Northern Territory Government

Former Rum Jungle Mine Site

Conceptual Rehabilitation Plan

May 2013

Acknowledgements

This report was prepared by the Northern Territory Department of Mines and Energy. Many people have contributed to writing this report.

Lead Author
Tania Laurencont

Contributing Authors
Ian Dixon, Cyrus Edwards, Mike Fawcett, Paul Ferguson, Lauren Keliher, Maria Kraatz, Virginia Leitch, Brendan Lewis, Andy Markham, Ranid May, Mitchell Rider, Howard Smith, Ross Smith, Corinne Unger, Peter Waggitt, and Richard Walton.

In particular, the significant contribution made by Corinne Unger in organising and coordinating all of the components of the report is acknowledged and appreciated.

This report was independently reviewed by Dr David Jones, B.Sc. (Hons 1), Ph.D, Principal, DR Jones Environmental Excellence and formerly Director of the Environmental Research Institute of the Supervising Scientist.

We appreciate the expertise, contributions and technical oversight made by the Rum Jungle Working Group. We have worked in close partnership with Kungarakan and Warai to develop a shared understanding of the importance of the site. The DME also wishes to recognise contributions of expert consultants and stakeholders groups.

Copy editor
Justine Gannon

31 July 2013
Northern Territory Government

Table of contents

List of abbreviations

AAEC	Australian Atomic Energy Commission
AAPA	Aboriginal Areas Protection Authority
ABS	Australian Bureau of Statistics
Ag	Silver
Al	Aluminium
ALRA	*Aboriginal Land Rights (Northern Territory) Act 1976*
AMD	Acid and metalliferous drainage
ANZECC	Australian and New Zealand Environment Consultative Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ARPANS Act	*Australian Radiation Protection and Nuclear Safety Act 1998*
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
As	Arsenic
AVHRR	Advanced Very High Resolution Radiometer
Ba	Barium
BOM	Bureau of Meteorology
Ca	Calcium
CCGC	Coomalie Community Government Council
Cd	Cadmium
CDA	Combined Development Agency
Co	Cobalt
CRA	Conzinc Riotinto of Australia Ltd
CSIRO	Commonwealth Scientific and Industrial Research Organisation
Cu	Copper
Cr	Chromium
DLPE	Northern Territory Department of Lands Planning and the Environment
DME	Northern Territory Department of Mines and Energy
EC	Electrical Conductivity
EMS	Ecological Management Services
EPBCA	*Environment Protection and Biodiversity Conservation Act 1999*
eriss	Environmental Research Institute of the Supervising Scientist

List of abbreviations (cont)

eU	Equivalent Uranium
EWLS	Earth Water Life Sciences Pty Ltd
Fe	Iron
FPXRF	Field Portable X-Ray Fluorescence Spectrometry
FW/SW	Freshwater/Seawater (interface)
GEP	Groupe d'Expertise Pluraliste
GmbH	Limited Liability Company (Germany)
H-x%PC	Highly disturbed ecosystem with an x% protective concentration recommended
HCV	High Conservation Value ecosystems
Hg	Mercury
IAEA	International Atomic Energy Agency
ICMM	International Council for Mining and Metals
ICRP	International Commission on Radiation Protection
IPCC	Intergovernmental Panel on Climate Change
Mg	Magnesium
Mn	Manganese
NAFI	North Australian Fire Information
NATO	North Atlantic Treaty Organization
NHMRC	National Health and Medical Research Council
Ni	Nickel
NLC	Northern Land Council
NPA	National Partnership Agreement
NOAA	National Oceanic and Atmospheric Administration
NRETAS	Northern Territory Department of Natural Resources, Environment, The Arts and Sport
NTU	Nephelometric Turbidity Units
OECD	Organization for Economic Cooperation and Development
OH&S	Occupational Health and Safety
OKC	O'Kane Consultants Pty Ltd

List of abbreviations (cont)

OSCE	Organization for Security and Co-operation in Europe
Pb	Lead
Rb	Rubidium
RBA	Reserve Bank of Australia
RET	Commonwealth Department of Resources, Energy, and Tourism
RGC	Robertson GeoConsultants Inc.
RJCS	Rum Jungle Creek South (Mine)
RJMC	Rum Jungle Monitoring Committee
RJPT	Rum Jungle Project Team
RJWG	Rum Jungle Working Group
Sb	Antimony
Se	Selenium
SSD	Commonwealth Supervising Scientist Division
SMD	Slightly/Moderately Disturbed ecosystems
SO_4	Sulfate
SOCS	Sites of Conservation Significance
Sr	Strontium
SRK	SRK Consulting (Australasia) Pty Ltd
TEP	Territory Enterprises Pty Ltd
U	Uranium
UKAEA	United Kingdom Atomic Energy Authority
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USAEC	United States Atomic Energy Commission
V	Vanadium
WQO	Water Quality Objectives
XRF	X-Ray Fluorescence Spectrometry
Zn	Zinc
Zr	Zirconium

Executive summary

History of mining and rehabilitation at Rum Jungle

The Rum Jungle uranium ore body was discovered in 1949. Mining was undertaken between 1952 and 1963 using open pit methods. All mining and processing operations at Rum Jungle ceased in 1971. The former Rum Jungle mine site consists of:

- three waste rock dumps — Main, Intermediate and Dysons
- two water-filled mine pits — Main and Intermediate
- one mine pit backfilled with tailings and overlain with contaminated soil (Dysons).

The mining and placement methods used for waste rock and process tailings during this time resulted in substantial volumes of acid and metalliferous drainage. Ongoing oxidation of sulfide minerals in the waste, followed by annual wet season leaching of soluble oxidation products released large concentrations of copper and other heavy metals and acid into the surrounding environment. The Commonwealth of Australia provided financial assistance to the Northern Territory to implement a four-year rehabilitation program between 1982 and 1986, to address these issues, followed by a 12-year monitoring program.

After the rehabilitation works were completed, a technical assessment determined the engineering and environmental criteria set for the rehabilitation project were successfully met. However, works did not result in a final condition for the site that would meet contemporary water quality standards. When funding for the 12-year monitoring program ceased, additional problems also arose with how to manage wildfire, weeds, feral animals, and access.

The Finniss River Land Claim No. 39 was lodged by the Northern Land Council on behalf of claimants on 20 July 1979, under section 50(1)(a) of the *Aboriginal Land Rights (Northern Territory) Act 1976* (ALRA). Rum Jungle formed part of the area subject to the claim. An inquiry into the claim was conducted by the Aboriginal Land Commissioner, who recommended that the majority of land subject to the claim, including Rum Jungle, be granted to Aboriginal Land Trusts established under ALRA. Kungarakan and Warai people were found to be traditional Aboriginal owners of Rum Jungle and other areas subject to claim.

The majority of the land recommended for grant was vested in two Aboriginal Land Trusts. No decision on the potential grant of the Rum Jungle site has yet been made, pending the outcome of negotiations between the Commonwealth, the Northern Land Council and Kungarakan and Warai people about the future of the site, including rehabilitation.

Current site condition

In response to these issues, the *National Partnership Agreement on the Management of the Former Rum Jungle Mine Site* (NPA) was established in 2009. The objectives of the NPA are to improve management of the site, undertake environmental monitoring and develop an improved rehabilitation strategy for the site that is consistent with the views and beliefs of the traditional Aboriginal owners.

Access tracks and roads within the site have been regularly maintained and upgraded to improve access for monitoring activities and site characterisation studies. The site is extensively infested with weeds – predominantly gamba grass – which has restricted native vegetation re-colonisation, significantly elevated the bushfire safety risk and is of substantial concern to traditional Aboriginal owners. Weed management activities include strategic herbicide application, fuel reduction burning and commencement of a revegetation trial over the former Borrow Area 5.

A comprehensive ground and surface water monitoring program has been a key component of the NPA. The monitoring is to gain a better understanding of the water quality conditions onsite and offsite, and also to provide data for the hydrogeological investigations and surface water flow and solute load studies. The network of streamflow and water quality measurement instrumentation has been progressively expanded to address the data requirements of the technical investigations being conducted. The network of groundwater monitoring bores has also been substantively expanded to address identified knowledge gaps.

A significant number of technical investigations have been conducted under the NPA. These investigations have identified that all waste materials stored onsite contains sulfides and elevated concentrations of metals (aluminium, cadmium, cobalt, copper, magnesium, nickel, selenium, uranium, sulphate and zinc), which generate AMD. AMD affects the East Branch of the Finniss River and the Finniss River downstream of the mine; concentrations of cobalt, copper, and nickel exceed ANZECC water quality guideline trigger values for the protection of aquatic ecosystems during low-flow periods in the river. Copper concentrations exceed the trigger values in the East Branch of the Finniss River under all flow conditions. These metals can precipitate onto the riverbed and re-mobilise in the 'first flush' of contaminants in the river system. The first flush can be detrimental to aquatic ecology due to the elevated metals concentrations. A comprehensive groundwater investigation identified localised groundwater contamination on the site.

Investigations also identified localised contamination of soil with metals that requires cleaning up, including the operations area, the old tailings dam area, and the fluvial areas. These areas may also include radiological contamination (e.g. unclaimed tailings, boulders).

The vegetation on the mine site is composed of mostly grass species, with significant weed infestations, leading to erosion and degradation of the existing covers on the waste rock dumps.

In May 2011, the NPA was expanded to include three additional sites that contributed to the mining operations at the main Rum Jungle site from 1954 to 1971. Deposits at Rum Jungle Creek South and Mount Burton were mined and then processed at the main Rum Jungle mine site. Mining exploration was also undertaken at the Mount Fitch site.

Conceptual Rehabilitation Plan

This report, the *Conceptual Rehabilitation Plan* documents the findings from technical investigations commissioned to fill key knowledge gaps about the current environmental status of the site, the outcomes of consultation with key stakeholders, site maintenance activities, and the process by which a preferred conceptual rehabilitation strategy has been developed. Both the long-term monitoring data and previous technical investigations on the site and downstream were intensively reviewed to identify areas of technical certainty and uncertainty. The key information gaps that were identified were used to scope and commission new investigations to inform the options being developed for rehabilitation of the site. In addition, both Aboriginal and non-Aboriginal cultural heritage attributes have been taken into account because they are fundamentally important to achieving a successful rehabilitation outcome for the site. Finally industry-specific leading practice principles, together with leading practice guidance from relevant national and international agencies has been incorporated into the project.

Selected remediation scenario

Five remediation scenarios were developed for evaluation. A rigorous evaluation was undertaken in February 2013 with input from the Rum Jungle Working Group and traditional Aboriginal owners. The evaluation process, known as Multiple Accounts Analysis, focused on four key categories: environmental, technical, cultural, and financial.

The preferred scenario addresses the issue of AMD by, where possible, returning waste material back to former mine pits and consolidating the remaining waste into a single location. Traditional Aboriginal owners have identified that they would like the site to return, where practical to its pre-mining topography and allow sustainable traditional land uses.

The details of the preferred scenario are:

- The preferred scenario relocates waste material from the top of Dysons backfilled pit, Intermediate waste rock dump and a small amount of the waste from the Main waste rock dump, with placement to the former mine pits. This waste rock has the highest potential to generate contaminants. Forty-eight per cent of the total volume of waste material currently stored on the site will be used to refill the former mine pits. The remaining waste rock will be consolidated into a new, purpose-built waste rock dump.
- Leading practice landform and cover designs will be developed and implemented for the in-filled pits and the waste rock dump. The design may include an option of shallow-water covers for the in-filled pits. All covers will be revegetated.
- Any residual contaminated soils will also be consolidated to the waste rock dump, including cleaning up of contaminated fluvial areas.
- The concept of passive water treatment systems requires investigation, including reactive barriers and wetlands. If they are required, passive water treatments will be incorporated into the final design for diversion drains and or drainage lines.
- The preferred scenario takes important cultural aspects of the landscape into account and tries, wherever possible, to protect or reinstate them.

The current NPA expires on 30 June 2013; however, the site will continue to require a level of ongoing maintenance and monitoring regardless of any future rehabilitation activities. A number of activities are needed to maintain the site and continue the collection of critical environmental data. Maintenance of the site in its current condition will not prevent the continuing decline in the performance of waste rock dump covers and the consequent increase in the pollutant load leaving the site. The projected costs for the 2013/14 financial year for maintenance and monitoring of Rum Jungle are estimated at $550,000.

To progress from the conceptual rehabilitation scenario delivered by this report through the NPA into a package of works that is ready for implementation will require substantially more work. It is proposed that this additional work is carried out through an extension of the current NPA, referred to as Stage 2. The projected costs estimated for Stage 2 are $11,288,000 over three years. Completion of Stage 2 will deliver a rigorously designed and fully costed rehabilitation program ready for implementation during the construction phase (i.e. Stage 3).

1. The Conceptual Rehabilitation Plan

1.1. Project initiation

Rum Jungle is a former mine site near Batchelor in the Northern Territory, approximately 105 kilometres, by road, south of Darwin. Between 1954 and 1971, Rum Jungle produced 3530 tonnes of uranium oxide and 20,000 tonnes of copper concentrate. As shown in Figure 1-1, the former Rum Jungle mine site consists of:

- three waste rock dumps — Main, Intermediate and Dysons
- two water-filled mine pits — Main and Intermediate
- one mine pit backfilled with tailings and overlain with contaminated soil and copper extraction pad material (Dysons).

Mining and mineral processing at the site created significant environmental impacts, primarily AMD, which polluted the East Branch of the Finniss River (East Branch). The site was rehabilitated between 1983 and 1986. At the time, the rehabilitation was deemed to have achieved its objectives. However, more recent studies have documented a gradual deterioration of the original rehabilitation works (Taylor, et al., 2003). The site was declared a Restricted Use Area in 1989 under the Northern Territory's *Soil Conservation and Land Utilisation Act* (NT Government Gazette, 1989), prohibiting access by the public that may cause soil erosion within the rehabilitated areas.

The Finniss River Land Claim No. 39 was lodged by the Northern Land Council on behalf of claimants on 20 July 1979, under section 50(1)(a) of the *Aboriginal Land Rights (Northern Territory) Act 1976* (ALRA). Rum Jungle formed part of the area subject to the claim. An inquiry into the claim was conducted by the Aboriginal Land Commissioners, Justice John Toohey, who presented findings in the Finniss River Land Claim No. 39 (Report No. 9) on 22 May 1981 (Commonwealth of Australia, 1981). The Aboriginal Land Commissioner recommended that the majority of land subject to the claim, including Rum Jungle, be granted to Aboriginal Land Trusts established under ALRA for the benefit of Aboriginals entitled to the use and occupation of the land. Kungarakan and Warai people were found to be traditional Aboriginal owners of Rum Jungle and other areas subject to claim. The Aboriginal Land Commissioner noted that it was open to the responsible Commonwealth Minister to act on all, some or none of the recommendations contained in Report No. 9.

In considering issues of potential detriment to carious parties in the event of an Aboriginal land grant under ALRA, the Aboriginal Land Commissioner noted that the making of a conditional recommendation for a grant of land is not appropriate, that the Commonwealth wished to embark on a project to rehabilitate Rum Jungle and so long as it had access to the site it was unlikely to suffer any detriment if the claim was acceded to.

Between 1991 and 1993, the majority of the land recommended for grant was vested in two Aboriginal Land Trusts. No decision on the potential grant of the Rum Jungle site has yet been made, pending the outcome of negotiations between the Commonwealth, the Northern Land Council and Kungarakan and Warai people about the future of the site, including rehabilitation.

Given advances in best practice standards in mine closure and rehabilitation, the Northern Territory and Australian Governments recognised a need to develop an improved rehabilitation strategy for the Rum Jungle site.

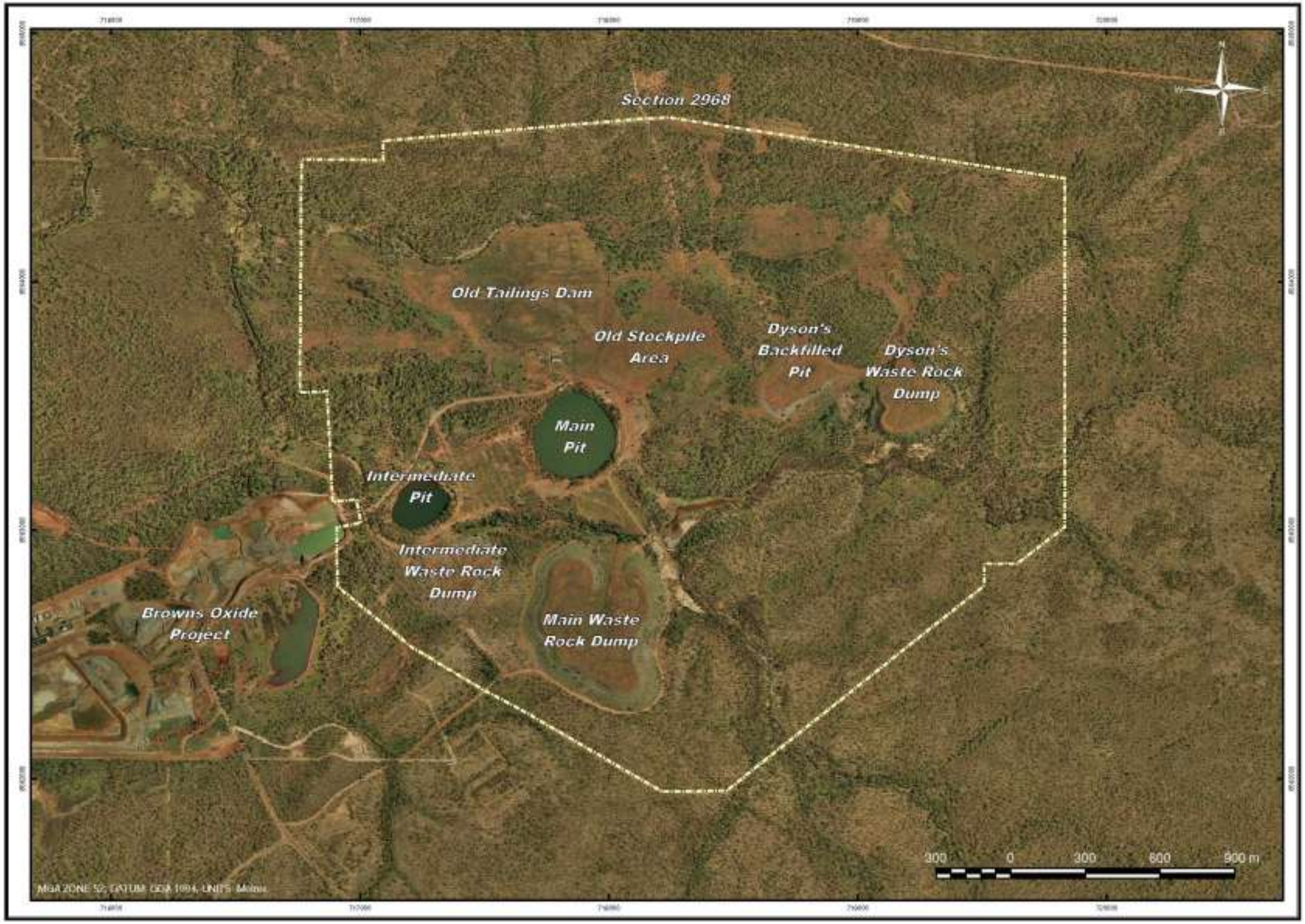


Figure 1-1 Rum Jungle site photo 2010

1.2. National Partnership Agreement

As part of the 2009–10 budget, the Australian Government committed $7 million over a four-year period for the environmental management of Rum Jungle (Commonwealth Government, 2009). To manage this commitment, the Northern Territory Government and the Commonwealth of Australia entered into a *National Partnership Agreement on the management of the former Rum Jungle mine site* (NPA). The NPA defines the overall objectives and outcomes for the program of works at Rum Jungle.

