounts Analysis Alternatives Evaluation Process Completed for the Reclamation of the Zortman and Landusky Mine Sites*, In National Association of Abandoned Mine Lands Annual Conference, 19-22 August 2001, Athens, Ohio.

19. Summary of Commitments

19.1. Commitments

The Project is committed to protecting the health and safety of the proposed Rum Jungle rehabilitation workforce and the safety of the public throughout the delivery of the proposed Rum Jungle Rehabilitation Stage 3 Project. The management controls required to achieve this are outlined within this EIS and will form the foundation of the future development of the Health, Safety and Environment Management System for this project, should funding arrangemnets for Stage 3 be secured.

Table 19-1 provides a summary of the commitments contained within this draft EIS to assist stakeholders and regulatory agencies.

Table 19-1: Summary of EIS Commitments

No	Commitment	Draft EIS Cross Reference
SYSTEMS		
1	The Proponent will comply with all necessary legal obligations applicable to managing the potential impacts of the project.	Chapter 3
2	The Proponent will establish a Governance model to oversee the delivery of the project in order to ensure conformance to Commonwealth and NT Government policies.	2.2
3	The Proponent will develop a project specific Health, Safety and Environment Management System for project delivery operations.	3.4, 15.2.2
4	The Proponent will continue to collaborate with the Traditional Owners of the project site to ensure they are fully aware of project activities and contribute to development of the project.	4.5
5	The Proponent will work with landowners of the potential borrow areas to develop agreements for borrow area access, utilisation and rehabilitation.	3.1.1
6	The Proponent will work with the Mt Burton landowner to develop an agreement for access and rehabilitation of this privately owned land.	3.1.1
7	A Waste Management Plan will be developed and implemented.	2.6.2
HISTORIC and CULTURAL HERITAGE		
8	Develop and implement a Cultural Heritage Management Plan.	8.3
9	Conform to requirements of AAPA Authority Certificate(s).	8.3.1
10	All employees to participate in a Cultural Heritage Induction.	13.3.1
11	Avoid disturbance of known cultural heritage as far as possible through project design.	8.2, 8.3
12	Develop and implement a Cycad Salvaging Procedure.	8.3.5, 14.4.1
13	Develop and implement a Weed Management Plan.	8.3.2, 14.4.2, 15.4.3
14	Develop a Cultural Heritage Centre.	8.3.3
15	Develop and implement a Fire Management Plan.	8.3.6, 15.4.3

TERRESTRIAL ENVIRONMENTAL QUALITY		
16	Develop and Implement an Erosion and Sediment Control Plan.	9.3.1, 10.7.1, 12.3.1
17	Develop and implement a Vegetation Clearing Procedure.	9.3.1, 12.3.1, 14.4.1
18	Develop and implement an Air and Dust Management Plan.	9.3.1
19	Construct the WSF in line with design and implement the QA/QC Plan for construction. Final Construction Report will document actions and results of the works.	9.3.2, 9.4.2
20	Develop and implement a Hazardous Materials Management Plan.	9.3.3
21	Accredited Auditor will assess comprehensiveness of the Remediation Action Plan, endorse sampling and validation plan and endorse the final land use plan including potential restrictions.	9.3.4, 16.3.3
22	Supervise and survey decontamination areas including implementation of the validation sample plan.	9.3.4
23	Decontamination validation report will be produced.	9.3.4
INLAND WATER QUALITY		
24	Water abstracted from the two pits during Main Pit backfilling will be treated prior to release to East Branch Finniss River.	7.10, 10.7.1
25	Contaminated groundwater will be pumped and treated prior to release to East Branch Finniss River.	7.10, 10.7.1
26	Treated water use will be maximised onsite in earthmoving works.	7.10, 10.7.1
27	LDWQOs have been established and will be applied for the Project.	7.10, 10.7.1
28	Intermediate Pit will be drawn down to provide freeboard capacity for high rainfall events to capture overflow water from the Main Pit during backfilling activities.	10.7.1
29	WSFs will be designed to best management standards (GARD)	10.7.2
30	Additional monitoring and reporting details will be established within the WDL process.	10.7.2
HYDROLOGICAL PROCESSES		
31	Treated water from the WTP will be recycled onsite as far as possible with earthmoving works.	11.3
32	East Branch Finniss River will be reinstated to original course as far as possible.	11.3.1
33	The Water Management Plan will be updated prior to commencement of Stage 3 and implemented.	11.3.1, 2.5.7, 10.7.1.
AQUATIC ECOSYSTEMS		
34	WRD deconstruction and WSF construction will be carried out in a manner that reduces the exposed horizontal area of waste rock.	12.3.1

35	A restoration plan will be developed and implemented for the East Branch Finniss River onsite. Morphological design principles will be employed to facilitate aquatic fauna passage.	12.3.2
36	Design of the East Branch Finniss River will be carried out by an appropriately qualified person.	12.3.2
SOCIAL AND ECONOMIC IMPACT		
37	Traffic management requirements as set by DIPL will be incorporated into project design and implementation.	13.2.3
38	An Emergency Response Plan will be developed and implemented.	13.2.3, 13.3.3
39	Stakeholder Communication and Engagement Strategy will be developed and implemented.	13.3.1, 16.3.3
40	A Local Industry Participation Plan will be developed and implemented.	13.3.2
41	An Indigenous Development Plan will be developed and implemented.	13.3.2
42	A Traineeship Program will be developed and implemented.	13.3.2
43	An Opportunity Plan for Traditional Owners will be developed and implemented.	13.3.2
44	An Accommodation Plan will be developed and implemented.	13.3.3
TERRESTRIAL FLORA AND FAUNA		
45	Riparian vegetation buffers will be applied to the borrow areas.	14.4.1
46	A Fauna Spotter Catcher will be present for all vegetation clearing works.	14.4.1
47	Darwin Cycads will be salvaged as per a Cycad Salvaging Procedure.	14.4.1
48	Mimosa and Gamba Management Plans will be developed and implemented.	14.4.2
49	Revegetation systems will be developed for site.	Chapter 7
HUMAN HEALTH AND SAFETY		
50	All built structures will comply with relevant Australian Standards.	15.4, 2.6.4
51	An Adverse Weather Procedure will be developed and implemented.	15.4.1
52	The Risk Register will be updated prior to commencement of the Stage 3 works and will form the foundation of the Health, Safety and Environment Management System.	15.4
53	A procedure for working in and around water bodies will be developed and implemented.	15.4.1
54	Dust suppression and mitigation activities will take place over all work surfaces.	15.4.2
55	Equipment cabins will be air conditioned with dust filters fitted to these systems.	15.4.2, 16.3.2
56	A Fitness for Work program will be developed and implemented.	15.4.4
57	Lightning tracking and stop work/refuge procedures will be developed and implemented.	15.4.4
58	A Lone and Isolated worker procedure will be developed and implemented.	15.4.4