Under the terms of the NPA, the Commonwealth and Northern Territory Government committed to improving the management of Rum Jungle in a way that is consistent with the interests of stakeholders, particularly traditional Aboriginal owners by:

- improving the understanding of the current state of the environment
- improving site management
- developing an improved rehabilitation strategy, which may lead to future rehabilitation works under new arrangements.

An associated Implementation Plan outlines the milestones, reporting requirements, and payment arrangements for the NPA. Both the NPA and the Implementation Plan are being driven by the Northern Territory Department of Mines and Energy (DME), with technical oversight from the Rum Jungle Working Group, comprised of Northern Territory and Australian Government agencies and the Northern Land Council.

In May 2011, the NPA was expanded to include three additional sites that contributed to the mining operations at the main Rum Jungle site from 1954 to 1971. Mineral deposits at Rum Jungle Creek South (RJCS) and Mount Burton were mined, with ore trucked to and processed at the main Rum Jungle mine site. Mining exploration was also undertaken at the Mount Fitch site.

1.3. Project objectives

The NPA must meet the objectives of the Commonwealth and Northern Territory Government, meet objectives to achieve improved environmental and social outcomes, and meet the objectives articulated by the traditional Aboriginal owners.

1.3.1 Objectives of the Commonwealth and Northern Territory Government

The NPA sets out the objectives of the Commonwealth and Northern Territory Government for the program of works at Rum Jungle:

- improved understanding of the current state of environment
- improved site management
- an improved rehabilitation strategy for the site.

This will be achieved by:

- ongoing environmental monitoring programs
- developing site management and rehabilitation strategies
- undertaking ongoing activities to maintain the site.

1.3.2 Rehabilitation objectives

Through consultation with stakeholders, rehabilitation objectives for Rum Jungle were developed and aim to create a landscape that:

- is safe for people and wildlife
- is chemically, radiologically and physically stable
- has a significantly reduced contaminant load (associated with AMD) travelling beyond the boundaries of the site
- supports sustainable land uses by traditional Aboriginal owners of the area with few, if any, limitations
- encourages beneficial alternative post-rehabilitation land uses.

1.3.3 Traditional Aboriginal owner objectives

The Kungarakan and Warai are recognised as joint traditional owners of the site. Their objectives for rehabilitation and post-rehabilitation land use are summed up in their vision for the site. As they do not differentiate between environment and culture, their vision is largely drawn from their cultural and social principles:

> **Kungarakan and Warai desire that Rum Jungle will be returned to a natural, living environment that also provides for a return to traditional ceremony, culture and subsistence use of natural resources. In modern society, this may include development of commercial operations that are managed according to Kungarakan and Warai traditional principles.**

The post-mining landform must be returned as close as possible to the landform that existed before mining, with no detrimental impacts on the downstream environment or on the neighbours of Kungarakan and Warai who live downstream.

To Kungarakan and Warai, rehabilitation of the physical landscape will allow spiritual healing of the country. The following outcomes are required for their vision and for the healing process to be achieved:

- culturally appropriate preservation of Aboriginal cultural heritage
- re-establishment of the original landform as far as achieving the best outcomes allows
- removing or neutralising pollution sources
- removing any risk of radiological hazard
- remediating polluted groundwater
- stopping surface water from being polluted
- restoring flora and fauna species endemic to the site and its immediate surrounds
- maximising employment and business opportunities throughout the rehabilitation process.

Under each of these high-level requirements are a number of individual elements, each of which contribute greater detail to more fully define the desired outcomes (refer to Appendix 1).

1.4. Staging of the Rum Jungle rehabilitation project

It is anticipated the rehabilitation of Rum Jungle will be undertaken in five stages, as shown in Figure 1-2.

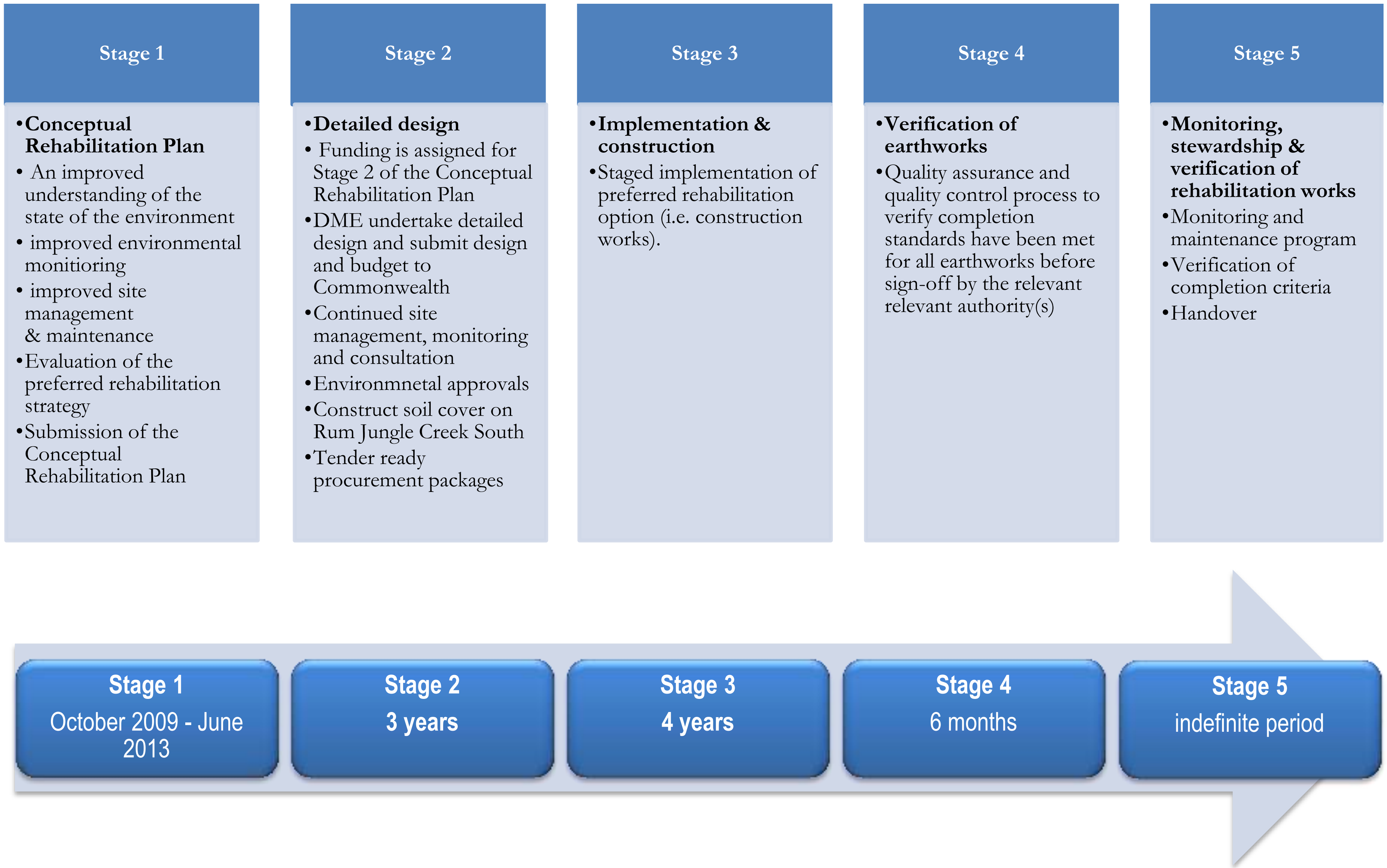


Figure 1-2 Stages of rehabilitation planning and implementation for Rum Jungle

1.4.1 Stage 1

This document is the output of Stage 1—the *Conceptual Rehabilitation Plan*. This plan is based on comprehensive technical studies commissioned as part of the NPA, developing an understanding of traditional Aboriginal owner requirements, and investigating leading practice rehabilitation methods around the world. The objectives of the *Conceptual Rehabilitation Plan* are detailed in Section 1.3.

The Rum Jungle Project Team (RJPT) undertook a detailed literature review and gap analysis of all historical reports, monitoring data, and work programs at the site dating back to the 1950s. This process identified key areas where data and information were lacking or non-existent. After the literature review and gap analysis was completed, a list of projects that needed to be undertaken was developed to fill data gaps and help the project team better understand the health and safety, environmental, and cultural heritage aspects and interactions at the site. These studies are described in Section 6 and include internal projects (undertaken by the project team) and external projects (undertaken by consultants).

Site management and monitoring has been a key aspect of the NPA, including monitoring of surface and ground water quality, enhancing site security and safety and weed and fire management.

A number of draft rehabilitation scenarios were evaluated to identify a preferred rehabilitation scenario. Some rehabilitation scenarios were rejected due to insufficient environmental improvement or because they cannot be undertaken in a culturally appropriate manner. Risk (scientific uncertainty) and sustainability of the physical environment, ecosystems, and socio-economic systems were considered for each scenario. The preferred rehabilitation scenario (refer to Section 7 for details) should be progressed in Stage 2 of the *Conceptual Rehabilitation Plan* through to detailed design and construction documentation, which will allow for immediate implementation should future funding be secured.

In parallel with progressing the technical components of the work, the RJPT developed and implemented a stakeholder consultation plan. The key stakeholders groups for this project are: traditional Aboriginal owners, the Rum Jungle Working Group (RJWG), state and federal government organisations, affected landowners, the community of Batchelor, non-government organisations, tourists, scientific research organisations and universities, prospective contractors and consultants and the media.

1.4.2 Stage 2

The activities for Stage 2 include detailed engineering design (including supporting investigations); scheduling arrangements (project management); preparation of detailed procurement packages; attainment of relevant environmental approvals; stakeholder engagement; and ongoing site monitoring and maintenance. The tasks outlined as part of Stage 2 are necessary for costing the selected rehabilitation scenario to a satisfactory level of accuracy to secure capital works funding, and for all regulatory and preparatory work to be completed for implementation in Stage 3.

1.4.3 Stages 3, 4, and 5

Stage 3 is the implementation phase (on the ground works) at Rum Jungle. Stage 4 is the post-rehabilitation verification and quality assurance phase. Stage 5 comprises ongoing monitoring and stewardship activities. Figure 1-2 shows the estimated time for each stage. Start dates for all the future stages are dependent on allocation of funding.

2. Ownership and legislation

2.1. Ownership

The tenure designation of Rum Jungle is Section 2968 (shown as the pale blue area Figure 2-1) of the Hundred of Goyder, held as vacant Northern Territory Crown Land. The site is subject to several exploration licences: ELR 146, EL 27007, EL 27559, EL 27560 and EL 27562, held by Compass Resources Limited as also shown in Figure 2-1.

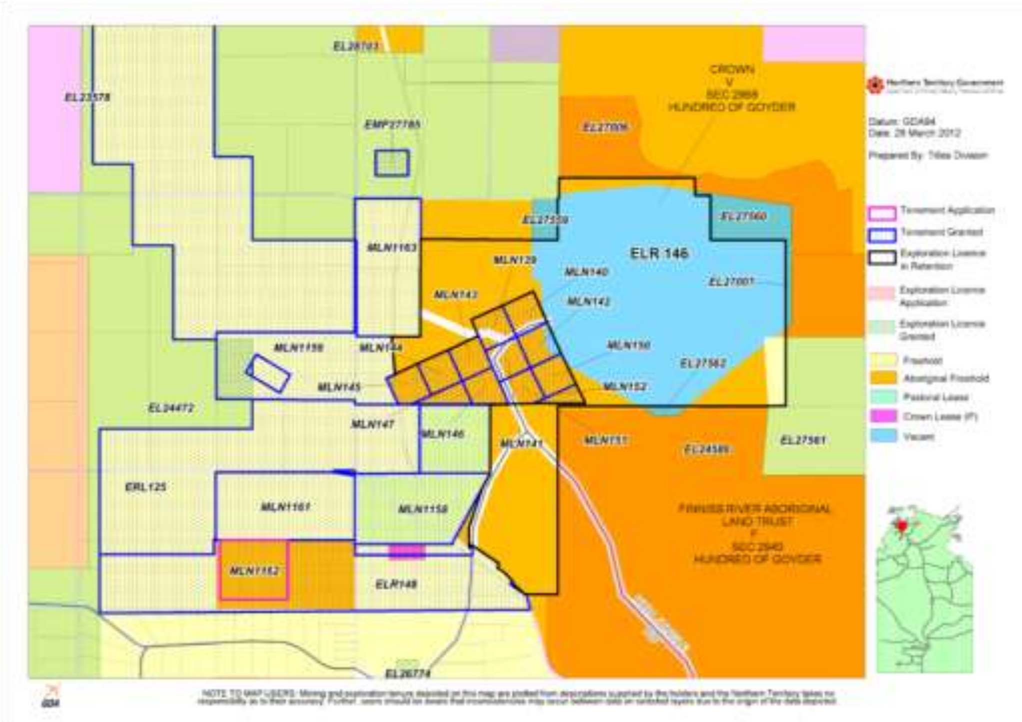


Figure 2-1 Exploration tenure in vicinity of Rum Jungle

If Rum Jungle is granted to traditional Aboriginal owners as freehold land, Commonwealth and Northern Territory legislation will continue to apply to the land, including in relation to the management and use of the land.

The Commonwealth and Northern Territory Governments may wish to continue to access Rum Jungle for the purpose of further rehabilitation. Where, on the vesting of land in a Land Trust, the land is being used or occupied by the Crown, the Crown is entitled to continue that occupation or use for such period as required (s 14 of the ALRA). Section 19 of the ALRA additionally providers that a Land Trust may grant an estate or interest in Aboriginal land vested in it to a third party, such as the Commonwealth of the Northern Territory. Therefore, if Rum Jungle were granted as Aboriginal land, the relevant Land Trust could grant a lease or other interest to government to facilitate further access to the land by government for the purpose of ongoing rehabilitation of the land. Under such an arrangement, the site could be returned to its traditional Aboriginal owners and cooperatively managed with government. The lease arrangement would clearly define each party's rights and responsibilities. For example, the government could be guaranteed access to assess the sustainability of the rehabilitation works, while also allowing traditional Aboriginal owners day-to-day involvement in managing and monitoring the site. Both the Northern Territory Government and Commonwealth recognise the traditional Aboriginal owners' aspiration to manage their land.

2.2. Legislation

Future rehabilitation works at Rum Jungle may trigger assessment under current Northern Territory and Commonwealth Government legislation.

2.2.1 Commonwealth Government Legislation

Environmental Protection and Biodiversity Conservation Act 1999

Triggering Commonwealth legislation will depend on assessment of matters of national environmental significance under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBCA).

Under the EPBCA, any project or activity will require Ministerial approval if it, 'has, will have or is likely to have a significant impact' on a matter of National Environmental Significance. The *Conceptual Rehabilitation Plan* for Rum Jungle will be referred to the Department of Sustainability, Environment, Water, Population, and Communities for a decision about whether future rehabilitation proposed requires approval under the EPBCA.

The department will consider:

- if there are any matters of national environmental significance in the area, including adjacent or downstream areas that may potentially be impacted
- if there is potential for impacts, including indirect impacts, on matters of national environmental significance
- if there are any proposed measures to avoid or reduce impacts on matters on national environmental significance
- if there are any impacts on matters of environmental significance that are likely to be significant.

Australian Radiation Protection and Nuclear Safety Act 1998

As Rum Jungle is the site of a former uranium mine which was operated by a contractor on behalf of the Commonwealth of Australia and there are residual radiological safety issues, provisions of the *Australian Radiation Protection and Nuclear Safety Act 1998* (ARPANS Act) may also need to be addressed.

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) is responsible for protecting the health and safety of people, and the environment, from the harmful effects of ionising and non-ionising radiation.

During rehabilitation works, and for long-term safety of the site after rehabilitation, ARPANSA and Northern Territory regulators require activities onsite to comply with the *Code of Practice & Safety Guide Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing* (the code) (ARPANSA, 2005). Consistent with international standards, the code establishes the mandatory requirements for occupational and public radiation exposures, and the management of radioactive wastes.

The Code also reflects the information contained in *Recommendations for Limiting Exposure to Ionizing Radiation* and *National Standard for Limiting Occupational Exposure to Ionizing Radiation* (ARPANSA, 2002). It has not yet been determined what operational role ARPANSA will have in any future remediation activities at Rum Jungle.

2.2.2 Northern Territory Government legislation

In the Northern Territory, any proposed new projects with potential to impact the environment may be subject to an environmental impact assessment process. The *Environmental Assessment Act 1982* and its subordinate Environmental Assessment Administrative Procedures 1984 form the basis of this process. This legislation is administered by the Northern Territory Environment Protection Authority.

The level of environmental assessment varies depending on the sensitivity of the local environment, the scale of the proposal, and its potential impact on the environment. If the proposal is considered to have the potential to significantly impact on the environment, proponents are directed to prepare either a Public Environment Report or an Environmental Impact Statement.

Bilateral agreements exist between the Australian Government and the Northern Territory to jointly assess proposals where the EPBCA is triggered. The Northern Territory and Australian Government decide whether to approve the proposal, with or without conditions.

The relevant Northern Territory Government departments will decide the level of assessment required based on the *Rum Jungle Conceptual Rehabilitation Plan*.

Implementing a rehabilitation program at Rum Jungle may also require an authorisation under the Northern Territory's *Mining Management Act*. This authorisation is issued when a Mining Management Plan for the proposed works is approved by the Mining Environmental Compliance Division of DME. Depending on the extent of activity, the Mining Management Plan may need to include a water management plan, descriptions of all proposed earthworks, and a radiation management plan for the implementing workforce.

Aboriginal Areas Protection Authority Certificate Process

The Aboriginal Areas Protection Authority (AAPA) is an independent statutory organisation responsible for administering the *Northern Territory Aboriginal Sacred Sites Act* (Sacred Sites Act). The act protects sacred sites, which are defined, 'as a site which is sacred to Aboriginals or is otherwise of significance according to Aboriginal tradition, and includes any land that, under a law of the Northern Territory, is declared to be sacred to Aboriginals or of significance according to Aboriginal tradition'. In more general terms, sacred sites are places within the landscape that have a special significance under Aboriginal tradition and may include hills, rocks, waterholes, trees, plains, and other natural features.

Under the Sacred Sites Act, custodians of sacred sites are recognised Aboriginals who, by tradition, have responsibility for that particular site. Before undertaking any works on land that may contain sacred sites, it is good practice to obtain an Authority Certificate issued by the AAPA. An Authority Certificate sets out conditions for using or carrying out works on land on, or near, sacred sites. The certificate indemnifies the holder for works carried out, provided they are carried out in accordance with the conditions of the certificate.

In 2010, DME lodged an application to start the Authority Certificate process to undertake site maintenance, monitoring activities, and site characterisation studies required under the NPA. The process involved several meetings with custodians, site visits, and anthropological research. The application process took approximately six months to complete. The Authority Certificate issued to DME outlines a number of conditions relating to the proposed activities, including the requirement for site inductions of any people undertaking works on site. All people who have accessed the site have undergone a detailed site induction process that reflects the requirements of the Authority Certificate conditions. Custodians of the site attended all inductions.

3. Leading practice in mine remediation

3.1. Case studies and guidelines

In developing the Rum Jungle Conceptual Rehabilitation Plan, the RJPT has incorporated industry-specific leading practice principles, together with leading practice guidance from relevant national and international agencies.

The concept of leading practice is (RET, 2011):

> "…about identifying and implementing the best way of doing things for a given site. As new challenges emerge and new solutions are developed, or better solutions are devised for existing issues, it is important that leading practice be flexible and innovative in developing solutions that match site-specific requirements. Although there are underpinning principles, leading practice is as much about approach and attitude as it is about a fixed set of practices or a particular technology."

A number of international case studies highlight the application of leading practice principles to managing and remediating abandoned mine sites. This section outlines four case studies to illustrate the key elements of leading practice in the rehabilitation of abandoned mines, including two examples of rehabilitation of uranium mines. Leading practice uranium mine rehabilitation reference documents are referenced in Section 3.3.

3.2. Wismut mine legacy rehabilitation in Germany

The former state-run (East) German uranium mining company, Wismut, operated for over 40 years. Wismut's operations were located in the regions of Saxony and Thuringia (Figure 3-1). The company was the world's third largest producer of uranium until 1990, with about 216,000 tonnes of uranium mined between 1946 and 1990. Wismut shut down in 1990 as part of the re-unification of Germany.

In 1990, Wismut's environmental liabilities were spread over 37 km^2, including 320 million m^3 of waste rock, 178 million m^3 of uranium mill tailings, one open pit, five large underground mines, and 1400 km of tunnels. In 1991, Wismut GmbH was set up as a federal government-owned company whose principal business is to decommission, clean-up, and rehabilitate Wismut's mining and processing sites across what is possibly the world's largest mine closure program (Paul et al., 2009). The budget for this project is the equivalent of €6.9 billion (1990) and work started in 1991. Twenty years after the start of work, Wismut showcased their progress (Wismut, 2011).

By 2008, more than 98 per cent of underground workings were remediated and 70 per cent of surface remediation was complete. The physical remediation works are expected to be completed by 2015, after which water treatment, environmental monitoring, and maintenance will be the primary focus of a scaled-back operation.

Figure 3-1 Location of Wismut rehabilitation areas, south-west of Dresden (Source: Paul, 2012)

3.2.1. Successful post-mining land uses

The remediation of the Wismut mine sites has enabled communities to stay in the region, living close to the former mine sites. As shown in Figure 3-2, many land uses have been incorporated into the project: a golf course, forests, grazing land, and wetlands. Two landmark projects have also been incorporated into the remediation works: Schlema, a town successfully restored as a spa town and Ronneburg where the rehabilitated mine landscape has become a visitors centre and event venue.

Source: Paul, 2012

Figure 3-2 Wismut's mined landscapes before and after rehabilitation

3.2.2. IBA-SEE regional regeneration project in Germany

The IBA-SEE was a 10-year rehabilitation project to regenerate both the landscape and economy of the Lusatian region in Germany completed in 2010. The IBA-SEE project successfully implemented a vision for the regeneration by stabilising open pits, creating a large interconnected lake system, water management, landscape rehabilitation, conservation of mining heritage features, and new infrastructure to support land uses focused on tourism and water-based activities (IBA-SEE, 2009) as shown in Figure 3-3.

The IBA-SEE project is based around ten principles (Unger, 2010):

1. Developing iconic sites as examples for other projects
2. Using resources effectively
3. Fostering identity (link between industrial heritage and new landscapes)
4. The importance of a long-term planning perspective
5. Shaping the process with strong leadership
6. Allowing for creativity and innovation
7. Generating pictures by visualisation of completed landscapes
8. Ensuring transparency
9. Building the organisational structure
10. The role of all levels of government collaborating to take responsibility.

Images courtesy of IBA Fürst-Pückler-Land, (L) Mesh design and (R) Profifoto Kliche in Unger (2010)

Figure 3-3 IBA post-mining lake landscape and conceptual design of one of the lakes

3.2.3. The Eden Project, England

The Eden Project in Cornwall, England has been described as a 'sustainability theme park'. Established within a reclaimed kaolinite clay pit, the Eden Project is a charity and tourist attraction focused on community education about sustainable development. In addition to the tourist attraction, a Post-Mining Alliance was formed to communicate what has been learnt from this project and other leading-practice mine rehabilitation projects globally, particularly focusing on projects with successful socio-economic regeneration (Unger, 2010). The Post-Mining Alliance observed that the key ingredients for successful regeneration projects include (Pearman, 2009):

- the development of local solutions to fit local circumstances
- leadership, vision, and commitment
- creative partnerships for funding
- development and implementation
- collaboration with 'unusual suspects'.

Successful partnerships involve shared interests with community involvement and consultation at all stages to develop joint responsibility and ownership.

Other factors that contribute to successful mine rehabilitation projects include: hybrid projects and multi-purpose sites, good locations linked to transport, being close to a sizable population if visitor-dependent, links between heritage attractions in the same region, government commitment to funding, and legislation where, for example, biodiversity is a priority (Pearman, 2009). However, some of these factors are site-specific.

3.2.4. Uranium mine rehabilitation in France

The French company now known as Areva had extensive uranium mining operations across France, with nearly 100 sites from 1948 until about 1990, after which production declined. The last mills owned by Areva were closed in 2001. The remediation of their numerous sites has been the subject of many papers. The diverse range of post-mining land uses has been a feature of their remediation program, ranging from a catch-and-release fly fishing club at a former open pit at Puy de L'Age, grassland at Bessines, and a photovoltaic farm at Ecarpiere. The Groupe d'Expertise Pluraliste (GEP) is a committee of experts and stakeholders tasked with studying the success of the Areva remediation works 10 or more years after completion (GEP, 2010). The GEP analysed 50 years of uranium mining in France and listed 15 major recommendations for improvements to the long-term management of former mining and production sites, covering both technical and administrative issues. The work of the GEP has been extended until 2013 to complete and extend various studies.

3.2.5. Nabarlek uranium mine rehabilitation in northern Australia

The Nabarlek uranium mine operated in northern Australia from 1979 until 1989 and was the first of the 'new generation' of uranium mines at that time to go through the cycle of environmental impact assessment, operation, and decommissioning. Located 300 kilometres east of Darwin, the mine was located on land owned by traditional Aboriginal owners, and cultural considerations were taken into account throughout the mine's life (Waggitt 2000). The mine produced about 11,000 tonnes of U_3O_8, with the ore body mined in one campaign in 1979 and milled over the next 10 years. Tailings were deposited directly into the mined-out pit. An initial clean-up of the plant and some facilities was undertaken in the year after operations ceased, but final decommissioning and remediation did not start until 1994.

Site work for decommissioning and rehabilitation was completed in 1995 and revegetation assessment has continued until the present. A cyclone and wild fires impacted the site over the years, adversely affecting revegetation progress (Waggitt, 2000; Paulka, 2009). Lessons learned from this project include that post-remediation radiological risks and risks to surface water quality can be minimised by burying radiological residues such as tailings and mineralised waste rock in the former mine pit. However, other significant environmental hazards such as fire, weeds, and feral animals will persist without appropriate post-rehabilitation management strategies being in place. These hazards pose ongoing threats to the successful establishment of sustainable ecosystems on remediated landforms and must be actively managed until sustainability can be achieved and verified.

3.2.6. Rehabilitation requirements for Rockhole Mine Creek in northern Australia

In contrast to the Nabarlek case study where the primary rehabilitation requirements related to solid materials produced by mining, Rockhole Mine Creek includes a waterway that is receiving contaminated drainage originating from mine workings. This case study has been included because it highlights the importance of undertaking rigorous investigations to determine the levels of management and interventions required. Rockhole Mine Creek is a small tributary of the upper South Alligator River in Kakadu National Park, which receives low-level acidic and metal-rich seepage water from the former Rockhole mine site. The water flows at a low rate (0.2–0.4 L/s) from the lower adit draining the abandoned Rockhole mine workings (see Figure 3-4).

Figure 3-4 Schematic (not to scale) of Rockhole Mine Creek showing the location of Adit 1 and two downstream seeps

Reviews and reports conducted in the early 2000s by the Supervising Scientist Division of the Australian Government's Department of Environment and Heritage (DEH), concluded there were no significant radiological issues in the creek, and only very localised effects on creek ecology from AMD, with no effects detected in the receiving waters of the South Alligator River. In addition, the site was not of significant cultural value to traditional Aboriginal owners. Based on this assessment, remediation was not recommended at the time. However, future periodic trend monitoring was recommended to ensure that the conditions in Rockhole Mine Creek did not deteriorate. Monitoring carried out over many years subsequent to the initial no remediation recommendation showed that the concentrations of metals that can impact ecosystem health had actually declined over time. Consequently, the Supervising Scientist Division continued to support the recommendation that no remedial action is required at this site (Turner, et. al., 2009).

While this case study describes a relatively low impact AMD site, it does provide insight into the value of scientific investigations to inform decision making. A particular strength of the Rockhole Mine Creek assessment was that it considered local water quality conditions in the context of stream health assessments using in-stream fauna, rather than relying solely on generic water quality guidelines. This case study also shows how long-term monitoring can be required to verify predictions and to provide assurance that the environment and communities will continue to be protected.

A rigorous assessment process is being applied at Rum Jungle, which includes identification of the environmental values of the Finniss River system and derivation of local water guidelines. Implementation of the preferred rehabilitation strategy will include ongoing post rehabilitation monitoring to verify predictions of performance and to provide assurance that environmental and community objectives are continuing to be met.

3.2.7. Other uranium mine remediation projects in the Northern Territory

In 1986, the Commonwealth Government surveyed all legacy uranium mine and milling sites other than Rum Jungle. These sites had operated in the 1950s and 1960s and most are located in the South Alligator River Valley (see Figure 3-5), which was incorporated into Kakadu National Park Stage 3. Mining in the area started with the discovery of the Coronation Hill deposit in 1953, and continued through to 1964. During that time, approximately 877 tonnes of U_3O_8 were produced from 13 small-scale uranium mines. When mining ceased, no substantial effort was made to clean-up and rehabilitate the mine and mill areas or camps.

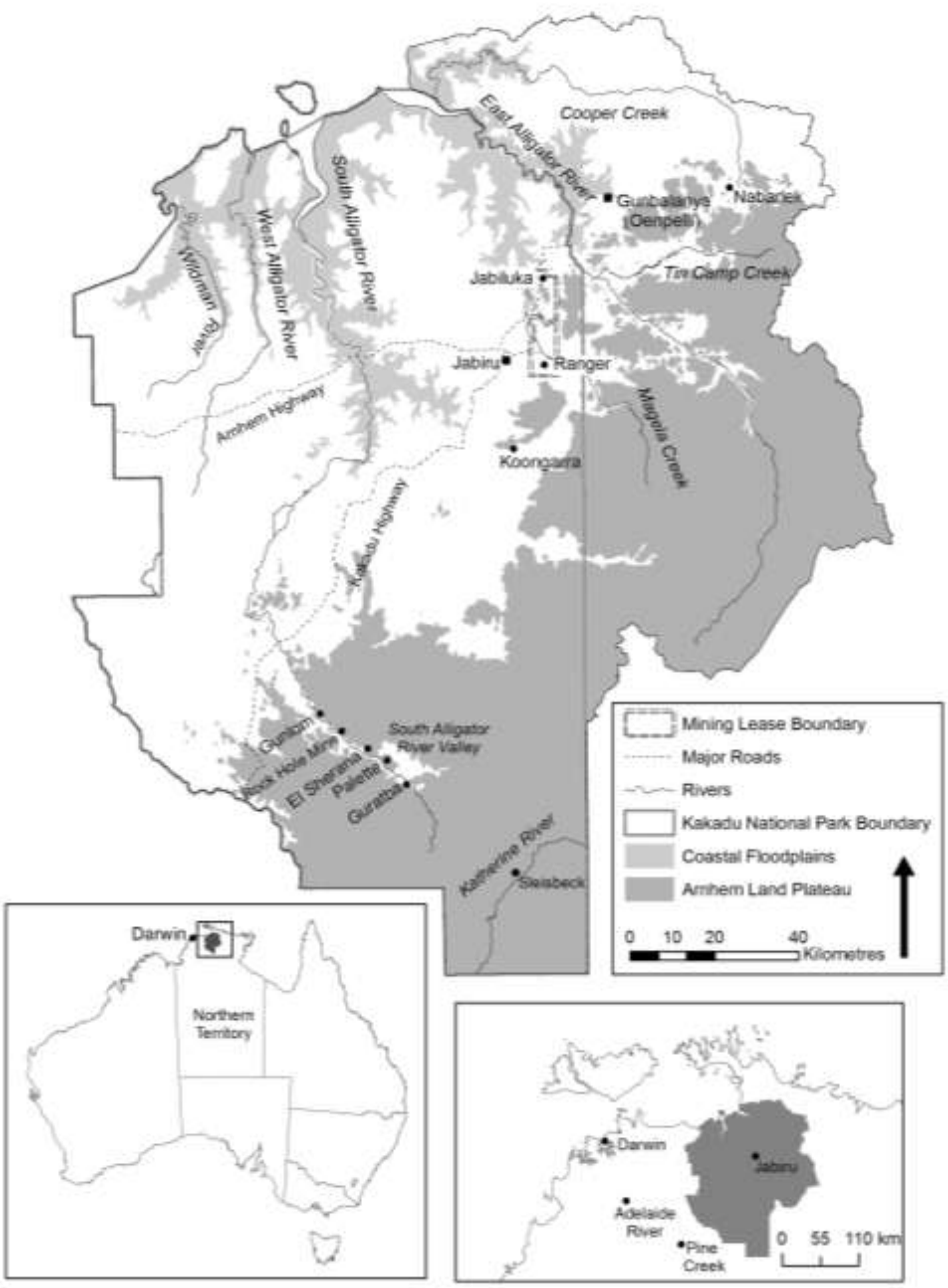
Between 1990–92 the Commonwealth Government conducted an initial program of hazard reduction to reduce the most substantive radiological and physical hazards at these sites. The most radiologically contaminated materials were buried in containments constructed in the valley (Battery bund, El Sherana Weighbridge Station, El Sherana, Saddle Ridge, and South Alligator Valley village) (Waggitt, 1996). Physical hazards were reduced by sealing adits and shafts, restricting road access with bunding and gates, and erecting fences and warning signs.

However, it was recognised that additional work was needed to bring these sites up to a standard that is sufficient to address the remediation obligations of the 1996 lease agreement between the Commonwealth and the Gunlom Land Trust (Waggitt, 2009). This lease agreement contained the terms for the Commonwealth Government to manage Stage 3 of Kakadu National Park in conjunction with the traditional Aboriginal owners.

In 2000, a program of site surveys and meetings with the traditional Aboriginal owners (the Jarwoyn people comprising the Gunlom Land Trust) began to fully delineate the technical and socio-cultural issues to ensure the success of the rehabilitation program. It was agreed to partition the sites with no radiological issues (Part A sites) from those with radiological issues (Part B sites) (Waggitt, 2004). A key learning from this process was the need to regularly engage with the traditional Aboriginal owners on country to ensure agreement between the technical components of the work and the expectations of the custodians of the land. Detailed programs of work were developed and the scope and cost estimates were submitted to the Commonwealth Government for assessment.

In 2006, the Commonwealth Government announced funding over four years for phased rehabilitation of the abandoned uranium mine sites in the South Alligator Valley. The last phase of the work was completed in late 2010, with a containment facility at El Sherana.

Although many sites of varying complexity and with different rehabilitation issues were addressed by this program of rehabilitation works, the locations of most relevance for rehabilitation of Rum Jungle are Sleisbeck and Guratba (Coronation Hill). The techniques used for remediation and stakeholder engagement, as well as the success of the project, provide useful references for planning rehabilitation at Rum Jungle.



Source: 2009–2010 SSD Annual Report

Figure 3-5 Location of the Alligator Rivers Region showing existing and former uranium mining sites, including the South Alligator Valley sites

3.2.8. Rehabilitation of Sleisbeck and Guratba (Coronation Hill)

Sleisbeck and Guratba mines are within the Gunlom Land Trust area, which is Aboriginal freehold land, currently leased to the Director National Parks (Commonwealth).

Parks Australia, through the office of the Director of National Parks, is responsible for managing the Gunlom Land Trust area as part of Kakadu National Park. Guratba (indigenous name for the Coronation Hill area) is in the catchment of the South Alligator River, while Sleisbeck is in the Katherine River catchment about 40 kilometres south-east of Guratba. Both are areas of high significance for natural and cultural values.

Rehabilitation works were undertaken at Guratba and Sleisbeck during the late dry-season of 2007 (Waggitt and Fawcett, 2008a). The rehabilitation plan considers a number of cultural issues, including limiting the use of explosives and heavy machinery.

The Sleisbeck site is of particular relevance for the proposed rehabilitation options for Rum Jungle, because rehabilitation included backfilling a small water-filled open pit with waste rock. The first stage involved pumping the water out of the pit. Chemical and radiochemical characterisation showed the water was of very high quality, meeting all environmental criteria for discharge. Five areas of waste rock had to be reclaimed and placed in the open pit. Radiological ‘hot spots’ were identified in the pit and the piles before the rehabilitation works started.

The spoil piles from when the exploration costeans were originally excavated provided the majority of the cover layer, which was spread across the backfilled pit surface in a single layer to a nominal depth of 700 mm, without compaction. A disused track provided the clean material for the upper 300 mm layer of cover. The track was built from fill across the floodplain 45 years earlier, sourced from a quarry east of the Sleisbeck Pit. This material acted as a rock armouring layer over the pit, given its higher content of competent, erosion resistant material.

When the waste rock was recovered from the waste heaps, the footprint of each area was ripped to a depth of approximately 300 mm to break up compaction and to provide a moisture-retaining seedbed for subsequent revegetation. Stockpiled cleared vegetation was spread back across the ripped areas. The site was revegetated in December 2007.

The steeply sloped Guratba site was in poor condition as it was abandoned with little or no attempt at rehabilitation. The basic rehabilitation concept for Guratba was to ‘landscape’ the site with minimal ground disturbance, using the smallest equipment practical. Material cut to form benches was placed back in the approximate positions that it was cut from to ‘smooth’ the hillside, drill-holes were plugged, and erosion features were remediated.
As well as landscaping, senior traditional Aboriginal owners requested a small stockpile (~ 200 m^3) of rock near the lower adit at the toe of the hill be returned to the open pit. This carbonaceous rock (black rock) had been mined from underground workings in the hill, which the traditional owners identified as the ‘essence of Bula’ and that it must returned to the heart of the hill, which had become an open pit.