59	A site induction will assist new employees to familiarise with site hazards.	15.4.4
60	Heat stress management training will be carried out for employees.	15.4.4
61	Qualified snake handlers will be present on site and flora and fauna awareness training delivered to employees.	15.4.6
62	Croc safety awareness training will be delivered as part of the induction program.	15.4.6
63	Site access and control procedures will be developed and implemented.	15.4.7
64	NTG contractor management systems and media/communications protocols will be employed.	15.4.7
RADIATION		
65	Radiological soils will be isolated prior to commencement of waste rock handling activities.	16.3.2
66	Uranium tailings will not be handled or exposed during earthworks.	16.3.2
67	The Radiation Management Plan will be updated prior to Stage 3 works and implemented.	16.3.2
68	A Radiation Safety Officer will be present onsite and carry out the RSO scope of work for the duration of site works.	16.3.2
69	Employees and visitors will participate in radiation training during the site induction.	16.3.2
70	Access will be restricted to identified areas of higher radiation.	16.3.2
71	Good hygiene practices will include access to personnel was facilities and mobile plant wash bays.	16.3.2
72	PPE will be removed and washed onsite at the end of each shift.	16.3.2
73	Mt Burton residents should not be present during relocation of waste rock from Mt Burton.	16.3.2
74	Radioactive material will be moved during low wind periods.	16.3.2
75	Equipment and vehicles will be decontaminated and checked prior to being permitted to leave site.	16.3.2
76	WSF cover will be a minimum of 2m	16.3.2
77	Further studies of the potential ingestion pathway in the post-rehabilitation scenario will be carried out.	16.3.2
78	Native food plants will be eliminated from the WSF revegetation.	Chapter 7, 16.3.3
79	Radiation Monitoring and Reporting will be carried out as per the Radiation Management Plan.	16.4
EPBC MATTERS		
80	ESD principles have been built into Project design and will form a core operational goal.	17.5.4
81	ESD improvement opportunities will be explored with Territory Resources Brown's Oxide.	17.5.3

82	Resources (rock armour, cleared vegetation etc.) will be salvaged and reused from within the project work area as far as possible.	17.5.3
83	Wastes will be stored and recycled onsite as far as possible.	17.5.3

20. Terms of Reference Cross Reference Checklist

Specific Terms of Reference (ToR)	Draft EIS Reference(s)
2.1.1 Existing environmental condition	
<u>Site layout, maps and information</u>	
· a map of the entire site, identifying the location and dimensions of existing disturbance, infrastructure and roads/tracks, and landforms resulting from historic mining activities	Fig 1-3 Existing site conditions at the former Rum Jungle Mine Site Fig 1-4 Site layout prior to rehabilitation Fig 2-1 Overall site layout Table 6-1 Mining landscape features, dimensions, history
· a map of the entire site, identifying geologic formations and faults	Fig 5-6 Geology of the RJ Mineral Field
· an aerial photograph / satellite imagery of the East Branch of the Finniss River prior to mining (if available) and analysis of how hydrological processes have been impacted by mining e.g. how the course of the East Branch of the Finniss River has been altered and diverted	Fig 6-2 & Fig 11-2 Original course of EBFR
· locations (i.e. source and destination), types/classes (e.g. tailings, waste rock), volumes and associated geochemical/geotechnical properties of materials to be rehabilitated in-situ or re-located to other area(s) on site/s	Fig 2-6 Areas and volumes of contam soils for excavation Fig 6-1 Existing features at RJM Table 6-1 Mining landscape features, dimensions, history Table 2-1 Estimated material movements Fig 2-8 Waste material movement schedule Chapter 6.3 Conceptual Site Model Appendix Jones 2019 Appendix Robertson GeoConsultants and Jones 2019
· information on point and diffuse sources of acid and metalliferous drainage (AMD), and current physical and geochemical impacts on water resources and sediments, including groundwater and the Finniss River	Fig 2-6 Areas and volumes of contaminated soils Fig 2-5 Areas of excavation under WSF Fig 6-3 Distribution of PAF materials by class Chapter 6.3 Conceptual Site Model Chapter 10 Appendix Robertson GeoConsultants 2019 Appendix Robertson GeoConsultants and Jones 2019
· locations and nature of contaminated soils and any asbestos or other contaminated wastes on the site/s	Chapter 6.3 Conceptual Site Model Fig 2-6 Areas and volumes of contaminated soils Fig 6-11 Radiological anomalies at RJ Fig 7-3 Earthworks plan Stage 3