When the work was completed, the whole site was re-vegetated to establish a tree and grass cover to eventually blend with the surrounding landscape.

Rehabilitation of both Sleisbeck and Guratba used a combination of science and technology, trading-off between radiological dose, risk, legal compliance, and the long-term stability of containment structures. Traditional beliefs and values were also respected and incorporated into the design, including minimising disturbance to country, protecting sacred sites and ceremonial places, meeting social concerns, and observing tradition. This unique rehabilitation project integrated both technical and indigenous land use objectives to achieve a successful outcome.

3.3. Leading practice guidelines

As well as applying leading practice principles from case studies, remediation of Rum Jungle will also draw on other leading practice guidelines.

3.3.1. Department of Resources, Energy and Tourism

A series of booklets called *Leading Practice Sustainable Development Program for the Mining Industry* produced by the Department of Resources, Energy and Tourism (RET) provide guidance on relevant themes including rehabilitation, mine closure, water management, community engagement, monitoring, and evaluation of performance. Although written for active mining projects, many of the principles in the booklets can be adapted for abandoned mine management.

Other leading practice guidelines relevant to planning rehabilitation at Rum Jungle are written by agencies such as:

- International Council for Mining and Metals (ICMM)
- International Atomic Energy Agency (IAEA)
- Australian Radiation Protection and Nuclear Safety Agency (ARPANSA)
- (Commonwealth) Environmental Protection Agency.
-

3.3.2. International Council for Mining and Metals

The ICMM produces a range of guidelines relevant to integrating biodiversity with mine closure, community development, and integrated mine closure. While focused on active mining projects, these guidelines have elements that are directly relevant to abandoned mine rehabilitation and closure, such as guidelines relating to transparency, engagement, risk-based approaches using valid data and sound science, biodiversity enhancement, respecting cultural aspects, and improvement in environmental management.

3.3.3. International Atomic Energy Agency

While a number of IAEA guidance documents relate to proposed or active mines, sections such as radiological safety, evaluation of options for siting waste impoundments, and post-closure monitoring, maintenance and management are also relevant to remediation planning for abandoned mines. Other IAEA documents also contain useful information about characterisation, remediation, and management of radioactively contaminated sites that were not specifically uranium mines or processing facilities.

The highest-level IAEA documents set out legal obligations such as 'Requirements'. 'Safety Guides' form the basis for standards and 'Safety Reports' explain how to implement these requirements to achieve the desired standards.

Because the Rum Jungle rehabilitation project considers the relocation of waste materials, it is important to take account of the published guidance on safety (e.g. IAEA, 2002). The IAEA states the design of waste management facilities should:

- maximise the use of natural materials for containment
- maximise the placement of waste material below ground level, or in some cases under water
- minimise the impact on the surrounding environment during operations and after closure
- minimises the need to retrieve or relocate the waste at closure
- minimise the need for surveillance and maintenance during operations and for institutional controls after closure.

- Some recent IAEA publications relevant to the Rum Jungle project include useful case studies:
- The Uranium Mining Remediation Exchange Group Selected Papers 1995–2007 (UMREG, 2011)
- Best Practice in Environmental Management of Uranium Mining (IAEA, 2010)
- Establishment of Uranium Mining and Processing Operations in the Context of Sustainable Development
(IAEA, 2009).
-

3.3.4. Australian Radiation Protection and Nuclear Safety Agency

ARPANSA is the regulator of the Australian Government's activities that involve radiation. ARPANSA publishes relevant leading practice guidance and other useful information.

ARPANSA also provides a link for state and territory jurisdictions to global leading practices such as:

- United Nations Scientific Committee on the Effects of Atomic Radiation, which provides details of latest scientific research
- International Commission on Radiation Protection (ICRP), which sets safety limits for the public i.e. 1 mSv per year above background doses
- IAEA, which develops practical standards and methods to legislate for the safety limits developed by ICRP, and implement protection measures
- Organization for Economic Cooperation and Development (OECD), which has a Nuclear Energy Agency that gathers information on remediation of radiation facilities.

Some relevant guidance documents include:

- RPS No. 9 — Code of Practice and Safety Guide, Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing (IAEA, 2005)
- Environmental Remediation of Uranium Production Facilities, (OECD, 2002)
- Environment and Security Initiative (UNDP, OSCE, NATO, & UNEP)
- Mining for Closure, Policies and Guidelines for Sustainable Mining Practice and Closure of Mines (UNDP, UNEP, OSCE, & NATO, 2005)
- IAEA Safety Requirement WS-R-3, Remediation of Areas Contaminated by Past Activities and Accidents (IAEA, 2003)
- IAEA Safety Report 27 Monitoring and surveillance of residues from the mining and milling of uranium and thorium (IAEA, 2002).

3.3.5. South Australian Environmental Protection Agency

The South Australian Environmental Protection Agency is developing close-out criteria for sites contaminated with radiological material in Australia. While this project is in its early stages, it will be monitored to ensure the RJPT is aware of evolving guidance.

3.4. Leading practice guidance on stakeholder engagement

Chapter 6 describes the stakeholder identification and engagement process for Rum Jungle and how it draws on leading practice engagement processes from other mining and rehabilitation projects.

3.5. Summary of key principles

From an overview of global and Australian leading practice guidance, a number of key principles are being applied to the rehabilitation planning process at Rum Jungle:

- development of a post-remediation vision with clear objectives as a foundation for planning and engagement
- effective engagement with stakeholders to gain local knowledge and collaboratively develop objectives and completion criteria to measure the success or otherwise of the project
- where traditional Aboriginal owners and important cultural heritage sites are impacted, the post-remediation cultural land use must also be integrated with planning
- taking a risk-based approach that includes multi-disciplinary teams to identify and address key knowledge gaps
- acquisition of robust technical data to evaluate options and refine rehabilitation plans
- endeavouring to develop socio-economic opportunities to support the ongoing use and maintenance of the remediated site, while establishing new land uses and business opportunities for communities
- use learnings from global leading practice guidance and case studies to build on existing knowledge of successes and failures, providing opportunities for continual improvement, and ensuring efficient use of scarce remediation resources.

4. Regional context

4.1. Location

Rum Jungle is located within the Coomalie Shire. The Shire has a population of approximately 1200 people, including the townships of Batchelor and Adelaide River (ABS, 2012) and covers approximately 1650 square kilometres (Coomalie Community Government Council, 2012) as shown in Figure 4-1.

The Rum Jungle site comprises approximately 650 hectares of relatively elevated ground, bisected by wet season ephemeral streams that feed into the East Branch. The East Branch joins the Finniss River about eight kilometres downstream of the mine site. The Finniss River then flows west for about 60 kilometres before emptying into Fog Bay.

The history of mining and current active exploration activities at Rum Jungle are indicators of the site's significance for minerals and mining. The area was originally quarried by traditional Aboriginal owners for stone and ochre (Hazelbane, pers. comm. 2012). Section 2968 has been explored for minerals more or less continually since European presence in the area.

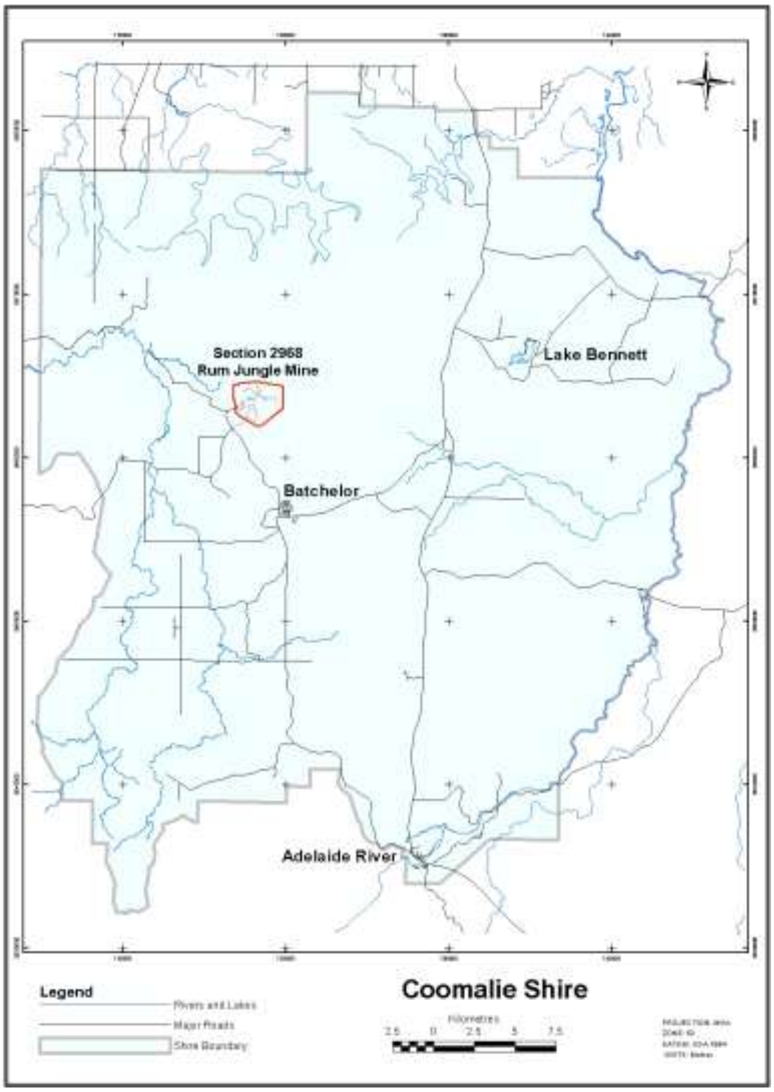


Figure 4-1 Coomalie Shire

4.2. Socio-economic landscape

The Coomalie region has always been heavily reliant on the pastoral and mining industries, with the townships of Batchelor and Adelaide River supplying provisions and accommodation to nearby operations. However, land use in the region has diversified (Department Lands, Planning and Environment 2000) over time to include:

- residential (urban and rural)
- commercial
- industrial
- tourism
- health and community facilities
- education
- open space and recreation
- mining and extractive industries
- horticulture and agriculture.

As the main entry point for Litchfield National Park, Batchelor also provides tourist-related services to the 280,000 visitors who visit the park each year (Coomalie Community Government Council, 2012).

4.3. Regional climate

The region is characterised by a tropical climate and receives about 1500 mm of annual rainfall (see Figure 4-2 and Figure 4-3) (BOM, 2012a). More than 90 per cent of the rainfall occurs during a distinct wet season that lasts from November to April. No substantial rainfall occurs from May to October. It is not uncommon for falls of more than several hundred millimetres a day during monsoons or tropical lows. This type of rainfall has important implications for both runoff and infiltration at Rum Jungle, because they drive generation of contaminated runoff and seepage.

Mean monthly maximum temperatures at the Batchelor Airport range from 31.2 °C in June to 36.8 °C in October, during the 'build up' to the wet season.

Rum Jungle is also located in the tropical savanna region of Australia. Tropical savanna climates have monthly mean temperature above 18 °C in every month of the year and a pronounced dry season. Tropical savannah is distinguished from the tropical rainforest (monsoonal) climate by the dryness of the driest month.

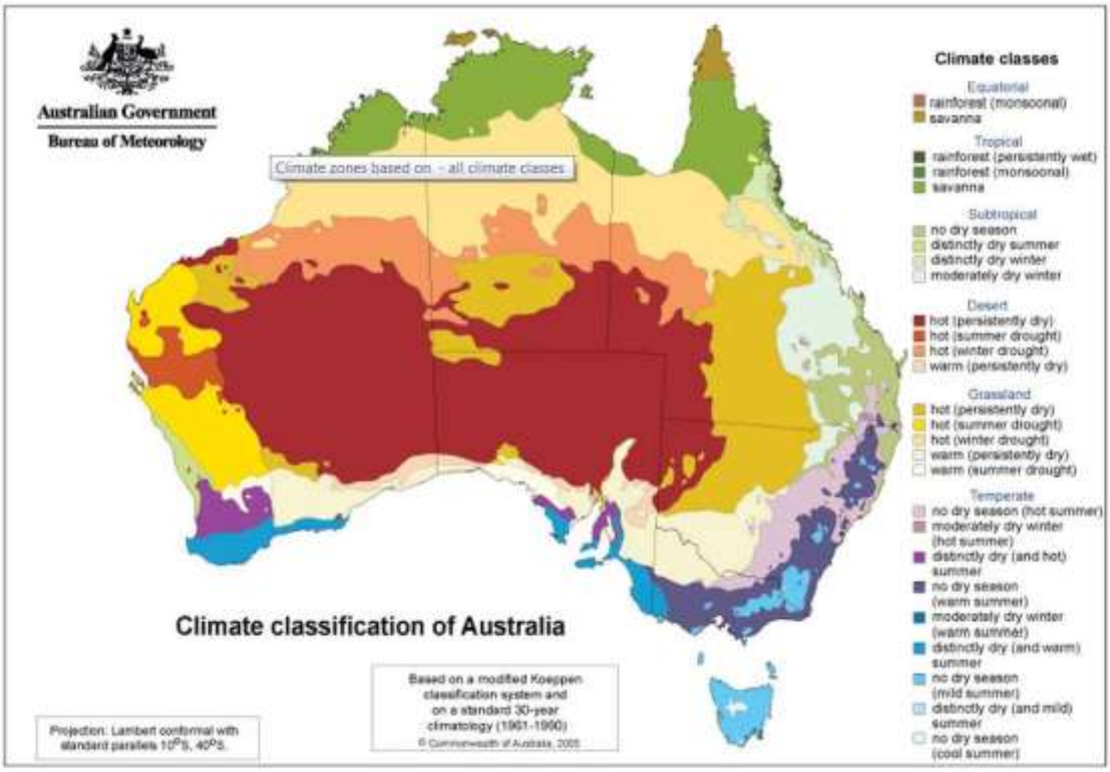


Figure 4-2 Climate classification of Australia (BOM, 2012)

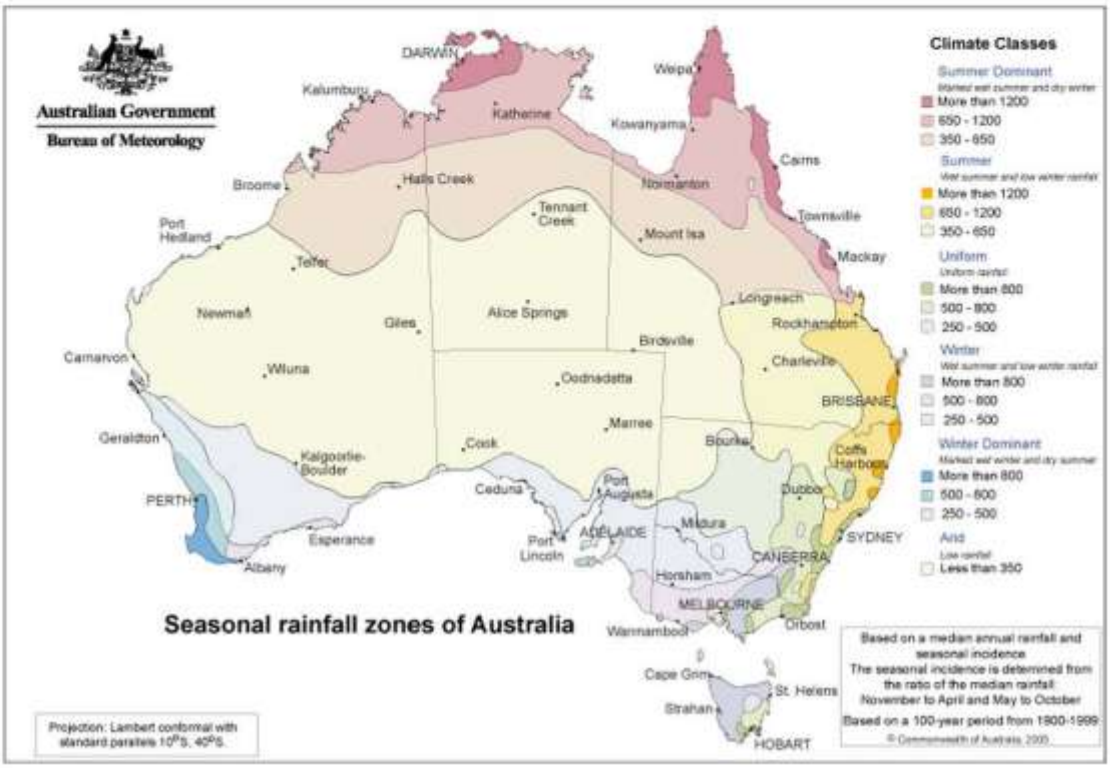


Figure 4-3 Climatic zones of Australia (BOM, 2012a)

4.3.1 Climate change

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Bureau of Meteorology (BoM) (CSIRO and BoM, 2012) report that::

> Australian average temperatures are projected to rise by 0.6–1.5 °C by 2030 when compared with the climate of 1980–1999. The warming is projected to be in the range of 1.0–5.0 °C by 2070 if global greenhouse gas emissions are within the range of projected future emission scenarios considered by the Intergovernmental Panel on Climate Change. These changes will be felt through an increase in the number of hot days and warm nights, and a decline in cool days and cold nights. Models generally indicate an increase in rainfall near the equator globally, but the direction of projected changes to average rainfall over northern Australia is unclear as there is a lack of consensus among the models.
>
> For Australia as a whole, an increase in the number of dry days is expected, but it is also likely that rainfall will be heavier during wet periods. It is also likely (with more than 66 per cent probability) that there will be fewer tropical cyclones in the Australian region, on average, but the proportion of intense cyclones is expected to increase.

Figure 4-4 to Figure 4-6 show the estimated variation in annual and summer temperature, rainfall, and potential evapotranspiration, respectively, for the Northern Territory for 2030, 2050 and 2070. Projections are given relative to the period 1980–1999 (referred to as the 1990 convenience). The 50th percentile estimates are shown, representing the current best estimate. Three emissions scenarios are provided from the Intergovernmental Panel on Climate Change (IPCC) *Special Report on Emission Scenarios* (2000, cited in CSIRO and BoM, 2012).

The Northern Territory climate projections in Figure 4-4 to Figure 4-6 show the following:

- Temperature:
  - is most likely to increase irrespective of the emission scenario
  - increases will continue throughout the century and occur more or less uniformly across the Northern Territory, with slightly higher increases in central Australia.
- Rainfall:
  - is relatively similar under different emission scenarios
  - will decrease in the south of the Northern Territory (central Australia) and shows no change in the north of the Northern Territory
  - will continue to decrease in central Australia, with minimal change in the north of the Northern Territory throughout this century.
- Potential evapotranspiration:
  - is relatively similar under different emission scenarios
  - will increase across the Northern Territory, with a larger increase in the north
  - will continue to increase across the Northern Territory throughout this century.

Source: BoM, 2012b

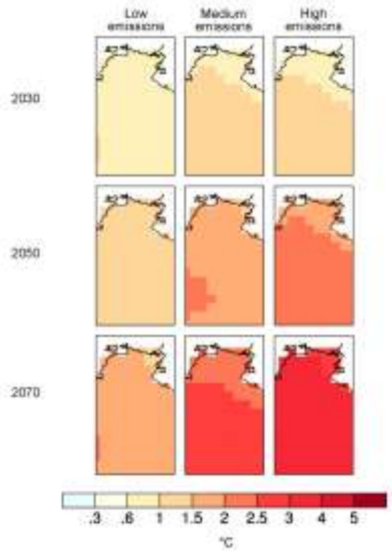


Figure 4-4 Predicted annual temperature change in the Northern Territory—50th percentile

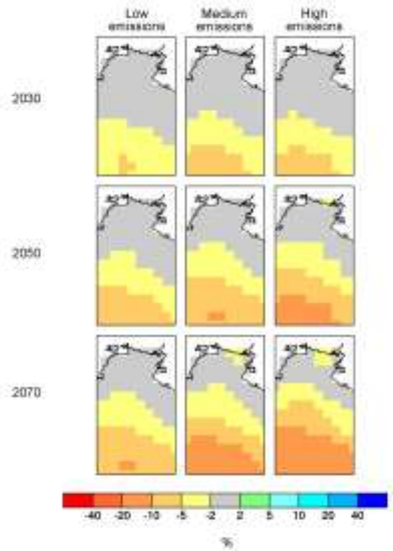


Figure 4-5 Predicted annual rainfall change in the Northern Territory—50th percentile

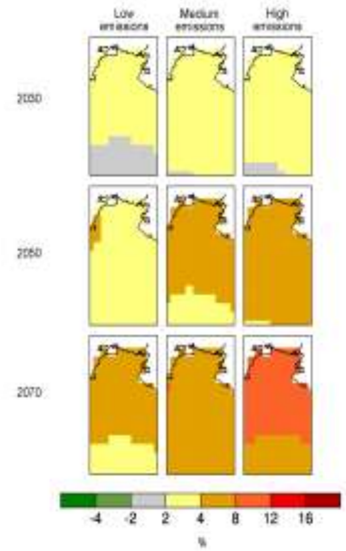


Figure 4-6 Predicted potential annual evapotranspiration change in the Northern Territory—50th percentile

Under the medium emission scenario, with the 50th percentile probability model estimates, Rum Jungle is located in an area that will experience the following extents of changes:

- an increase in average temperature of about 1.5 °C by 2030 and 2.5 °C by 2070
- no change in average annual rainfall
- an increase in potential evapotranspiration of three per cent by 2030 and six per cent by 2070.

It is unclear what impact this will have on the vegetation at Rum Jungle. Changes in climate may lead to changes in the vegetation to form an ecosystem that is more tolerant of higher temperature and there may also be indirect influences on vegetation from changes in annual bushfire regimes (R.Walton pers comm, January 2013).

4.4. Environment

4.4.1 Environmental context of the site

To ensure the long-term success of rehabilitation at Rum Jungle, broader environmental issues across the region must be understood and considered, both for the initial design of the rehabilitation and for devising an appropriate post-rehabilitation management and maintenance program. The most significant environmental issues in the Coomalie Shire that could seriously impact the long-term success of rehabilitation include weeds, fire, and feral animals. How these issues are currently being addressed at Rum Jungle is described in Sections 4.4.2, 4.4.3, and 4.4.4.

The Coomalie Shire lies towards the western boundaries of the Pine Creek bioregion, which is comprised primarily of eucalypt woodlands and patches of monsoon forest on hilly to rugged ridges and undulating plains (Bastin et al., 2008). Undisturbed soils within, and adjacent to, the former mine site are categorised as tenosols, which are soils with weakly developed profiles.

The waters draining from Rum Jungle flow into the Finniss River, which is part of the Darwin Coastal bioregion, and into Fog Bay. Both the Finniss River coastal floodplain and Fog Bay are designated Sites of Conservation Significance due to internationally significant wildlife aggregations, including shorebirds, waterbirds, seabirds, and marine turtles (Harrison et al., 2009). Beneficial Uses of ‘aquatic ecosystem protection’ and ‘recreational water quality and aesthetics’ were declared for the waters of Fog Bay under the *Water Act 1992* in March 1998. Environmental values associated with the Finniss River are discussed in Section 6.10.

At a regional scale, Rum Jungle is located close to two conservation areas. The northern boundary of the 1800 km² Litchfield National Park is approximately eight kilometres to the south-west of the site, while the Darwin River Dam catchment is less than two kilometres north of the site (DLPE, 2000).

While three proposed water supply dams are also within, or close to, the Coomalie Shire, only the catchment of the proposed Mount Bennett Dam includes Rum Jungle.

Within the Coomalie Shire, 17 plant, fish, reptile, bird, and mammal species have been identified as ‘threatened’ under Northern Territory legislation. These threatened species include the endangered flowering plant *Helicteres* sp. Glenluckie Creek; the endangered Gouldian finch (*Erythrura gouldiae*); and the critically endangered northern quoll (*Dasyurus hallucatus*). These threatened species are also identified as ‘endangered’ under the EPBC Act. Further information about flora and fauna in and around Rum Jungle is in Section 6.11.

Community groups that operate around and downstream of Rum Jungle include the Coomalie Landcare Group and indigenous ranger groups based at Batchelor and Bulgul (at the northern end of Fog Bay). These groups have primarily focused on weed management (Harrison et al., 2009; Jaime Paige, pers. comm. 29 November 2012).

4.4.2 Weeds

The draft natural resource management strategy for the Coomalie Shire identified at least 47 environmental weed species in the wider Coomalie Shire. Gamba grass was identified as 'probably the most serious environmental problem' in the region (Price and Baker, 2003). The Coomalie Shire lies within the Gamba Grass Management Zone, which imposes a legal obligation on landholders to contain existing infestations and eradicate any smaller or new infestations. A 2008 survey found that gamba grass was found in more than 90 per cent of properties surveyed in the Coomalie Shire and that the average density of gamba grass cover at Rum Jungle was between > 1–10 per cent (NRETAS, 2008). While mission grass is not as prevalent in the Coomalie Shire as gamba grass, controlling gamba grass could provide opportunities for more mission grass infestation. Concurrent control of both species was recommended by the Northern Territory Department of Natural Resources, Environment, the Arts and Sport (NRETAS).

In 2003, *Mimosa pigra* (Mimosa) was formally recorded in about 90 sites throughout the Coomalie Shire, but the species 'occurred in the headwaters of nearly all creeks and rivers in the region' providing a seed source for downstream infestations (Price and Baker, 2003).

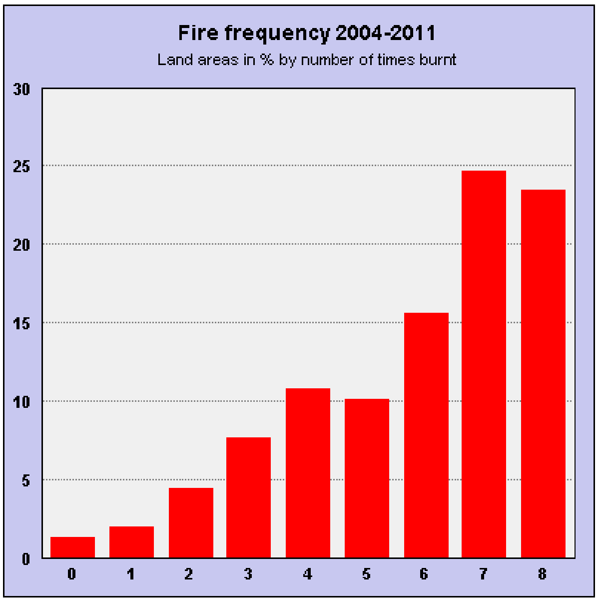
4.4.3 Fire

Managing outbreaks of fire in and around Rum Jungle is an ongoing issue and will continue to be an issue into the future, particularly given the increase in high fuel-load weeds, such as gamba and mission grasses. Data from the North Australian Fire Information website confirms the high frequency and large extent of fires in the district. For example, between 2004 and 2011 almost one quarter of a 130 km^2 area surrounding Rum Jungle was burnt every year (see Figure 4-7). The majority of burning occurs in May and June (NAFI, 2012).

4.4.4 Feral animals

Feral animals in the Pine Creek bioregion include cane toads, black rats, wild dogs, horses, pigs, swamp buffalo, cattle, and sambar deer (NT NRM Infonet website, 2012). Price and Baker (2003) noted that the distribution of feral animals across the Coomalie Shire was very poorly known and that the control of pigs and cats should be given priority.

Years burnt	Area (km^2)	Area (%)
0	1.8	1.4
1	2.7	2.0
2	5.9	4.4
3	10.2	7.6
4	14.4	10.7
5	13.6	10.1
6	20.9	15.6
7	33.0	24.7
8	31.4	23.4
Total area: 133.8		



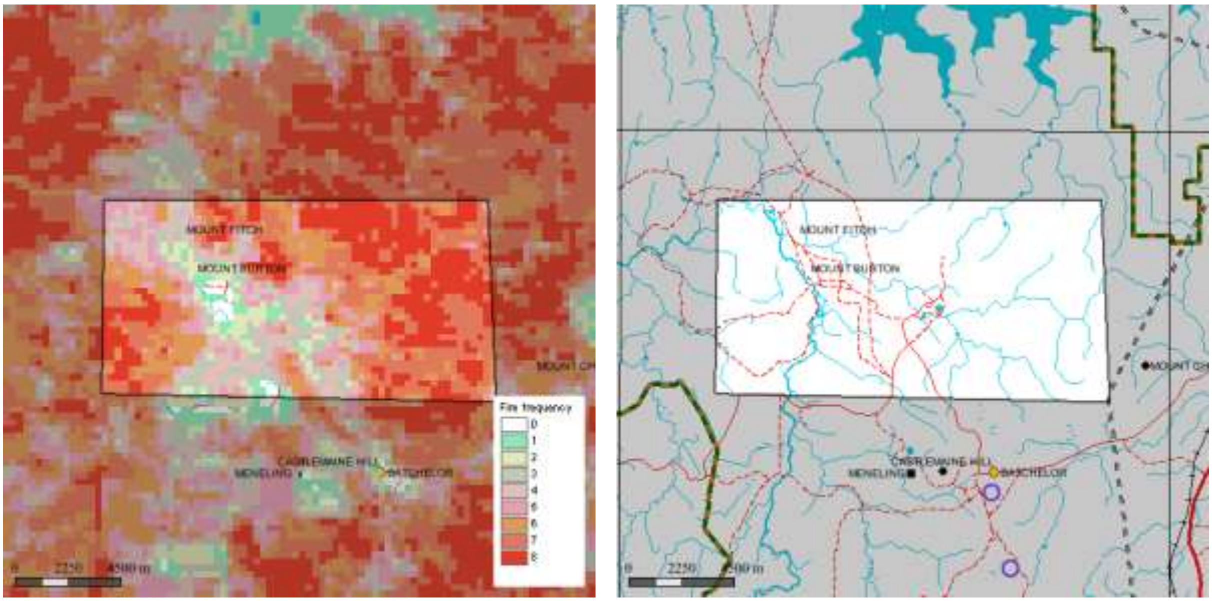


Figure 4-7 Fire frequency between 2004 and 2011 in an area surrounding Rum Jungle, including Mount Fitch and Mount Burton (Source: NAFI website 2012)[1]

[1] The fire frequency (250 m) layer is derived from satellite imagery sources from the Advanced Very High Resolution Radiometer (AVHRR) on NOAA satellites. Spatial resolution: 1.1 m x 1.1 km pixels (at Nadir) Extent: whole of Australia.

4.5. Geology

The former Rum Jungle mine site is located in the Rum Jungle mineral field of northern Australia. The mineral field is centered on the town of Batchelor within a deformed and metamorphosed sedimentary basin called the Pine Creek Orogen. The Pine Creek Orogen covers an area of about 66,000 km^2 and extends north from Katherine to near Darwin (McCready et al., 2004).

The former Rum Jungle mine site is situated in a triangular area of the Rum Jungle mineral field that is bounded by the Giants Reef Fault to the south and a series of east-trending ridges to the north (Figure 4-8). This triangular area is known as "The Embayment" and it lies on the shallow-dipping limb of a north-east trending, south-west plunging, asymmetric syncline that has been cut by northerly dipping faults.

The main lithologic units in The Embayment are granites of the Rum Jungle Complex and meta-sedimentary rocks of the Mount Partridge Group. The Rum Jungle Complex occurs primarily along the south-eastern side of the Giants Reef Fault, whereas the Mount Partridge Group occurs north of the fault. The Embayment contains numerous uranium and polymetallic ore deposits that were mined in the 1950s, 1960s and more recently. These deposits included Woodcutters, Rum Jungle Creek South, Mount Burton, Mount Fitch, the Main, Intermediate, and Dysons ore bodies at the former Rum Jungle mine site, and the partially mined Browns Oxide ore body (McCready et al., 2004).

Each of the polymetallic ore deposits in The Embayment occurs within the Whites Formation near its contact with the Coomalie Dolostone and mineralisation is structurally controlled, and therefore associated with fault zones. Ore has been deposited in carbonaceous slates of the Whites Formation by selective replacement along shear zones that intersect local faults (Ahmad et al., 2006).

Source: McKay and Miezitis, 2001

Figure 4-8 Regional geology near the former Rum Jungle mine site

4.6. Related sites

In May 2011, the NPA was expanded to include three additional sites that contributed to the mining operations at the main Rum Jungle site from 1954 to 1971. Mines at Rum Jungle Creek South (RJCS) and Mount Burton were mined, with ore trucked to and processed at the main Rum Jungle mine site. Mining exploration was also undertaken at the Mount Fitch site. Figure 4-9shows the location of these sites relative to the Rum Jungle mine area (section 2968).

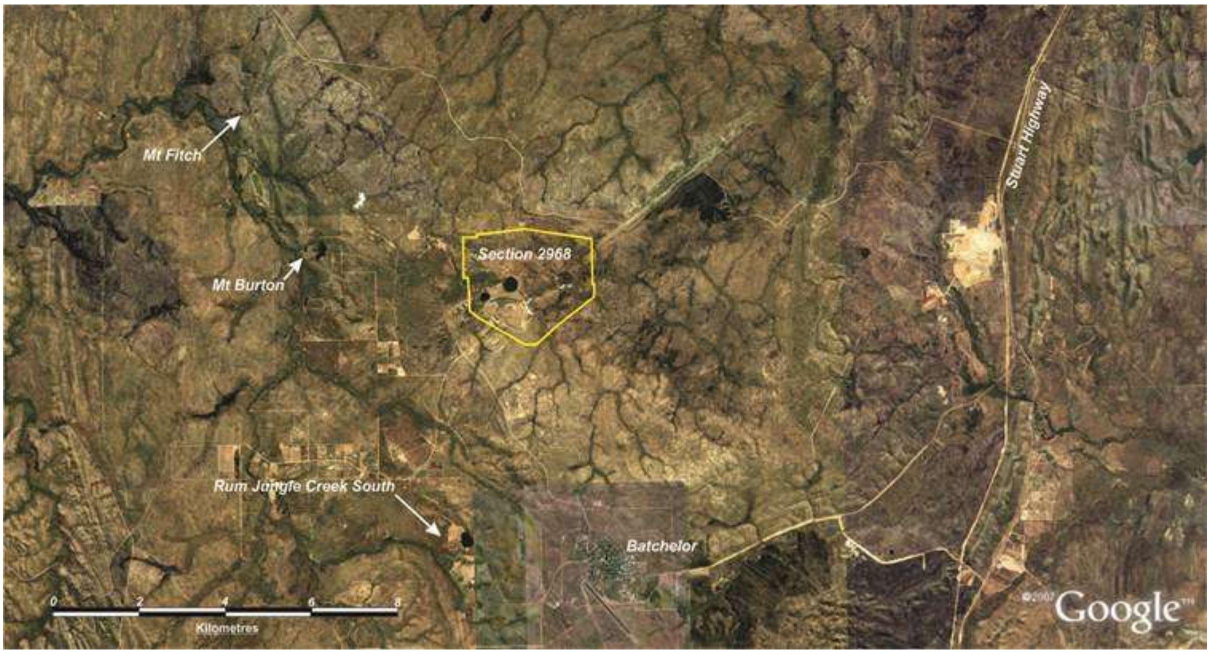


Figure 4-9 Rum Jungle location relative to Batchelor township and other mines including Mt Fitch, Mt Burton and Rum Jungle Creek South

4.6.1 Rum Jungle Creek South

RJCS is located approximately 100 kilometres (by road) south of Darwin and five kilometres south of the (main) Rum Jungle mine site. RJCS was mined from 1961 to 1963 and produced approximately 2000 tonnes of uranium oxide, or 60 per cent of the total production of the entire Rum Jungle operations. In 1971, the 66-metre deep RJCS pit was allowed to fill with water and became an artificial lake. The RJCS site has since been used by the public for recreational activities. In 1973, the site was declared a 'Recreational Reserve for the amusement of the public' by the Minister of State for the Northern Territory (Government Gazette, 1973).

In 1986 a radiological assessment was conducted at the site to determine if rehabilitation was required. Figure 4-10 shows an image of the site at this time. The assessment proposed four rehabilitation options to reduce potential radiation doses to members of the public accessing the site. The context for the extent of work to be done was the forthcoming reduction in the maximum annual public radiation dose limit from 5 mSv per year to 1 mSv per year, set by the International Commission on Radiological Protection. The maximum allowable dose to the public remains at 1 mSv. Each rehabilitation option was assessed using the 'as low as reasonably achievable (ALARA) cost–benefit principle', taking social and economic factors into account (Kvasnicka, 1986).

In 1990–91, a program of rehabilitation works was undertaken at the site (Kvasnicka, 1986). The rehabilitation works were designed and supervised by the Northern Territory Government and funded by the Commonwealth Government. The works involved scraping, removing, and disposing of uranium ore and contaminated soil onto the waste rock dump; excavating soil and gravel borrow material to replace removed material; reshaping the waste rock dump and covering it with topsoil; constructing a drainage system; and undertaking revegetation activities.

A follow-up radiological survey (Kvasnicka et al., 1992) found that radiological conditions at the site had improved significantly as a result of the rehabilitation works and concluded that it was appropriate for the site to continue to be used as a public recreation area. In 1998 the land was transferred to Coomalie Community Government Council as freehold title.

In 2010, DME assessed the site in response to stakeholder concerns about potential changes in radiological conditions that may have occurred since the site was rehabilitated. DME noted elevated gamma dose readings on a small portion of the rehabilitated waste rock dump. These readings were verified by the Department of Health. Based on these preliminary readings, DME recommended the Coomalie Community Government Council, as land titleholders, close the site to public access as a precautionary measure, pending more detailed assessment. Figure 4-11 shows the site in its current state.

Figure 4-10 1986 aerial photograph of the Rum Jungle Creek South site before rehabilitation

Figure 4-11 Current site photograph of Rum Jungle Creek South (2009)

The DME and RET agreed to amend the original NPA to include a radiological assessment at RJCS.