· the extent of native vegetation communities within and adjacent to the Proposal area	Fig 5-11 Veg communities in the Coomalie region Fig 7-11 Veg units RJM Fig 14-3 Vegetation communities in the region Fig 14-4 Veg communities in the RJ site Fig 14-12 Veg Communities in the granular borrow Fig 14-14 Veg communities in the low permeability borrow Appendix EcoLogical 2014 Appendix EcOz 2019
· the extent of introduced and invasive species (both flora and fauna) within and adjacent to the Proposal area, including weed species declared under the Weeds Management Act 2001	Fig 14-18 Extent of Gamba Grass infestations at RJM (2018) Table 14-2 Most common weeds within 30km radius of RJM Table 14-4 Pest animals known or likely to occur within project footprint
· information on the fire regime, including factors that influence the fire frequency and intensity, such as the presence and extent of high fuel load weeds.	Fig 5-12 Coomalie region fire history, 200-20018 Fig 14-2 Fire history across RJ region
<u>Existing legacy conditions</u> Provide an assessment of baseline (current) water quality, including a comparison with relevant water quality guidelines (e.g. ANZG 2018) and locally derived water quality objectives, of: · receiving waters (surface and groundwater) including the East Branch of the Finniss River and the Finniss River reaches downstream	Chapter 6 Existing Environmental Conditions Chapter 10 Inland Water Environmental Quality Appendix Hydrobiology 2013-2019 Appendix Robertson GeoConsultants and Jones 2019
· pit water at Main Pit and Intermediate Pit	Table 10-7 Pit water quality profiling Main Pit Table 10-8 Pit water quality profiling Intermediate Pit
· groundwater	Chapter 10 Inland Water Environmental Quality Appendix Robertson GeoConsultants and Jones 2019
Provide a sufficiently detailed hydrogeological model, incorporating:	Chapter 10 Inland Water Environmental Quality Appendix Robertson GeoConsultants and Jones 2019
· the existing source(s) of contaminants	Fig 10-3, 10-4
· the flows and loads of contaminants	Chapter 6-3 Summary Conceptual Site Model
the mechanism(s) of their release	Appendix Robertson GeoConsultants 2019
· the pathway(s) for transport	Chapter 6-3 Summary Conceptual Site Model Chapter 10 Inland Water Environmental Quality Appendix Robertson GeoConsultants 2019
· the potential for human and ecological exposure to these contaminants	Chapter 10 Inland Water Environmental Quality Appendix Robertson GeoConsultants and Jones 2019
Provide an assessment of the existing waste storages and their performance to inform design improvements in the Proposal landforms.	Chapter 7.8.2 and 7.8.3 Waste Placement and Cover System Appendix Taylor et.al. 2003
2.1.2 Rehabilitation strategy <u>Site layout maps</u>	

· the location and approximate dimensions of areas to be disturbed, structures to be built or repurposed as part of the Proposal, including (as relevant):	Chapter 7 Rehabilitation Strategy
o all areas to be cleared or disturbed including the vegetation types present	Table 2-3 Project land disturbance Table 14-9 Areas of remnant bushland that will be cleared
o borrow pits (within and outside the mine site)	Fig 2-5 Areas of excavation under WSF Fig 1-2 Project Overview Chapter 7-9 Borrow and Other Materials Fig 7-3 Earthworks Plan Stage 3 Fig 7-8 WSF footprint prelim investigation into recoverable soils Fig 7-9 Potential Borrow Pits Fig 14-12 Veg comm in granular borrow Fig 14-14 Veg comm in low perm borrow
o roads, and other related infrastructure	Fig 1-2 Project overview Fig 2-4 Indicative haul road layout
o buildings such as office facilities	Fig 2-4 Indicative haul road layout
o temporary stockpiles	NA
o permanent waste storage facilities	Fig 2-5 Areas of excavation under WSF Fig 7-3 Earthworks Plan for Stage 3
o water-related infrastructure (e.g. storage/treatment facilities, extraction/discharge points)	Fig 2-4 Indicative haul road layout Fig 11-5 Water Management Layout
o any other rehabilitation or ancillary infrastructure.	Fig 14-23 Vine forest Mt Fitch
· the Proposal layout overlain with the environmental values such as the location of waterbodies/waterways and native vegetation	Fig 2-1 Overall site layout across project area Fig 2-5 areas of excavation Full set of SLR drawings supplied to NTEPA (redacted for cultural heritage values protection) Fig 14-12 Veg Comm in the granular borrow Fig 14-14 Veg Comm in the low perm borrow Fig 14-20 Rainforest adjacent Mt Burton Fig 14-22 Vine forest within RJ Fig 14-25 Historic threatened species records in vicinity of project Fig 14-28 Buffers within the granular borrow
Rehabilitation strategy The EIS should provide a detailed description of the methods and processes for the Proposal, including but not limited to: · establishment of rehabilitation objectives and completion criteria for the various components of the Proposal (including off-site borrow areas) with measurable performance indicators/thresholds to demonstrate that completion criteria are likely to be met, including for the longer-term use of the Proposal area	Chapter 1.2.1 Summary of Project Objectives Chapter 7.11 Ecological rehabilitation strategy Chapter 7.12 Rehabilitation success

· design and construction methods of the proposed rehabilitated landforms, including the final landform, cover and waste rock dump designs, and any temporary measures to manage materials that may become a source of contamination during construction	Chapter 7 Rehabilitation Strategy Chapter 9.2 Potential Impacts and Risks
· clearing and preparation of the proposed borrow areas and new waste storage facility, including handling/stockpiling/disposal of vegetation and topsoil	Chapter 7.8 New WSF construction Chapter 14.4.1 Vegetation Clearing
· sources and volumes of materials required for construction, such as fill, clays and consumables (e.g. neutralising agents), including materials on-site suitable for re-use	Chapter 2.5 Stage 3 Schedule Inputs and Outputs Chapter 7.9 Borrow and Other Materials
· timeframes for all relevant aspects of the Proposal	Chapter 2.4 Stage 3 Project Stages Fig 2-3 RJ Rehab project schedule
· responsibilities and funding arrangements for post-rehabilitation monitoring and maintenance programs	This is outside of the scope of Stage 3 works
· systems and processes for the retention of rehabilitation and monitoring data records	Chapter 7.121. Rehabilitation Success Metrics
· reporting program for site monitoring and maintenance activities	Chapter 3.1.1 Approvals and agreements Chapter 7.12.1 Rehabilitation success metrics Chapter 10.1.3 Preferred Rehabilitation Strategy Chapter 10.2.3 Construction Phase WQOs
· regulatory requirements, including any licences and associated reporting requirements.	3.1.1 Approvals and agreements
<u>Water</u>	
· a water balance prepared in consideration of MCA 2014 Water Accounting Framework	Chapter 10.5.2 Simulated Current Conditions Chapter 10.6.2 Predictive Surface Water Quality Modelling 11.2.1 Impacts due to altered flow regimes Appendix Robertson GeoConsultants 2019 - Chapter 5 and 6.2
· predicted water demand requirements for each aspect and all phases of the Proposal (including dust suppression, drinking water, road construction, wetting of rehabilitation materials and any other uses)	Potable - 2.5.7 Chapter 11.2.1 Impacts due to altered flow regimes
· proposed water supply sources, volumes and yields (including details of any peak periods and seasonal variations)	Chapter 2.5.7 Water Management Chapter 11.2.1 Impacts due to altered flow regimes
· details of any proposed dewatering and groundwater extraction including anticipated extraction rates and volumes, treatment, storage, usage/reuse and disposal options	Chapter 2.4.6 Water Treatment - Groundwater Chapter 2.5.7 Water Management Chapter 7.10 Water Management Chapter 11.2 Potential Impacts and Risks
· details of existing or proposed surface water diversions including designs	Chapter 2.5.7 Water Management Chapter 7.7.1 Restoring EBFR Flow Chapter 7.10 Water Management

· requirement for discharge and a waste discharge licence under the Water Act 1992	Chapter 3.1.1 Approvals and Agreements Chapter 7.12.1 Rehabilitation Success Metrics Chapter 10.1.3 Rehabilitation Strategy
· requirement for extraction licence or permit to interfere with a waterway under the Water Act 1992	Chapter 3.1.1 Approvals and Agreements
Transport	
· access and haul road construction/ upgrade and maintenance requirements, including maximum widths, and sources and extraction of materials	Chapter 2.4.1 Project Establishment Chapter 2.5.4 Transport and Logistics Network Chapter 5.3 Existing Services and Infrastructure Chapter 13.2.3 Services and Infrastructure
· methods for crossing sensitive areas, such as waterways and/or land units with poor soil recovery potential, where relevant	Chapter 2.4.1 Project Establishment
· methods for intersecting linear infrastructure and major roads, where relevant	Chapter 2.4.1 Project Establishment
· identify which sections of public road would be used by the Proposal and whether any sections of public road may require upgrading (and summary of engagement with NT Government road authority stakeholder)	Chapter 5.3 Existing Services and Infrastructure Fig 2-4 Indicative haul road layout
· volumes of existing vehicles using the proposed transport routes	Chapter 5.3 Existing Services and Infrastructure Table 5-1 Calculated Annual ADT Batchelor Table 5-2 Vehicle Classification Batchelor
· estimated vehicle types and frequency (over seasons and hours/days) of Proposal-related vehicle use on public roads	Table 2-1 Estimated material movement rates
· transport of hazardous or dangerous materials (e.g. heavy machinery, fuel, reagents)	Chapter 2.6.4 Maintenance Workshop, Chemical and Hydrocarbon Storage/Transport
Non-mineral waste and hazardous materials	2.6.4 Maintenance Workshop, Chemical and Hydrocarbon Storage/Transport
· list and description of potentially hazardous materials to be used or produced and methods for storage, transport, handling, containment, disposal and emergency management of these materials (including fuel)	Chapter 2.6.2 Waste Management Chapter 2.6.4 Maintenance Workshop, Chemical and Hydrocarbon Storage/Transport Chapter 2.6.5 Emergency Management Chapter 3.2 Applicable Standards
· descriptions of predicted solid and liquid waste streams, both industrial and domestic, and waste management strategies for storage, transport and disposal, taking into account the waste hierarchy	Chapter 2.6.2 Waste Management Chapter 9.2.3 & 9.3.3 Introduced Contamination Risk
Energy	
· the Proposal's energy requirements and proposed source	Chapter 2.6.1 Electricity Supply
· estimate of the greenhouse gas emissions from the proposal	Chapter 2.6.4 Maintenance Workshop, …
Workforce	Chapter 2.5.2 Workforce
· summary of the estimated number of people to be employed, skills base required, likely sources (local, regional, overseas) and accommodation requirements	Chapter 2.5.3 Accommodation Chapter 13.3.2 Employment and Economies Chapter 13.3.3 Services and Infrastructure
Alternatives	

The choice of the preferred option(s) should be clearly explained and justified. Discussion of alternatives should include, but not be limited to: · not proceeding with the Proposal · site selection for Proposal components, including alternative layouts and alternative locations that improve Proposal outcomes · alternative designs, construction and rehabilitation methods for Proposal components such as the Main Pit waste backfill option with pit lake or complete backfill option versus above ground waste storage for the most problematic wastes · management of wastes · water management · technologies and treatment methods to address AMD and other legacy issues · options to optimise ecological sustainability for the Proposal, such as alternatives to reduce / offset the Proposal's environmental footprint · consideration of alternative environmental management measures for key potential impacts and risks.	Chapter 18 Project Alternatives Chapter 18.2.1 No rehabilitation works Chapter 18.3.3 WSF Location Chapter 18.3.2 Main Pit Rehab Landform Chapter 18.4.1 Water Management Chapter 18.4.2 AMD Technologies Chapter 18.4.3 Borrow Pit Locations Chapter 18.4.5 Browns Oxide Mine Chapter 17.4.2 Environmental Offsets
2.2.1 Terrestrial Flora and Fauna	
General .. matters that must be addressed under Schedule 4 of the Environment Protection and Biodiversity Conservation Regulations 2000.	Chapter 17 EPBC Matters
Environmental values Provide updated results of targeted surveys for threatened species in areas where vegetation is to be cleared as part of the Proposal. The EIS should identify and discuss: · the presence or likely presence of species listed under the EPBC Act and/or the Territory Parks and Wildlife Conservation Act 1976, including but not limited to Partridge pigeon (eastern) (Geophaps smithii smithii) and black-footed tree-rat (Mesembriomys gouldii gouldii)[2] · the presence of suitable habitat for listed threatened species · the presence, or likely occurrence, of introduced and invasive species · the presence of groundwater dependent communities within the Proposal area and more broadly, the East Branch of the Finniss River	Chapter 14.2 Threatened Species Appendix EcOz 2019a Chapter 14.2 Threatened Species Appendix EcOz 2019a Chapter 14.2 Threatened Species Chapter 14.1.5 Weeds Chapter 14.1.9 Pest Animals Chapter 14.1.7 Groundwater-Dependant Ecosystems Figure 14-22 Vine forest within RJ