DME then engaged the Commonwealth Environmental Research Institute of the Supervising Scientist (*eriss*) to undertake a comprehensive radiological assessment of the site, noting that previous radiological surveys did not consider potential doses from the consumption of bush foods.

The *eriss* assessment considered the most important pathways through which the public could potentially be exposed to radiation, with environmental sampling and measurements conducted to collect radioactivity information specific to each pathway. The exposure pathways investigated were:

- external gamma radiation
- radon and radon decay products
- radionuclides in dust
- radionuclides in lake and creek water
- radionuclides in bush foods.

The assessment considered different access scenarios to estimate radiation doses the public may potentially receive from the site, and compared the results with typical background doses of radiation. The scenarios included:

- Short-term visits — assuming a person (adult or child) accessed the site 14 times in a single year for daytime picnics between 12.00 pm and 6.00 pm. No bush foods or water from the site were consumed.

- Long-term visits — assuming a person (adult or child) camped at the site for 14 days per year and collected and consumed bush foods and water from the site.
- Visits by instructors and students of the Batchelor Outdoor Education Unit — assuming that participating children accessed the site once per year as part of the program whereas instructors accessed the site up to 40 times a year.

The *eriss* report (Bollhöfer et al., 2012) found that for the scenarios considered, the annual radiation doses received by people visiting would be low and generally within the natural variation of typical yearly background doses across Australia. In addition, the radiation doses received from recreational use of the site are less than internationally recommended reference levels for decision making about restricting individual doses through intervening actions, such as further site rehabilitation or access restrictions. Following acceptance of the findings in the *eriss* report by the relevant authorities in the Northern Territory Government, the Coomalie Community Government Council re-opened the site for public access in August 2012.

4.6.2 Mount Burton mine

The Mount Burton mine site is located approximately four kilometres west of the main Rum Jungle site, on the north flank of a low ridge of Acacia Gap quartzites (see Figure 4-9). An open pit was mined to a depth of 35 metres between October and November 1958. The Mount Burton Mine produced 6000 tonnes of uranium–copper ore, including 2400 tonnes of bogum (below ore grade uranium material) and 1400 tonnes of copper ore. Approximately 100,000m^3 of overburden were placed in a waste rock dump located immediately east of the open pit (see Figure 4-12). The pit was allowed to flood after mining ceased in 1958. The Finniss River is 200 metres west of the open pit. Overflow from the pit flows into Mount Burton Spring Creek to the north of the pit, which then flows into the Finniss River.

After mining ceased, the land that Mount Burton mine is situated on was converted to private freehold in 1965 and remains occupied by the same family today. There has been no post-mining remediation of the site.

Figure 4-12 Mt Burton historic mining area (NTG, 2011)

4.6.3 Mount Fitch mine

The Mount Fitch site is approximately 3.5 kilometres northwest of Mount Burton mine on a low rise east of the Finniss River (Figure 4-9). In 1966, exploration drilling was carried out to a depth of 130 metres and a small open pit was excavated for process evaluation. However, the ore was not recovered and was left in the pit (Davy, 1975). A small overburden heap is located directly south of the pit and some surface disturbance is evident to the west (see Figure 4-13). The pit itself was allowed to fill with water following completion of activities in 1969.

Presently, the land on which Mount Fitch is situated is held by the Northern Territory as a form of Crown Lease. There has been no post-mining remediation of this site.

Figure 4-13 Mt Fitch exploration area (NTG, 2011)

4.7. Other sites in close proximity to Rum Jungle

The Browns Oxide mine site is located immediately adjacent (west) of Rum Jungle as shown in Figure 4-14. The mine site consists of an open pit, processing plant, infrastructure, tailings storage facility, sediment dam and ore stockpiles. The mine is operated by HNC (Australia) Resources Holding Pty Ltd whose parent company is Hunan Nonferrous Metals Corporation Limited. The base metals in the ore resource are poly-metallic and include Cobalt, Copper, Lead, Nickel and Silver.

Mining operations commenced in 2007, however in 2009 the site entered into care and maintenance status (NRETAS, 2011). The care and maintenance status of the mine will remain indefinitely pending completion of feasibility studies of possible mining and processing scenarios.

Current activities at the site are focused on managing surface water arising from rainfall in the wet season and removing reagents from the plant. The site has an approved Waste Discharge Licence, which permits releases of water from the site to the East Branch under stringent conditions. The Licence is administered by the Northern Territory Environmental Protection Agency.

Figure 4-14 Browns Oxide mine immediately west of the Rum Jungle site (NTG, 2011)

5. Rum Jungle site knowledge

5.1. History of mining at Rum Jungle

On the 5 April 1948 the Commonwealth Gazette announced rewards for the discovery of uranium in Australia and its territories. The maximum reward was fixed at £25,000 (Barrie, 1982). Economically viable uranium mineralisation was discovered in the Rum Jungle area by a local prospector and farmer, John (Jack) White, in August 1949. White owned a farm on the East Branch about five kilometres downstream from where he discovered a 'distinctive and unfamiliar mineral occurrence'.

During this period it was common for prospectors to pay local Aboriginal people to bring them interesting stones (Mills, pers. comm., 2010) and some mineral discoveries in the region can be attributed to this practice. Given that Jack White had an Aboriginal partner at this time, her potential contribution to the discovery cannot be discounted.

Figure 5-1 From left to right Mr Donald Dyson, Mr Jack White and Mr Hector Ward (National Archives of Australia: A1200, L19445)

White believed the discovery to be uraniferous, based on a Bureau of Mineral Resources pamphlet on radioactive minerals (Berkman, 1968). On 12 August 1949, White dug a trench and collected green and yellow rock samples, which he delivered to the Mines Branch in Darwin (Barrie, 1982). The Minister for the Interior announced the find on 6 September 1949 (Barrie, 1982).

White could not be granted a lease or claim because the land was freehold. The Hundred of Goyder is an area with Rum Jungle in the approximate centre. A 'Hundred' was a land division unit used by Goyder when surveying the Top End in 1869. It was approximately 168 square miles and was based on the amount of land assumed to be needed to support 100 families. Commonwealth control of material (mineral) laws also limited White's ability to obtain a lease on the land. He was paid £1,000 for his discovery in October 1950, based on a proven deposit of 25 tonnes of uranium oxide. A second payment of £7,000 was made in September 1952 after further exploration. Once a substantial body of ore was confirmed, the government paid White a third reward payment of £17,000, for a total of £25,000 ($760,000 in 2009 dollars (RBA, 2013)) for his uranium find (Barrie, 1982).

The Bureau of Mineral Resources explored the area between 1949 and 1952, confirming a viable ore deposit known as Whites. Prospective anomalies were also identified at Dysons Deposit and Mount Fitch (Berkman, 1968). Exploration continued with two shafts sunk. On 1 November 1951, a cross-cut from one of the shafts hit ore 22 feet from the shaft, extending for a considerable distance into high-grade ore.

The Commonwealth Government initially held title to uranium under the *Atomic Energy (Controls of Materials) Act 1942–1952.* This act was superseded by the *Atomic Energy Act 1953,* under which the Australian Atomic Energy Commission (AAEC) was formed in April 1953. In 1953, the Commonwealth declared the Hundred of Goyder a restricted area.

In March 1952, representatives of the United States Atomic Energy Commission (USAEC) and the United Kingdom Atomic Energy Authority (UKAEA) visited Australia and discussed the development of the Rum Jungle uranium field. Funds to develop the Rum Jungle project were provided by the Combined Development Agency (CDA)[2], with an exclusive supply contract signed between the Commonwealth and the CDA (Berkman, 1968). The U_3O_8 produced between 1954 and January 1963 filled the supply contract with the CDA. The CDA was the sole customer of the mine.

The Commonwealth entered into a contract with the Consolidated Zinc Group in August 1952 to develop and operate the Rum Jungle project on behalf of the Commonwealth. In 1952, Consolidated Zinc formed a wholly owned subsidiary, Territory Enterprises Pty Ltd (TEP), to manage all aspects of the operation including exploration, mining, and milling. The AAEC had overall control of mine operations (Berkman, 1968). On 1 January 1953, TEP took over the development and management of Rum Jungle as an agent for the Commonwealth (Davy, 1975).

In 1962, Consolidated Zinc merged with the Rio Tinto Mining Company of Australia Ltd to form Conzinc Rio Tinto of Australia Ltd (CRA) without a change to the arrangements between TEP and AAEC (Davey, 1975).

The Rum Jungle project was the first large industrial enterprise undertaken in the Northern Territory, with the total capital and operating and expenditure to January 1963 being £19.6 million ($465 million in 2009 dollars, (RBA, 2013)), most of which was spent in the NT. Accounts from the period 1954 to January 1963 showed a total net profit of £3,380,000 ($80 million in 2009 dollars (RBA, 2013)) (Davey, 1975). The national benefit from Rum Jungle was substantial. In addition to cash profits and a stockpile of uranium, the operation significantly contributed to developing the Northern Territory and provided experience in mining in monsoonal conditions, which provided useful lessons (Davey, 1975).

5.2. Ore production at Rum Jungle

The Main[3] Deposit was the first uranium to be mined on the site. Other ores from the Main Deposit included copper, lead, nickel, and some traces of silver. After an initial proposal to mine the Main Deposit using conventional underground techniques was abandoned as being too difficult, all Rum Jungle deposits were mined via open cut methods.

[2] The Combined Development Agency (CDA) was a defence purchasing authority established in 1948 by the governments of the United States and the United Kingdom. Its role was to ensure adequate supplies of uranium for the respective countries' weapons development programs. The CDA initiated a range of incentives in several countries to encourage exploration and a fast build-up of mineral reserves. The main countries targeted were the US, Canada, South Africa, and, to a limited extent, Australia (Wikipedia, 2013).

[3] Following a request from the traditional Aboriginal owners of the area, the term 'Whites Deposit' was replaced by the term Main Deposit.

As well as the Main Deposit, there were three other open pit mines onsite: the Main Extended Deposit (uranium); Dysons Deposit (uranium); and the Intermediate Deposit (copper). The Intermediate Deposit was mined by the Australian Mining and Smelting Company Ltd, also a subsidiary of the Consolidated Zinc Corporation Ltd. In addition to the copper, uranium, and lead ores extracted and mined at Rum Jungle, small amounts of zinc and nickel were also mined or stockpiled for later processing (Ritchie, 1985).

6000 tonnes of uranium-copper ore was also obtained from the Mount Burton deposit, five kilometres west of the main Rum Jungle site. The Mount Burton mine had relatively minor ore deposits of uranium and copper. The mineralisation, which was defined in 1954, occurred as near-surface, secondary mineralisation. Exploration drilling was carried out in 1957 and the ores were extracted in 1958, using open cut methods. The copper and bogum (below ore grade uranium material) ores were stockpiled onsite in 1969.

In 1966, further exploration revealed a secondary uranium and copper mineralisation on a low rise east of the Finniss River, which became known as the Mount Fitch mine. Exploration drilling discovered another uranium deposit. Although some mining activities were undertaken at Mount Finch, there are no records of the volume of ore produced and no excavation or processing of these ores is apparent. The ore was left in situ in 1969.

The RJCS Deposit was discovered in 1959. In total, 2.43 million m^3 of material was excavated from RJCS between 1961 and mid-1963, for 650,000 tonnes of uranium ore that was stockpiled for future processing at the main Rum Jungle site. The RCJS Deposit was of a higher uranium grade and quantity than both the Main and Dyson's Deposits. An additional 114,000 tonnes of bogum material was also stockpiled at RJCS. Eventually, the stockpiled ore was processed at Rum Jungle.

Over the course of the CDA contract, 3530 tonnes of uranium oxide and approximately 20,000 tonnes of copper concentrate were produced (Davy, 1975). In total, 863,000 tonnes of blended uranium ore, grading between 0.27– 0.43 per cent uranium oxide (U_3O_8) was treated at the Rum Jungle treatment plant. Another, 85,000 tonnes of lead containing ore was mined and stockpiled, but not processed.

Production continued after the completion of the original supply contract in January 1963, with the U_3O_8 stockpiled by the Commonwealth. The stockpile of 2053 tonnes of uranium oxide, which was stored at Lucas Heights near Sydney, was sold in 1993–94 and 1994–95 for electricity production in nuclear power stations in North America (Senate Uranium Mining and Milling Committee, 1997).

5.3. Processing

5.3.1. Treatment of the ore

The uranium ore treatment plant was constructed in 1954 and operated until 1971 when the plant was closed. The plant used a standard acid leach process to extract the uranium from the crushed and milled ores.

This acid leach used sulphuric acid manufactured onsite. Until 1962, uranium was recovered from the acid leach liquor by ion exchange, followed by elution and precipitation by adding magnesia. After 1962, a solvent extraction process, using a water-immiscible organic solvent phase, was used. Uranium was stripped from the organic phase by adding alkali, followed by precipitation of the final product with caustic soda. Ore from the Main Deposit was initially treated, and then as ore was stockpiled, suitable blends were made of high and low grade ores to maintain average feed grade of three kilograms per tonne to the processing plant (Davey, 1975).

In addition to the uranium about 360,000 tonnes of high grade copper ore (> 2% Cu) was and treated in the TEP plant, with a further 370,000 tonnes of lower grade ore (0.7–2.0% Cu) heap leached.

Initially, tailings from the processing plant were deposited in a 30-hectare, low flat area north-west of the plant. Later known as the Old Tailings Dam, the area was subjected to annual wet season inundation, which dispersed tailings and process liquors into the East Branch and the Finniss River. Tailings were later deposited into the Dysons open pit until processing ceased in 1971 (Fawcett and Rider, 2010).

5.3.2. Copper extraction pad

In 1966, two separate copper extraction pad heaps comprising approximately 0.3 million tonnes (two hectares) of low-grade copper sulfide and oxide ores were constructed between the Main and Intermediate Deposits. The heaps were treated with acid to extract the copper. The acid (pH2) was made from a mix of treatment plant raffinate, barren liquor, and water from the Main open pit and sprayed over the top of the piles to create leaching, to produce soluble copper and sulfuric acid. The sulfide and oxide liquors were collected around the boundaries of the piles or constructed pads via culverts. The sulfide ore liquor was pumped back up to the top of the oxide pile, where the copper was dissolved by the acid. The low-grade liquors from the oxide pile were collected in three constructed ponds: a pregnant liquor pond, an acid water pond, and a barren dam pond. The low-grade liquor was pumped from the ponds to the copper launders for copper extraction via cementation.

All overflows, including any excess barren liquor, was discharged into Copper Creek, which drained into the East Branch.

Ultimately, the copper extraction pad experiment was deemed commercially unviable. Approximately 3500 tonnes of copper was left in the heap after the mine closed. Copper sulfide ore from the heap continued to oxidise and release large concentrations of copper and other heavy metals and acid into the surrounding environment after the mine closed.

5.4. Previous rehabilitation

In the early 1960s, the significant environmental impacts of the mining activities and the resulting pollution of the East Branch, primarily caused by AMD, were recognised in correspondence between the Australian Atomic Energy Commission and the Northern Territory Administration (National Archives of Australia, 1962/1824). The Commonwealth Government initiated an aesthetic clean-up of the mine site in 1977. The government also formed the RJWG to develop rehabilitation options for the site. The outcome of this technical assessment and planning effort was a four-year rehabilitation project funded by the Commonwealth Government and undertaken from 1982–1986. The total cost was $18.6 million (Allen & Verhoeven 1986), the major proportion of which was spent treating highly contaminated water in the Main pit. The *Final Project Report* (Allen and Verhoeven, 1986) provided a full description of the remediation project, including the rationale for the rehabilitation and the results of preliminary monitoring.

The rehabilitated site was considered to have successfully achieved its set engineering and environmental criteria, based on the results of a 12-year monitoring program undertaken between 1986 and 1998 funded jointly by the Commonwealth and Northern Territory Governments (Pidsley et al., 2002). The rehabilitation of the Rum Jungle site was recognised as being world-leading practice at the time, especially the installation of a multi-layer cover system. Cover system design and construction technologies were then in their infancy, so the site attracted international attention as one of the first implementations of a cover system for remediation of sulfidic waste rock dumps.

5.4.1. Rehabilitation objectives and treatments (1982–1986)

According to Allen and Verhoeven (1986), the objectives of the Rum Jungle Rehabilitation Project were to:

1. achieve a major reduction in surface water pollution, aimed at reducing the average quantities of copper (by 70 per cent); zinc (by 70 per cent), and manganese (by 56 per cent) as measured at the confluence of the East Branch and the Finniss River
2. reduce pollution levels in the Main and Intermediate pits
3. reduce public health hazards, including radiation levels at the site to at least the standards set by the *Code of Practice on Radiation Protection in the Mining and Milling of Radioactive Ores* (Commonwealth of Australia, 1980)
4. implement aesthetic improvements, including revegetation.

Four primary rehabilitation treatments were undertaken:

1. A three-layer cover system was constructed over the waste rock dumps to reduce infiltration to less than five per cent of rainfall. The waste rock dumps were also reshaped and drainage structures installed to mitigate erosion and maintain the integrity of vegetation cover. A mix of introduced pastures and legumes were used for rapid revegetation. Grass cover was the specified re-vegetation condition for the waste rock dumps.
2. A water treatment plant was constructed to treat heavily contaminated water from the Main pit. Water was withdrawn from depth, with lower density treated water returned to the surface of the pit where it formed a layer of clean water overlying the untreated water at depth. Water in the Intermediate pit was treated in-situ with lime to remove heavy metals and neutralise pH. Wet season flows were then re-instated through both pits so that the system would be flushed each wet season. Based on the results from limnological modelling, it was anticipated this process would slowly cleanse the contaminated water that remained at depth in the pits by a combination of seasonal partial vertical mixing and wet-season flushing of the surface layers. Filter cake from the water treatment process was buried in Borrow Area 5, to the north of the site and capped with a three-layer cover system.
3. Dysons pit was partially backfilled with tailings from the tailings area and Tailings Creek. The surface of the tailings was covered with a coarse geotextile and an approximately one-metre thick rock blanket drainage layer. The drainage layer was overlain with low-grade copper ore, copper launders from the copper extraction pad, and contaminated soils from both sites. A moisture barrier, a moisture retention zone, and an erosion-resistant cover were installed on top and the final surface revegetated in the same way as the waste rock dumps.
4. After the tailings were removed to Dysons pit, the tailings area footprint was reshaped to control drainage, limed, and covered with a one-layer system (of soil) to enable revegetation with introduced pastures and native trees and shrubs.

A sub-surface drainage system and a four-layer cover system were also installed over the copper extraction pad area to address residual surface and sub-surface contamination. The surface was revegetated in the same way as the waste rock dumps.

5.4.2. Lessons learnt from previous rehabilitation

The results from the 1993–1998 monitoring period conclude that the rehabilitation objectives, 'reflected contemporary thinking in mine site rehabilitation and were considered appropriate and practical considering the scope of the problems to be dealt with and the level of resources available' (Kraatz, 2002). Monitoring identified that all four key objectives were successfully achieved (Kraatz and Applegate, 1992; Kraatz, 1998; Pidsley, 2002). However, this work did not result in a final condition for the site that would meet contemporary water quality standards. It should be noted that no studies were undertaken on radiological conditions or soil contamination surveys in the years following remediation, based on the absence of such information in the post-rehabilitation monitoring reports.