· listed threatened communities.	Figure 14-27 Suitable Darwin Cycad Habitat Table 14-7 Summary assessment of significance terrestrial threatened species Chapter 17.3 Protected Matters Search
Quantify and map values associated with sensitive or significant vegetation types and ecosystems including but not limited to:	Chapter 14.1.6 Significant Vegetation Table 17-1 Summary of Protected Matters
· Cycads	Chapter 14.2.2 Assessment of Significance - Darwin Cycad Table 14-6 Darwin Cycad density estimates within and proximate to the footprint
· Riparian vegetation	Fig 14-12 Veg Comm in the granular borrow Fig 14-14 Veg Comm in the low perm borrow Fig 14-28 Buffers within the granular borrow
· Groundwater dependent ecosystems.	Fig 14-22 Vine forest within RJ Chapter 14.1.7 Groundwater dependent ecosystems
<u>Potential impacts and risks</u> Quantify and/or discuss any potential for a decline in distribution, abundance or health of identified values due to:	
· clearing of vegetation or other habitat disturbance	Table 2-3 Project land disturbance Table 14-9 Areas of remnant bushland that will be cleared Chapter 14.3.1 Impacts due to Land Clearing Chatper 14.3.6 Threatened Species
· road traffic impacts on wildlife	Table 14-8 Potential impacts to biodiversity that have low inherent risk
· dust, noise, vibration and light	Table 14-8 Potential impacts to biodiversity that have low inherent risk Chapter 14.3.3 Impacts due to dust
· decline in terrestrial habitat quality, barrier effects, and habitat and population fragmentation	Chapter 14.3 Potential Impacts and Risk Table 14-8 Potential impacts to biodiversity that have low inherent risk
· pit dewatering	Chapter 11.2.1 Impacts due to Altered Flow Regimes Chapter 11.3.2 Groundwater Drawdown Chapter 11.3.1 Altered Surface Flow Regimes Chapter 11.3.2 Groundwater Drawdown Chapter 14.3.5 Impacts due to Groundwater Extraction
· transportation and/or disposal of hazardous material (including naturally occurring radioactive material (NORM)) or wastes	Chapter 16.2 Potential Impacts and Risk
· radionuclide exposure from dust emissions, contaminated water resources or other sources of exposure	Chapter 16.2 Potential Impacts and Risk
· the introduction and/or spread of weeds[3] and feral fauna species	Chapter 14.3.2 Impacts due to Weeds

· increased fire risk · ongoing post-rehabilitation maintenance activities (e.g. weed and fire management, remedial earthworks)	Chapter 14.3.4 Impacts due to Bushfire Outside of scope of Stage 3 project
Mitigation and management Address any potential impacts identified above in accordance with the mitigation hierarchy[4] to meet completion criteria for the Proposal, including rehabilitation of borrow areas. Information requirements for safeguards and mitigation measures proposed to prevent, minimise or compensate for the relevant impacts of the Proposal on threatened species must consider Schedule 4 of the EPBC Act (Attachment A). In addressing Matters of National Environmental Significance (MNES), the EIS should either incorporate a guidance table referencing the sections of the EIS in which relevant EPBC Act matters are addressed, or a dedicated EPBC Act Chapter that addresses all relevant EPBC Act matters.	Chapter 14.3 Mitigation and Management Chapter 16 Radiation Appendix EcOz 2019 Radiation Management Plan and Hazard Assessment Chapter 17 EPBC Matters Table 17-3 EIS Chapters addressing the EPBC Act Controlling Provisions
Monitoring and reporting Address, at a minimum, a plan for monitoring completion criteria for terrestrial flora and fauna in Proposal area.	Chapter 14.5 Monitoring and Reporting
Residual impact Provide a statement of the expected condition of terrestrial flora and fauna values when the completion criteria for this factor are met. Assess the significance of any residual impact of the Proposal to identified values, in consideration of the information requirements in Attachment A. In the event that significant residual impacts remain for listed threatened species and/or the environment following application of the proposed mitigation measures, offsets should be proposed. Should this be required, the proponent must include details of a proposed offset package to be implemented to compensate for the residual significant impact of the Proposal and an analysis of how the offset meets the requirements of the Department of the Environment and Energy EPBC Act Offsets Policy[5].	Chapter 14.6 Statement of Residual Impact Chapter 17 EPBC Matters Chapter 17.4.2 Environmental Offsets
2.2.2 Terrestrial Environmental Quality	
Environmental values Describe the terrestrial environmental values within the Proposal area that could be potentially impacted by the Proposal, including: · regional and significant topography, geomorphology and geology including faults · soil types and land units, including a summary of expected natural elevations of minerals in the terrestrial environment	Chapter 9.1 Terrestrial Environmental Values Chapter 9.1.1 Regional and Significant Topography Chapter 9.1.2 Geology Fig 10-5 Water quality observations includes localised geology map Appendix Robertson (No Suggestions) 2019 Chapter 3.4 and 3.6 Chapter 9.1.3 Soil Types and Land Units

<u>Potential impacts and risks</u> Quantify and/or discuss the potential impacts of the Proposal, related to: · erosion of land/soils and the movement of sediment · possible release of hazardous substances and subsequent contamination, with reference to the volumes of each hazardous material (including hydrocarbons) to be used/stored on site · generation and release of contaminants from historic waste materials, including for the long term post-rehabilitation period · long term stability of landforms considering erosion and seismic activity The discussion must refer to a material characterisation that identifies the existing extent of AMD or other contaminants or materials that present risks to the environment from mined materials, including a comprehensive classification of waste rock, tailings and other materials in accordance with the NT EPA's Environmental Assessment Guidelines for Acid and Metalliferous Drainage (NT EPA 2013a) and best practice guidance to characterise AMD.	Chapter 9.2.1 Erosion and Movement of Sediment Chapter 9.2.3 Introduced Contamination Risks Chapter 6.3 – Summary Conceptual Site Model Chapter 10.6 Predicted Water Quality Improvements Chapter 9.2.2 Long Term Stability Chapter 9.3.2 Long Term Stability Chapter 6.3 – Summary Conceptual Model Chapter 7.3 Remediation Action Plan Chapter 7.8 New NSF Construction Appendix Robertson GeoConsultants and Jones 2019 Appendix Jones 2019
<u>Mitigation and management</u> Address all potential impacts identified above in accordance with the mitigation hierarchy to meet established completion criteria	Chapter 9.3 Mitigation and Management
<u>Monitoring and reporting</u> Address, at a minimum: · monitoring and reporting of results of contaminated site remediation · monitoring of rehabilitation completion criteria that includes: o use of recognised or acceptable monitoring methodologies and standards o monitoring that takes into account the wider receiving environments, receptors and exposure pathways o monitoring using appropriate quality control systems and procedures in sampling, analysis and reporting of results o predicted timeframe for each monitoring program to demonstrate that completion criteria have been met o performance indicators to monitor the trajectory for meeting completion criteria o planned maintenance programs (e.g. weed and fire management, revegetation, minor remedial earthworks) o contingency strategies, should monitoring data indicate key environmental performance indicators have moved outside the agreed trajectory for achieving completion criteria Provide comment on the National Environment Protection (Assessment of Site Contamination) Measure 1999 and how it might apply to this Proposal in the context of completion and final land use.	Chapter 9.4 Monitoring and reporting Chapter 7.12 Rehab strategy success Chapter 6.2.1 Background