Richards, Applegate, and Ritchies (1996, as cited in Kraatz, 2004) observed that the treatments were focused on water quality improvements and 'compromise(s) were made on other lesser objectives in order to prolong the life of pollution control structures'. For example, the rapid establishment of vegetation and prevention of erosion using introduced pastures overrode the original intention to maintain similar vegetation to the surrounding environment.

Apart from significant changes that have occurred in rehabilitation standards and practice over the last thirty years, there is sufficient anecdotal and documentary evidence to suggest that certain factors impacted the implementation of the rehabilitation program as it was originally conceived. These factors included budgetary overruns and inconsistent adherence to design criteria, especially in construction and quality control for the covers over the waste rock dumps (as shown in Figure 5-2 with a 0.2 m clay layer on the Main waste rock dump when the design thickness was 0.5 m) . Significant budget overruns in the early stages of the program substantially impacted on the remaining budget and the ability to complete the rehabilitation program as it was originally intended.

Figure 5-2 Main waste rock dump cover detail

Subsequent monitoring has identified ongoing site management issues relating to wildfires, weeds, feral animals, and control of access by the public. These issues largely resulted from an extended interruption to funding after 1998 despite recommendations in the final monitoring report (Pidsley, 2002) that site maintenance activities should continue in relation to weed and fire management and erosion control.

Cessation of weed management and consequent invasion by gamba grass (*Andropogon gayanus*), with a subsequent substantial increase in fire risk (and intensity when a fire occurs), resulted in:

- general degradation of vegetation density and diversity
- erosion of waste rock covers.

These problems provide valuable lessons for implementing any future rehabilitation and ongoing management measures.

5.5. Current site condition

Changes in environmental standards, policy and legislation, and remediation technologies over the past two decades are now indicating there is a need for substantial follow up work to be undertaken. This is required to not only bring the site's environmental performance to contemporary standards (prior to being able to be handed back under the terms of the Finniss River Land Grant), but also to prevent the regression in performance that will otherwise occur as the existing physical structures degrade further.

Since the start of the NPA in October 2009, the DME has progressively been working to improve both the management of the site and the scope and effectiveness of the environmental monitoring.

There is currently limited infrastructure on site; the only physical remnants from the mine include three sheds, a decommissioned drill rig, a gatehouse, and a concrete water tank. A site-wide survey conducted in 2011 provided an assessment of the potential heritage significance of these structures (Earthsea, 2011). Earthsea also found a number of archaeological scatters and sites considered culturally sensitive or significant to traditional Aboriginal owners (Earthsea, 2011). The site has environmental monitoring instrumentation including a weather station (see Figure 5-3), surface water gauging stations similar to that shown in Figure 5-4(two located on the lease and two off the lease), weir monitoring equipment, and numerous ground water bores.

Figure 5-3 Weather monitoring station on the northern edge of Main waste rock dump

Figure 5-4 Gauge station 8150097 downstream of Rum Jungle mine lease on the East Finniss

With respect to site security, historic perimeter fencing has degraded over time with limited fencing remaining. The main access points to the site have been fenced and lockable gates installed in an effort to prevent unauthorised access. Section 2968 remains a restricted use area under the *Soil Conservation and Land Utilisation Act*. DME has also installed restricted area signs (Figure 5-5 shows typical signage installed at main access gates).

Figure 5-5 Main access gate signage

The upper reaches of the East Branch in the central mining area are ephemeral systems and the physical site aesthetics change significantly between the wet and dry seasons. During high-flow rainfall, the diversion channels direct water through the East Branch and through inflows to Main and Intermediate pits, a strategy adopted as part of the previous rehabilitation works to improve the surface water quality of the pits. During the dry season (e.g. August–November) the water bodies evaporate and salt efflorescence becomes more pronounced (see Figure 5-6), particularly where seepage occurs directly to the riverbed (e.g. toes of Main and Intermediate waste rock dumps).

Previously disturbed areas on the site remain highly impacted by weed species, particularly the waste rock dumps. Gamba grass is the dominant weed species onsite and is declared a Class B species under the *Weeds Management Act,* and requires active control to reduce the spread of the weeds (Wildman, 2011). This is achieved by annual herbicide application (particularly around tracks and other site infrastructure) and hazard reduction burning undertaken each year by the Batchelor-based fire volunteers. Other weed species identified in the Wildman (2011) report are controlled where appropriate and in the case of *Mimosa pigra*, all attempts are made to eradicate plants as and when they are discovered on site.

A gamba grass eradication trial has been initiated for the 20 hectare area enclosing the former Borrow Area 5 (see Figure 5-7). The aim of this trial is to identify if eradicating weeds prior to undertaking direct seeding with native species, substantially improves revegetation success. If successful, the trial can be scaled up for future rehabilitation purposes and will also allow ongoing study particularly with respect to species suitability for a climax woodland composition.

Figure 5-6 Salt efflorescence and seepage in the diversion drain at the toe of Intermediate waste rock dump

Figure 5-7 Former Rum Jungle mine site showing location of Borrow Area 5 (NTG, 2011)

6. Rum Jungle baseline studies

6.1. Background to the baseline studies

One of the three key objectives of the NPA is an improved understanding of the current state of the environment at Rum Jungle. A better understanding of the site is needed to achieve the other two objectives of the NPA, which are improved site management and an improved rehabilitation strategy.

The RJPT undertook a detailed literature review and gap analysis of all historical reports, monitoring data, and work programs undertaken for the site dating back to the 1950s. Key areas where data and information were lacking or non-existent were identified. After the literature review and gap analysis was completed, a list of projects (see Appendix 2) was developed to fill data gaps and help the project team better understand the health and safety and environmental and cultural heritage aspects of the site.

These studies include internal projects (undertaken by the project team) and external projects (undertaken by consultants). Both the historical, long-term monitoring programs and recent investigations create the knowledge base for the rehabilitation strategy for Rum Jungle.

The baseline studies are grouped in the chapter under:

- radiological information
- contaminated soil assessments
- geochemical characterisation of waste
- rainfall–runoff modelling
- pit limnology
- hydrogeology
- cover design
- weed management
- mine model
- environmental values
- flora and fauna.

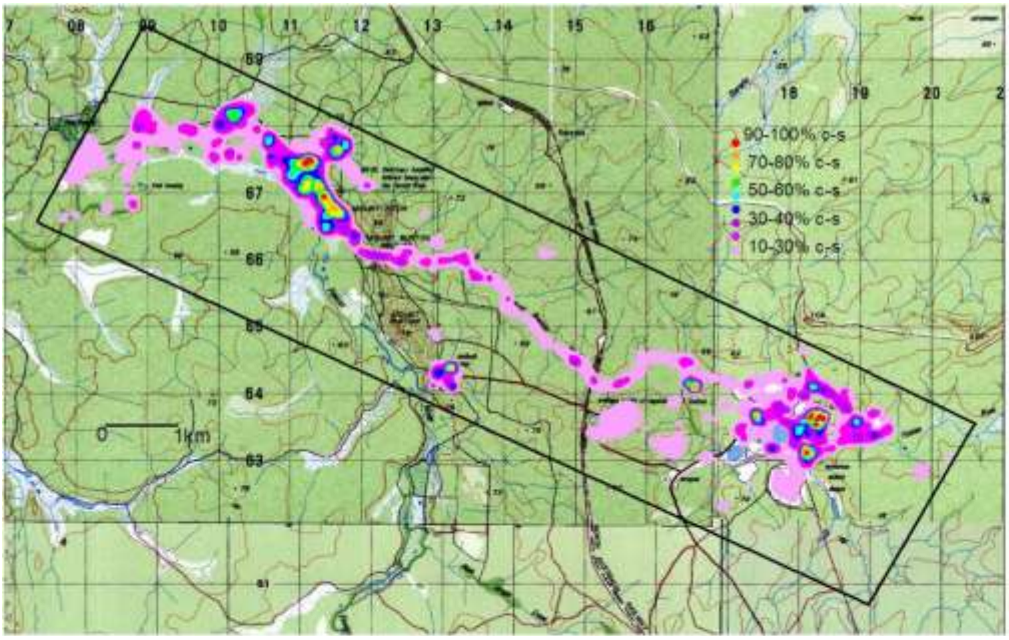
6.2. Radiological studies

The Commonwealth Supervising Scientist Division was commissioned by the then Northern Territory Department of Natural Resources, Environment and the Arts to determine the current radiological conditions at the Rum Jungle site and, based on this information, if any restrictions on use of the site should be applied. This information was to be used to assist any future works at the site (e.g. radiation protection plans) as well as provide baseline information on human habitation and restrictions that may need to be considered if the land is handed back to the traditional Aboriginal owners in future.

Bollhöfer et al. (2008) assessed the radiological status of Rum Jungle at the end of the 2006 dry season, including a multi-pathway (external gamma, inhalation, and ingestion) radiological dose risk assessment under two scenarios:

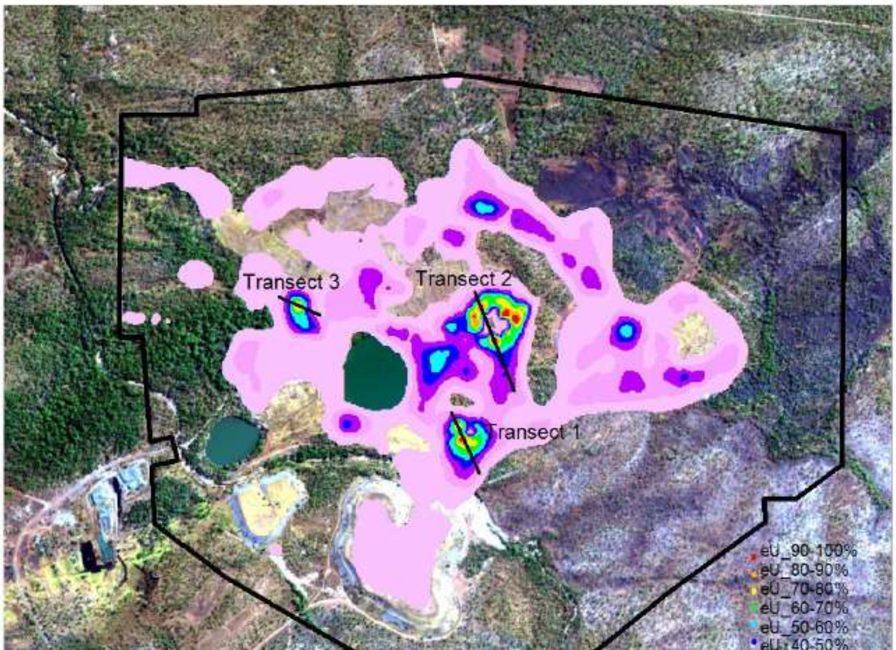
1. occupation of the area by traditional Aboriginal owners and other local Aboriginal people
2. allowing workers to access the site during mining operations at Browns Oxide Deposit.

Airborne gamma radiometric data identified radiation 'hot spots', shown in Figure 6-1 and Figure 6-2. Three specific areas on site were identified as having the highest radiological signatures: an area close to the acid dam, an area west of Dysons backfilled pit, and an area close to the old tailings dam area. A transect was set up across each area to provide ground-truthing data to calibrate the readings from the airborne gamma survey. The transect lines were based on greatest expected gradient of soil uranium activity concentration.



Note: The rectangle shows the extent of the airborne gamma survey.

Figure 6-1 Topographical map with airborne eU data overlaid



Note: The black line indicates the extent of the fenced area. The locations of the three transects are also shown.

Figure 6-2 CASI satellite data of Rum Jungle with airborne eU data overlaid

Measurements of airborne radon concentrations and radon emanation were made during the dry season, as well as long-lived alpha activity contributed by dust. The contribution of radionuclides via the ingestion pathway in bushfoods was estimated using dietary information provided by local people, radionuclide concentrations measured in bushfoods collected on site, and radionuclide concentration factors obtained from other studies in the Top End.

The total radiological doses for the two scenarios, and selected subsets, were compared with the current recommendations for human exposure made by the International Commission for Radiological Protection (ICRP 1999, 2005).

Bollhöfer et al. (2008) made a number of conclusions based on a realistic scenario of traditional Aboriginal owners leading a semi-traditional lifestyle on the Rum Jungle site and frequenting areas immediately downstream. This scenario was developed after consultation with local people. The anticipated total radiation dose above the background dose would be 0.5 mSv per year based on living on the site for a total of one month during the dry season. This dose is small compared to the average background dose of approximately 4 mSv per year in the local area. The dose is also well below the 1mSv per year for exposure of members of the general public (ICRP, 1999).

In an unlikely scenario of traditional Aboriginal owners living on the site for five months of the year during the dry season, the total annual dose would be 6–7 mSv. This dose is below the dose constraint of 10 mSv specified by the ICRP as the level at which remediation should be initiated (ICRP 1999). Intervention is not likely to be justifiable at levels below this dose constraint of 10 mSv per year.

If the site was permanently inhabited by traditional Aboriginal owners who relied on traditional hunting and gathering practices for food supply, the total annual dose would approach 10 mSv.[4]

Annual doses approaching 10 mSv per year would also occur under the unlikely scenario of the area close to the former acid dam being inhabited for five months during the dry season. In this case, the ICRP guidelines state that action to reduce exposure may be warranted. However, occupation of this area is extremely unlikely given it is environmentally inhospitable.

For a hypothetical group living on the mine site, most of the dose would be from a combination of radon and external gamma radiation and from the ingestion of traditional bushfood. In contrast, for a hypothetical group living five kilometres downstream of the site, most of their dose would be from ingestion of aquatic food due to the poor quality of water in the Finniss River.

Workers will need to access the site for implementing any rehabilitation strategy and for monitoring and maintenance works. If workers access the site during the day for 2000 hours per year per worker, the total dose is 0.3 mSv, and no extra precautions need to be taken for access. However, if activities such as drilling and digging are undertaken onsite, the OH&S management plan for the site would need to incorporate monitoring various exposure pathways, especially dust pathways.

Bollhöfer et al. (2008) recommended that the Finniss River and water bodies onsite should not be used as permanent sources of drinking water or for aquatic foods such as fish or mussels. They also recommended that a radium 226 (^{226}Ra) monitoring program be initiated downstream of Rum Jungle to obtain a more reliable measure than is currently available of ^{226}Ra activity concentrations throughout the year. Sampling aquatic foods along the river was also recommended for a more robust estimate of the contribution of these foods to the ingestion pathway.

A radiation-monitoring plan should be a substantial part of the environmental management system, and include monitoring the radiation exposure of workers, as well as environmental monitoring of areas offsite.

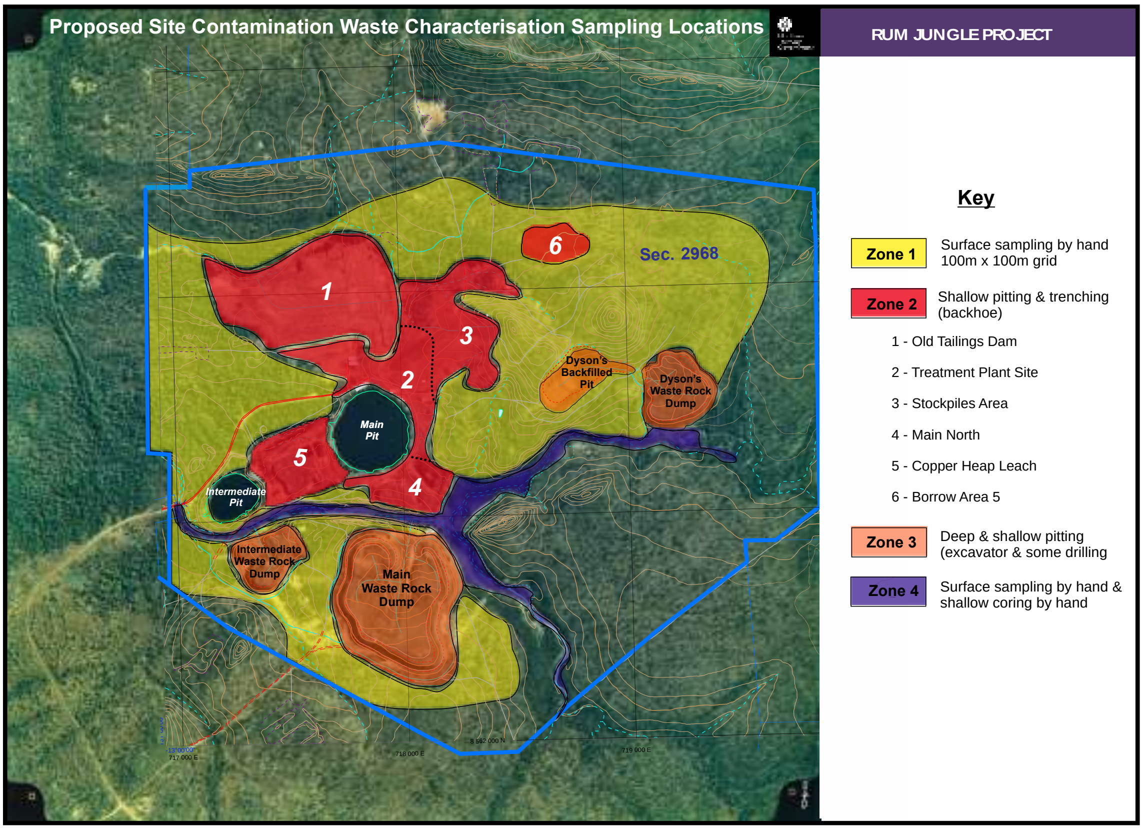
[4] These amounts are based on the assumption that all food items are available, which is unlikely for aquatic organisms given the elevated metal concentrations in the water.

6.3. Contaminated site soil assessment

During site visits by the RJPT, evidence of surface contamination, such as the appearance of salt efflorescence and areas devoid of vegetation, was noted across previously disturbed and undisturbed areas of the site. DME commissioned a detailed survey of the site to determine the metal levels in surface and near-surface soils, fluvial sediments and deep soils. The objective of the project was to determine the metal levels and estimate volumes of contaminated soils onsite that would need to be relocated under future rehabilitation options for the site. Volumes of contaminated material are important to determine in order to develop costs for the rehabilitation strategy.

A detailed site investigation was undertaken by CSA Global Pty Ltd, designed in accordance with the *Australian Standard 4482. 2005 Australian Standard: Guide to the investigation and sampling of sites with potentially contaminated soil*, *Part 1: Non-volatile and semi-volatile compounds* (Australian Standards, 2005). In this context, contaminated material is defined as material containing elevated or anomalous metal concentrations based on pre-defined, cut-off parameters.

The Rum Jungle site was divided into four major sampling zones shown in Figure 6-3. Zone 1 represents areas where there was minimal previous rehabilitation. Zone 2 represents areas of previous disturbance that were rehabilitated during the 1983–86 program of work. Zone 3 represents the waste rock dumps, which were not sampled in this investigation but in a separate contract of work (see section 6.4). Zone 4 represents fluvial areas across the site.