<u>Residual impact</u> Provide a statement of the expected environmental condition of the Proposal area when the completion criteria for this factor are met and assess the significance of any residual impact from the Proposal to identified values.	Chapter 9.5 statement of residual impact
2.2.3 Hydrological Processes	
<u>Environmental values</u> Characterise the current hydrological regime and receiving waterways that are impacted by previous mining and rehabilitation activities, using maps and/or schematic diagrams of flow directions where applicable, including:	Chapter 10.5 Simulated Current Conditions Chapter 11.1 Environmental Values Appendix Robertson GeoConsultants 2019 Chapter 3
· the surface water hydrology, such as:	
o major and minor rivers, drainage lines and wetlands (permanent and ephemeral) including diversions	Fig 11-1 Surface water features
o surface water flow directions and rates, based on field data and modelled data including assumptions	Fig 11-3 GS8150204 flow rate avail data
o water reservoirs (natural and artificial)	Fig 11-1 Surface water features
o beneficial uses	Chapter 11.1.3 Beneficial uses
· groundwater aquifers and hydrogeological properties, including:	Chapter 5.5.6 Water
o groundwater flows and connectivity (considering seasonal variation) between existing pits, waste rock dumps and the surrounding groundwater environment	Chapter 10.5 Simulated Current Conditions Fig 10-4 Observed sulphate concentrations - figure includes groundwater flow field map and surface drainage mapping Fig 10-16 Simulated groundwater flow field Fig 10-17 Simulated site features showing inflows and outflows
o groundwater behaviour in the vicinity of the proposed waste storage facilities and pits	Fig 10-16 Simulated groundwater flow field
o surface connections via springs or recharge zones including assumptions	Chapter 10.5.2 Simulated Current Conditions Fig 10-6 Daily Average discharge EBFR Fig 10-7 Daily average discharge in EBFR
o local and regional aquifers	Chapter 10.6 Predicted Water Quality Impacts
· depth to water tables, including temporal variation	Appendix Robertson GeoConsultants 2019 - Table 2-1, 2-2, 2-3
<u>Potential impacts and risks</u> Quantify and/or discuss the potential impacts during construction of the Proposal and post-rehabilitation, including a comparison of options such as the proposed flow-through pit with retention of the current diversion, related to:	Chapter 10.7 Potential Impacts and Risks Chapter 11.2 Potential Impacts and Risks
· altered surface water flow pathways, volumes and timing (seasonality)	Chapter 11.2.1 Impacts due to Altered Flow Regimes Table 11-2 Impact of proposed WTP discharge regime during Main Pit backfilling

· impacts to the site and consequences of the 1% Annual Exceedance Probability (AEP) Riverine flooding from the East Branch of the Finniss River and other water courses	Chapter 11.3.1 Altered surface flow regimes
· any groundwater drawdown	Chapter 11.2.2 Impacts due to Groundwater Drawdown Chapter 11.3.2 Groundwater Drawdown Figure 11-4 Predicted Drawdown Year 4 Stage 3 Figure 11-5 Predicted Drawdown Year 10 Stage 3 Chapter 14.3.5 Impacts due to Groundwater Extraction
· volumes of discharge to the environment (ground or surface) from the pit lakes	Chapter 11.2.1 Impact due to Altered Flow Regime
· availability of surface water and groundwater resources to other persons and the environment	Chapter 11.2.2 Impacts due to Groundwater Drawdown Chapter 11.3.2 Groundwater Drawdown Figure 11-4 Predicted Drawdown Year 4 Stage 3 Figure 11-5 Predicted Drawdown Year 10 Stage 3 Chapter 14.3.5 Impacts due to Groundwater Extraction
Mitigation and management Address, at a minimum: · groundwater levels and flows (rate and direction) · surface water volumes and flow rates · connectivity between groundwater and surface water systems	Chapter 11.3 Mitigation and Management Chapter 10.7 Potential Impacts and Risks
Residual impact Provide a statement of the expected environmental condition of the Proposal area when the completion criteria for Hydrological processes are met and assess the significance of any residual impact from the Proposal to identified values.	Chapter 11.5 Statement of Residual Impact Chapter 10.7 Potential Impacts and Risks
2.2.4 Inland water environmental quality	
Environmental values Describe the values associated with the quality of surface water and groundwater within and downstream of the Proposal area that are proposed to be restored, such as the beneficial uses declared for receiving waters (including a map of any beneficial use areas).	Chapter 10.2 Environmental Values Chapter 5.5.6 Water
Potential impacts and risks Analyse and quantify historic impacts to water quality within and downstream of the Proposal area including the flows and loads of contaminants from current waste rock dumps and pits. Quantify and/or discuss the potential impacts of implementing the Proposal and post-rehabilitation, related to:	Chapter 10.4 Existing Water quality Impacts Chapter 6.3 Summary Conceptual Site Model

· passive discharge or seepage of non-benign contaminants from historic or Proposal-related mine waste storages[8], including: o the release of water from the Proposal area through unintended loss of control/containment or intended discharge o potential unintended release of any hazardous substances (including hydrocarbons) o saline drainage from lime-amended waste rock · erosion and sediment loads in stormwater during seasonal and extreme rainfall events	Chapter 10.6 Predicted water Quality Improvements for Rehabilitation Chapter 10.7 Potential Impacts and Risks Chapter 11.2 Potential Impacts and Risks Chapter 10.6.1 Predicted Groundwater Modelling Chapter 10.7.1 Construction Phase Chapter 2.6.2 Waste Management Chapter 12.2.1 Impacts due to Water Contamination Chapter 7.8.5 WSF Seepage Chapter 10.4.3 EBFR Water Quality Impacts Chapter 9 Terrestrial Environmental Quality Chapter 5.5.6 Water Table 6-4 Conceptual Site Model Appendix Water Management Plan Appendix Robertson GeoConsultants 2019 Appendix Robertson GeoConsultants and Jones 2019
This should be supported by a conceptual site model describing sources of potential contaminants, mechanisms for their release, transport pathways, receptors, and fate of any potentially contaminated waters from the Proposal, with reference to the NT EPA Guidelines on Conceptual Site Models (NT EPA 2013c).	Chapter 6.3 Summary Conceptual Site Model Table 6-4 Conceptual Site Model
An assessment of cumulative impacts to the receiving environment should be undertaken that considers the potential impacts to the Proposal's objectives from existing developments and reasonably foreseeable future developments.	Chapter 5.8 Cumulative Impacts Table 12-3 Potential impacts to aquatic ecosystems - low inherent risk
<u>Mitigation and management</u> Provide a Water Management Plan (WMP) to demonstrate that the potential impacts identified above will be sufficiently addressed to meet established completion criteria, including:	Appendix – Water Management Plan
· predicted post-rehabilitation flows and loads of contaminants from proposed waste storage facilities and pits · methodologies for treating any poor-quality water requiring discharge · sufficient detail to demonstrate that rehabilitation strategies will effectively ensure values dependent on good water quality achieve agreed performance indicators and completion criteria, both during construction and into the long-term	Chapter 10.6 Predicted Water Quality Improvements Chapter 10.7 Potential Impacts and Risks Fig 10-38 Predicted post rehabilitation sulphate and copper in EBFR Appendix Robertson GeoConsultants 2019
The WMP should undergo a process of peer review by an independent, appropriately qualified expert with a peer review report included as an attachment to the WMP.	Appendix – Water Management Plan
<u>Monitoring and reporting</u> Address and include a monitoring plan for the Proposal (including post-rehabilitation) for: · pit lakes · groundwater in the vicinity of the Proposal and downstream	Chapter 10.3 Routine water monitoring - the existing program as described here will continue

· surface water in the vicinity of the Proposal and downstream The monitoring plan should include: · groundwater contour mapping · methods to monitor for impacts on surface and groundwater quality · water quality performance indicators triggering management actions · contingencies to be implemented should monitoring identify an unacceptable impact · provisions to notify and respond to environmental and human health risks associated with water quality, or other water related emergency	Chapter 10.7 Potential Impacts and Risks Chapter 11.4.2 Monitoring Plan Table 11-3 Proposed Monitoring Plan
<u>Residual impact</u> Provide a statement of the expected water quality as a result of the Proposal when the completion criteria for this factor are met and assess the significance of any residual impact from the Proposal to identified values.	10.7.2 Potential Impacts and Risks
2.2.5 Aquatic ecosystems <u>Environmental values</u> Describe the values of all aquatic ecosystems in the area where hydrological processes and inland water environmental quality may be impacted by the Proposal. This is to include: · a map delineating the area of existing impact · distribution and abundance or extent of aquatic ecosystems within the impacted area and any comparable control areas · baseline data (current condition) from aquatic ecosystems downstream of the Proposal that are sufficiently statistically robust to determine ecosystem recovery or detect any impacts to these ecosystems as a result of rehabilitation activities	12.1 Environmental Values Chapter 5.5.6 Water Fig 5-8 Finniss River Zones Fig 5-9 Dissolved Copper concentrations Fig 12-1 Surface water features and zones Chapter 12.1 Environmental Values Appendix Hydrobiology 2013, 2016a, 2016b, 2019 Appendix EcOz 2014a, 2014b
<u>Potential impacts and risks</u> Quantify and/or discuss the potential impacts during construction of the Proposal and post-rehabilitation, related to: · changes, in comparison to the current condition, in the distribution, abundance or health of aquatic ecosystems and their constituent taxa due to (at a minimum): o changes to hydrological processes (including reduction or increase in surface water flows or ephemeral pools) o changes in water quality (including from erosion/sedimentation and contamination of water resources)	Chapter 12.2 Potential Impacts and Risks Chapter 11.2 Potential Impacts and Risks Chapter 12.1.4 Threatened Species
<u>Mitigation and management</u>	

Address all potential impacts identified above in accordance with the mitigation hierarchy to meet established completion criteria. Discuss and justify the proposed level/s of protection to be adopted for aquatic ecosystems in accordance with ANZG (2018) within reaches of the Finniss River impacted by the activities on and off site.	Chapter 12.3 Mitigation and Management Chapter 11.3 Mitigation and Management Appendix Hydrobiology 2013, 2016a 2016b, 2019
Monitoring and reporting Address and include a monitoring plan for, at a minimum: · water availability (quantity and quality) for aquatic ecosystems · distribution, abundance and/or health of aquatic ecosystems and constituent taxa	Chapter 12.4 Monitoring and Reporting Chapter 11.4 Monitoring and Reporting
Residual impact Provide a statement of the expected aquatic ecosystem condition as a result of the Proposal when the completion criteria for this factor are met and assess the significance of any residual impact from the Proposal to identified values.	12.5 Statement of Residual Impact
2.2.6 Social, economic and cultural surroundings	
General The description of values and assessment of potential impacts in this factor should take into account the community's views on these matters, as understood by the proponent from stakeholder and community engagement undertaken in accordance with section 2.4 of the NT EPA General Guidance for Proponents Preparing an EIS.	
Environmental values Describe, using maps where appropriate, the existing social, economic and cultural values of the region, including:	Chapter 5.2 Social Setting Chapter 5.3 Existing Services and Infrastructure Chapter 5.4 Economic Setting Chapter 13.1 Socio-Economic Environmental
· population and demographics of the Proposal area and nearby towns, using the most recent statistics	Chapter 13.1.2 People and Community
· economy in the region such as tourism and recreation, pastoral, horticultural and mineral industries	Chapter 13.1.2 Employment and Economies Table 13-2 Industries of employment Fig 13-2 Change in output by industry sector
· areas listed on Australian Government and Northern Territory Government registers of natural, historic and/or cultural heritage	Chapter 8 Historic and Cultural Heritage Appendix Martin-Stone 2019

· a description and location of Aboriginal and non-Aboriginal sites, places or objects of historic or cultural heritage value	Information redacted to protect cultural knowledge - non-redacted data provided to NTEPA for assessment purposes only Chapter 1.4 Traditional Owners Chapter 8.1 Cultural Heritage Values Chapter 4.3.2 Cultural Themes Appendix Martin-Stone 2019
· laws, customs and/or culture of the Traditional Owners and Custodians, including utilisation of Proposal areas and spiritual/cultural significance of potentially affected areas, to establish a baseline for aspects of traditional Aboriginal culture	Chapter 1.4 Traditional Owners Chapter 5.2 Social Setting Chapter 8.1 Cultural Heritage Values Appendix Martin-Stone 2019
· Survey and map the location of large and multi-stemmed cycad trees and large *Livistonia humilis* within proximity of the proposal.	Chapter 8.1.4 Culturally Significant Species Figure 14-27 Suitable Darwin Cycad Habitat
<u>Potential impacts and risks</u> Quantify and/or discuss the following potential impacts for the Proposal, including post-rehabilitation: · social and economic value and potential benefits and impacts of the Proposal on the region and more broadly, where relevant, including: o training and employment opportunities, including for Aboriginal people o changes to economic and social activity in Batchelor and the region, which may have positive and/or negative impacts on local people o impacts on public road networks and users[9] · biophysical and intangible (e.g. amenity or access) changes to sacred sites, heritage objects or places or other places with identified cultural or social values · details of the significance of potential risks to implementation of the Proposal and associated mitigation measures, including the capacity to cost for rehabilitation and ongoing monitoring/maintenance activities	Chapter 13.2 Potential Impacts and Risks Chapter 8.2 Potential Impacts and Risks Appendix GHD 2019e Appendix Martin-Stone 2019
<u>Mitigation and management</u> Address all potential impacts identified above and include: · identification and management of potential local and regional business and employment opportunities related to the Proposal	Chapter 13.3 Mitigation and Management

· strategies for engaging with local Aboriginal communities to facilitate employment including identification of suitable roles, how training may be delivered, and how cultural values would be accommodated	Chapter 13.3 Mitigation and Management
· assessment criteria that would give early warning in the event that management measures are not achieving the expected benefits or are not avoiding negative impacts	
· procedures that would be implemented in the event that any objects or places of heritage and/or cultural significance (additional to those identified in the EIS) are identified during implementation of the Proposal	Chapter 8.3 Mitigation and Management
· measures to avoid impacts to sacred sites[12]	Chapter 8.3 Mitigation and Management
· an outline of a plan for ongoing stakeholder engagement	Chapter 4.5 Future Stakeholder Engagement
<u>Monitoring and reporting</u> Address, at a minimum: · social and economic benefits and impacts · condition of cultural sites	Chapter 8.4 Monitoring and Reporting
<u>Residual impacts</u> Assess the significance of any residual impacts of the Proposal to identified values for Social, economic and cultural surroundings, and discuss how such impacts may affect the achievement of completion criteria for this factor.	Chapter 8.5 Statement of Residual Impact Chapter 13.4 Statement of Residual Impact
2.2.7 Health	
<u>Environmental values</u> Describe the sensitive human receptors within and outside the Proposal area that may be impacted, both during construction and into the long term following rehabilitation.	Chapter 15.1 Introduction Chapter 16.1 Context Appendix EcOz 2019b
<u>Potential impacts and risks</u> Quantify and/or discuss the following potential impacts for the Proposal, including post-rehabilitation: · Radiological impacts including: o details of radiation dose potential from Proposal elements to human health including consideration of exposure due to all pathways: radon and its decay products, radioactive particles in dust, and alpha and gamma radiation o assessment of potential radiation dose delivered via the consumption of local commonly-utilised bush foods and/or livestock where applicable o potential for radioactive elements to concentrate and partition in waste rock disposal facilities and waste rock disposal facility seepage / discharges.	Chapter 16.1.4 Hasard Assessment Chapter 16.1.5 Health Impacts Chapter 16.2 Potential Impacts and Risks Appendix EcOz 2019b

· the potential impacts and risks during the construction and post-rehabilitation phases of the Proposal associated with: o fire, including combustible materials and wildfire o emergency situations and exclusions/evacuation zones o increased traffic and use of existing road networks o hazardous materials exposure, including asbestos and other contaminant sources	Chapter 15.2 Stage 3 Delivery Health and Safety Chapter 15.3 Potential Impacts and Risks
<u>Mitigation and management</u> Address all potential impacts identified above and include:	
· proposed measures to identify, avoid, mitigate and monitor for radiation impacts from the Proposal	Chapter 16.3 Proposed Mitigation and Management EcOz 2019 Radiation Management Plan
· emergency plans and response procedures developed as a contingency in the event of an emergency or accident (e.g. chemical spillages, leaks, fire and explosions, traffic accident) that may impact on the Proposal area, its surrounds, personnel or the public.	Chapter 15.2.5 Emergency Management Chapter 15.4 Mitigation and Management Chapter 2.6.5 Emergency Management Chapter 13.3.3 Services and Infrastructure
MNES should be addressed either through referencing relevant EIS sections in a guidance table or including a dedicated EPBC Act Chapter that addresses all relevant EPBC Act matters.	Chapter 17 EPBC Matters Chapter 17.4 Relevant Matters of National Environmental Significance
<u>Monitoring and reporting</u> Address[14], at a minimum:	
· a radiation-monitoring program that includes radiation monitoring for a critical group. The radiation dose to the critical group is estimated from modelling that requires a discharge-source term	Chapter 16.4 Monitoring and Reporting Appendix EcOz 2019 Section 7
· a monitoring and reporting program to determine the effectiveness of mitigation measures, including identification of when further action is required and outline contingency measures should the proposed mitigation measures not meet outcomes expected and identified by the proponent	Chapter 15.2.6 Reporting and Audits
· a systematic hazard and risk review process to assess the effectiveness of proposed measures in meeting objectives of a radiation management plan and completion criteria	Chapter 15.2.2 Management Framework
· responsibilities and liabilities in an emergency event.	Chapter 15.2.5 Emergency Management Chapter 15.4 Mitigation and Management Chapter 2.6.5 Emergency Management Appendix EcOz 2019 Section 5.1
<u>Residual impacts</u> Provide a statement of the expected condition of the Proposal area when the completion criteria for this factor are met and assess the significance of any residual impact to human health post-rehabilitation.	Chapter 15.5 Statement of Residual Impact Chapter 16.5 Statement of Residual Impact

21. Appendix

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