Note: Zone 3 excluded from scope

Figure 6-3 Sampling zones

Field sampling was undertaken over seven weeks from 1 November 2010. Samples were collected using a variety of methods including hand (mattock, shovel, auger), bobcat auger and excavators (mini, 11 tonne, and 30 tonne) as shown in Figure 6-4.

Field samples were screened using Field Portable X-Ray Fluorescence Spectrometry (FPXRF) as shown in Figure 6-5. They were also analysed using laboratory based XRF with validation samples analysed by NATA-accredited laboratories. All analysis was completed by February 2011. Samples were analysed for Ag, As, Ba, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Rb, Sb, Sr, U, V, Zn and Zr.

Figure 6-4 Excavator backfilling a sample pit

Figure 6-5 Hand-held X-ray fluorescence spectrometer being used on a sample

Interim threshold (trigger) values for determining volumes of mine-related sample material are in Table 6-1. The rationale for choosing these values (rather than published Health Investigation Levels) is discussed in Lindsay-Park and Margereson (2011). Ongoing consultation with stakeholders will determine intended future land use, which will inform the final set of elements and threshold values. These final values will be used to refine the areas and volumes of contaminated material that require remediation.

Table 6-1 Interim trigger levels for identifying site contamination

Element	As	Cr	Cu	Fe	Mn	Ni	Pb	Rb	Sr	U	V	Zn
Units	ppm	Ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Value	200	300	2000	15	7000	600	1000	200	50	100	350	3000

Area and volume calculations of material exceeding trigger values are also in Lindsay-Park and Margereson (2011). In all sampling zones, a single occurrence of any element that is over the trigger value constitutes a contaminated sample. The area and volume calculations are independent of the total number of elements above trigger values in each area.

Summary results of approximate area and volume of mine-related material exceeding interim trigger levels are in Table 6-2, separated into the zones identified in Figure 6-3. Each zone is further divided into discreet sections that are either separated geographically or associated with a known rehabilitated area. Due to variations in the projected area between depths, the maximum area of all depths is used and the volume is summed for all sampling depths.

From Table 6-2, the volume of material exceeding trigger levels in Zone 1 (minimal previous rehabilitation effort) is approximately 165,000 m^3 with 46 per cent of the material located to 1.5 metres depth across eight hectares north of the old tailings dam either side of the northern access road. The remainder of the material is widely dispersed across 42 hectares in shallow soils (0.2 metres) to the east and west of the central mine area. The material that registered above trigger values in Zone 2 (the previously rehabilitated areas) is dispersed through depths of up to five metres with the majority (64 per cent) of the 891,000 m^3 in the old tailings dam and stockpile areas. The rest of the material is equally dispersed between the historic plant, the Main Deposit North, and the copper extraction pad, with a small amount (5 per cent) in Borrow Area 5. Most (80 per cent) of the fluvial material above the trigger levels is within the footprint of the historic acid and sweet water dam areas to a measured depth of 1.3 metres. Material with elevated metal levels is likely to be located below this depth, but sampling was constrained due to cultural sensitivities.

Table 6-2 Approximate area and volume of mine-related material exceeding interim trigger levels

Zone	Section	Approx. Area (ha)	Total volume (m^3)	%	Maximum depth (m)
1	West of central mine area	20.98	40,568	25	0.2
1	Central, north of old tailings dam	8.14	75,697	46	1.5
1	Dysons surrounds	21.49	37,148	22	0.2
1	Central around Main Extended	4.59	8,754	5	0.2
1	Western toe of Intermediate waste rock dump	1.55	3,052	2	0.2
	Subtotal	*56.75*	*165,219*	*100*	
2	Old tailings area	9.92	309,207	35	5
2	Plant area	3.49	88,300	10	5
2	Stockpile area	10.43	257,884	29	4
2	Main North	2.9	100,052	11	5
2	Copper extraction pad	4.75	88,168	10	4
2	Borrow Area 5	2.47	47,802	5	4
	Subtotal	*33.96*	*891,413*	*100*	
4	Sweet water and acid dams	13.93	87,705	80	1.3
4	East Branch adjacent to Dysons	2.72	21,937	20	1.3
	Subtotal	*16.65*	*109,642*	*100*	
All	**Total**	**107.36**	**1,166,274**		

The site investigation identified substantial quantities of soil and rock with elevated levels of metals consistent with mining-related impacts. The total reported volume of material that needs to be considered in rehabilitation planning is approximately 1.16 million m^3, dispersed over an area of approximately 107 hectares, with 76 per cent within previously rehabilitated areas. The next step will be to further define the intended future land use of the site, which will help identify the most relevant guidelines to refine the areas and volumes of contaminated material.

6.4. Geochemical characterisation of waste

A key consideration for developing rehabilitation scenarios is to understand the geochemical properties of the waste material in the four onsite waste storage structures. The geochemical processes occurring in the structures and the extent sulfide material is oxidising and generating acid needs to be known to assess the impact on the surrounding environment. This information can be used to prioritise waste material and to determine a strategy for materials handling, specifically residue management requirements, for example relocating the material below ground to prevent further oxidation and acid generation. Information from this project assisted parallel studies, including the hydrogeology work, by gauging seepage rates and concentrations from the waste rock dumps, and assisting cover designs of suitable protection systems to reduce the release of contaminants to the environment.

An investigation into the geochemical characterisation of the waste material contained in the Main, Intermediate and Dysons Deposits waste rock dumps and Dysons backfilled pit was completed in 2012 (SRK Consulting, 2012).

Samples were collected from the three waste rock dumps and the backfilled pit using excavators (see Figure 6-6) and a sonic coring drill rig (see Figure 6-7). A total of 317 profile samples were tested in the field for paste pH and paste electrical conductivity (EC). A sub-set of these samples (110) was characterised in more detail using laboratory tests to determine sulfur and carbon speciation, acid neutralising capacity, net acid generation potential, mineralogy, elemental composition, and leachable metals (see Table 6-3). Only a small proportion of the 110 samples were subjected to the full suite of tests.

Figure 6-6 Pit excavation in Dysons waste rock dump

Figure 6-7 Sonic drill rig on Dysons backfilled pit

Table 6-3 Tests and number of samples tested

Test	Number of samples
Total sulfur	110
ANC	110
NAG	110
Carbon speciation	25
Whole rock assay	102
Leach extraction	18
Net acid generation leach tests	12
Mineralogical assays	40

Source: SRK Consulting, 2012

Two piezometers and two sets of instrumentation were installed through the profile of Dysons backfilled pit. The instrumentation allowed oxygen concentration and temperature to be measured along vertical profiles. The depth to the groundwater table was also measured.

6.4.1. Waste characteristics

SRK Consulting (2012) observed that waste material in the waste rock dumps was very heterogeneous in colour, texture, and grain sizes over varying scales that ranged from centimetres to many metres, both vertically and laterally. Materials in Dysons backfilled pit showed a lesser degree of heterogeneity.

It was initially anticipated that the extent of oxidation and the lithological provenance of the waste could be inferred from visual observations. This approach would have reduced the laboratory characterisation work with fewer samples able to be subjected to more detailed analysis. Unfortunately, geochemical characteristics such as acid potential and leachable metal content did not correlate with the visual characteristics.

The majority of waste materials sampled had an acidic paste pH and high EC, which is consistent with the presence of abundant stored oxidation products. At some sampling locations, depth profiles showed trends towards increased paste EC with depth, which is consistent with soluble salts and metals being leached from upper to lower parts of the profile.

The neutralising potential of the waste material was typically low, which may indicate that if significant amounts of neutralising minerals had been present, they are now depleted in the upper horizons of the waste profile. Initial neutralising capacity will relate to lithology, with waste of carbonate origin having a greater and more readily reactive neutralising capability.

The results from 3:1 liquid-to-solid ratio water leach extractions identified a number of readily soluble solutes that exceeded the *ANZECC Stock Water Quality Guidelines 2000* (ANZECC, 2000a) in most of the samples tested. These solutes are summarised for each of the facilities sampled in Table 6-4.

The leach test results from SRK Consulting (2012) agree with the analysis of waste structure seepage water quality completed in 2011 by Robertson Geoconsultants (2011). In general, the seepage water was much more acidic (lower pH values) than the leachates from the waste rock samples, with substantially higher solute concentrations (higher EC). The result for EC is not unexpected given the higher liquid-to-solid ratio for the laboratory leach test compared with the column leach condition in the waste structures. However, the poor match for pH suggests a potential issue with the selection of the sub-samples for leach testing.

Table 6-4 Comparison of findings from water leach tests and analysis of seepage water quality

Facility	Elements & compounds in leach extract solution at concentrations that exceed ANZECC stock water quality guidelines	Elements & compounds in seepage water at concentrations that exceed ANZECC stock water quality guidelines	Priority ranking (3 = highest)
Main waste rock dump	Al, B, Cd, Co, Cu, Se, SO_4,	Al, Co, Cu, Mg, Ni, U, SO_4	1
Intermediate waste rock dump	Al, As, Cd, Co, Cu, Ni, Pb, Se, SO_4, Zn	Al, Co, Cu, Mg, Ni, Se, U, SO_4	3
Dysons waste rock dump	Al, Cd, Co, Cu, Ni, Pb, Se, U, SO_4,	Al, Cd, Co, Cu, Ni, Se, U, SO_4	2
Dysons backfilled pit (Cu extraction residue/contaminated soils)	Al, Co, Cu, Ni, Se, U, SO_4,	Al, Co, Cu, Ni, Se, U, SO_4	1
Dysons backfilled pit (tailings)	Co, Cu, Ni, Se, U, SO_4,		n/a*

* It is assumed that this material is already stored in the best possible location.

Geochemical modelling calculations indicated the mineralogical controls on solute loads: sulfate (gypsum, jarosite), iron and aluminum (iron and aluminum hydroxides, amorphous silica). The findings from the leach test results indicated that releases of minor and trace elements were not likely to be limited by mineral solubility.

6.4.2. Potential for long-term acid and metalliferous drainage

SRK Consulting (2012) identified that with the exception of Dysons waste rock dump, all structures contain substantial residual sulfides and they have the potential to continue to oxidise and to generate acidic and metalliferous drainage conditions into the future (see Table 6-5). In addition, there is substantial acidity stored in leachable solids of low solubility (e.g. jarosite). Average values for the maximum acid generating potential (based on sulfide-S content) for each of the dumps and the backfilled pit are also summarised in Table 6-5.

Table 6-5 Average maximum acid generating potentials for tested facilities

Facility	Average acid potential, kgH_2SO_4/t[1]	Priority ranking (3 = highest)
Main waste rock dump	26	2
Intermediate waste rock dump	60	3
Dysons waste rock dump	7	1
Dysons backfilled pit (Cu extraction residue/contaminated soils)	61	3
Dysons backfilled pit (tailings)	47	n/a

[1] Based on the sulfide sulfur content of the materials and not taking into account neutralising capacity

The results of the net acid generation tests identified that a number of elements would likely continue to be released from the ongoing oxidation of sulfides. These elements included Fe and a range of metals and metalloids that are typically present as major components or trace inclusions within sulfide minerals, including As, Cd, Co, Cu, Ni, Se and Zn. Dissolution of other (non-sulfide) mineral phases by generated acidity would result in elements such as Al, Si (aluminosilicates), Cr, Mn (oxides) and Ca, Mg, Mn (calcite, dolomite, rhodocrosite) being released.

The results from the AMD characterisation work can help prioritise management of the various waste sources. For example, based on the Table 6-5, the Intermediate waste rock dump and the top of Dysons backfilled pit could be given priority over Dysons waste rock dump. Much of the tailings in Dysons backfilled pit is currently below the water table, and protected from further oxidation. While the tailings have a comparatively high acidification potential, it will not be able to be realized, unlike the unsaturated waste materials elsewhere. Therefore, the in-place tailings would not be prioritised for remedial work if maximum acid-generating potential is used as a key risk factor.

The findings from the leach test and seepage quality assessments provide another dimension to prioritising management of the site. This information indicates the current magnitude of the source terms, as distinct from future magnitude that is indicated by maximum acid generating potential. Combining both the acid generating and leach test and seepage results yields the combined ranking assessment shown in Table 6-6.

Table 6-6 Combined ranking assessment

Facility	Average maximum acid generating potential	Numbers of contaminants exceeding ANZECC guidelines	Overall ranking score [1]
Main waste rock dump	2	1	3
Intermediate waste rock dump	3	3	6
Dysons waste rock dump	1	2	3
Top of Dysons backfilled pit	3	1	4

[1] Sum of columns 1 and 2

The results of the leach tests can also be used to indicate potential composition of pore water generated if some of the waste is backfilled into the mine pits. It may be preferable to use waste with a lower leachable component, but with higher unoxidised sulfide content so the initial groundwater source term is lower. Prior consideration of the amount of treatment (for example kg/t of lime) required to reduce concentrations of metals in pore water, can ultimately reduce the amount of lime required especially if waste is strategically selected. Given the importance of this issue and the need for better quantification of the leachable fraction of salts and metals in the waste sources, a substantially greater number of samples (than the current 18) should be leach tested and measured for neutralant demand.

6.5. Rainfall–runoff modelling

The purpose of the rainfall–runoff modelling project was to develop a site water balance that can quantify the inputs and outputs of water to and from Rum Jungle, including surface and groundwater interactions. This water balance can be applied to rehabilitation scenarios to help identify mitigation strategies to reduce contaminated water generation and flows from the site.

6.5.1. Surface water catchments

Figure 6-8 and Figure 6-9 show the current surface water catchments in the Rum Jungle area, with overlays of 2010 aerial photography and the local geology for reference.

6.5.2. Impact of the mine site on the discharge of the East Finniss River

The relevant areas of the catchment and key mine site features are:

- East Finniss River Catchment area to GS8150097 = 71 km^2, which is the bulk of the catchment area of the East Branch, noting that the length of this reach is approximately 18 kilometres.
- Rum Jungle Lease area = 6.5 km^2 (9.2 per cent of East Finniss River catchment to GS8150097).
- The combined area of all waste rock dumps (Main, Intermediate, and Dysons) and Dysons backfilled pit is 0.54 km^2 (0.76 per cent of the East Finniss River catchment to GS8150097).

GS8150097 is at an excellent location to capture all flows from upstream; flow data measured here is highly reliable.

Rum Jungle is considered to make an insignificant contribution to the total flows or to the flow regime in the East Finniss River at gauging station GS8150097 because:

- the total area of the waste rock dumps and backfilled pit is a very small proportion of the total catchment area (0.76 per cent); therefore, any change in the runoff or infiltration response of the dumps or backfilled pit under natural conditions will be undetectable at the catchment level
- the total lease area of Rum Jungle is only nine per cent of the catchment area upstream of GS8150097.

Because the stream length of the current stream diversion between the Main and Intermediate pits and the Intermediate waste rock dump is only 1.26 kilometres, compared with a total stream length of 17.8 kilometres to gauging station GS8150097 (7.1 per cent), the diversion channel will have a very small influence on streamflow travel times. Therefore, any realignment or remodelling of the current diversion channel as part of the rehabilitation is expected to have an undetectable effect on the flow regime measured at GS8150097.

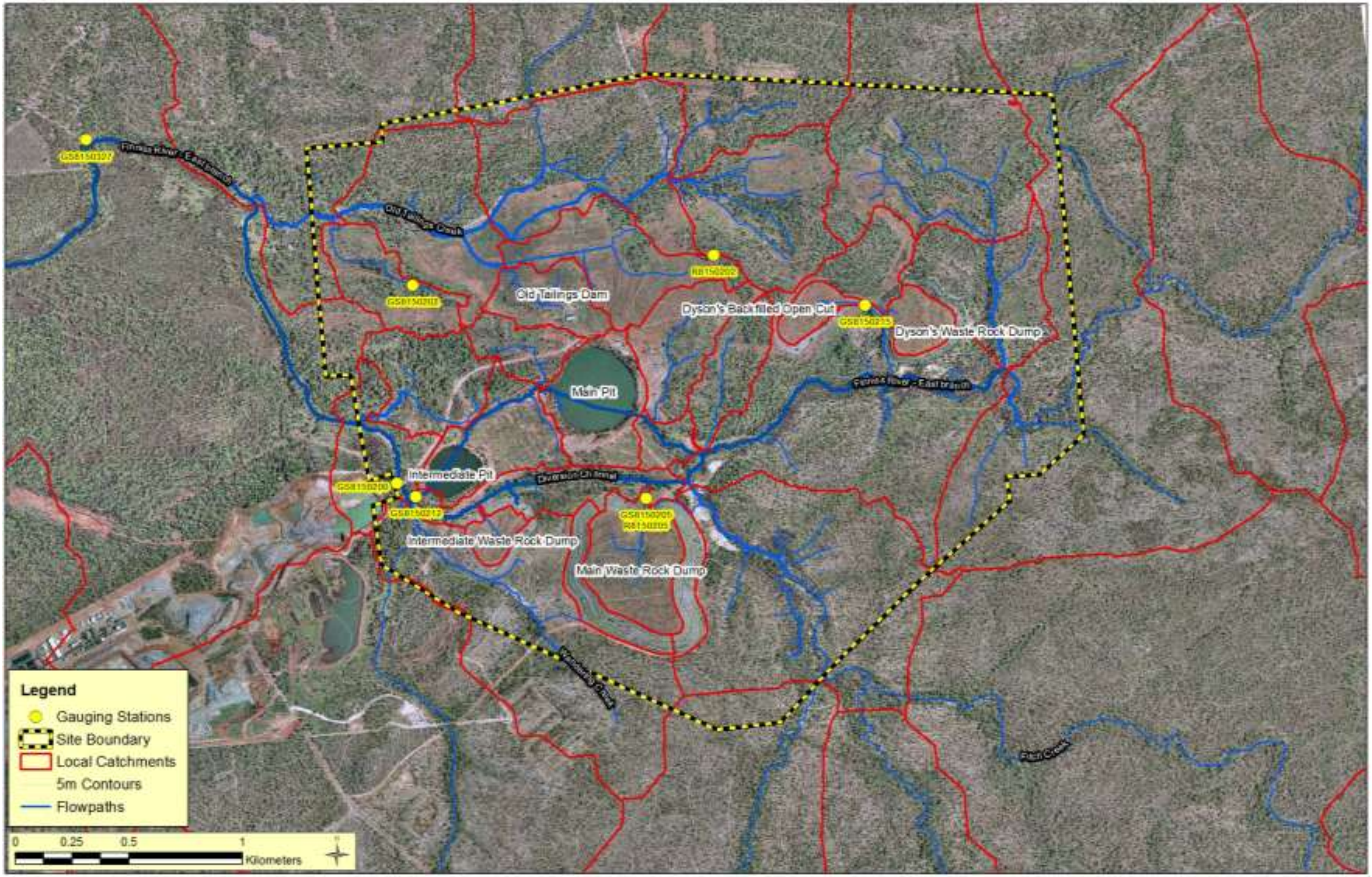


Figure 6-8 Current surface water catchments in Rum Jungle — aerial photography

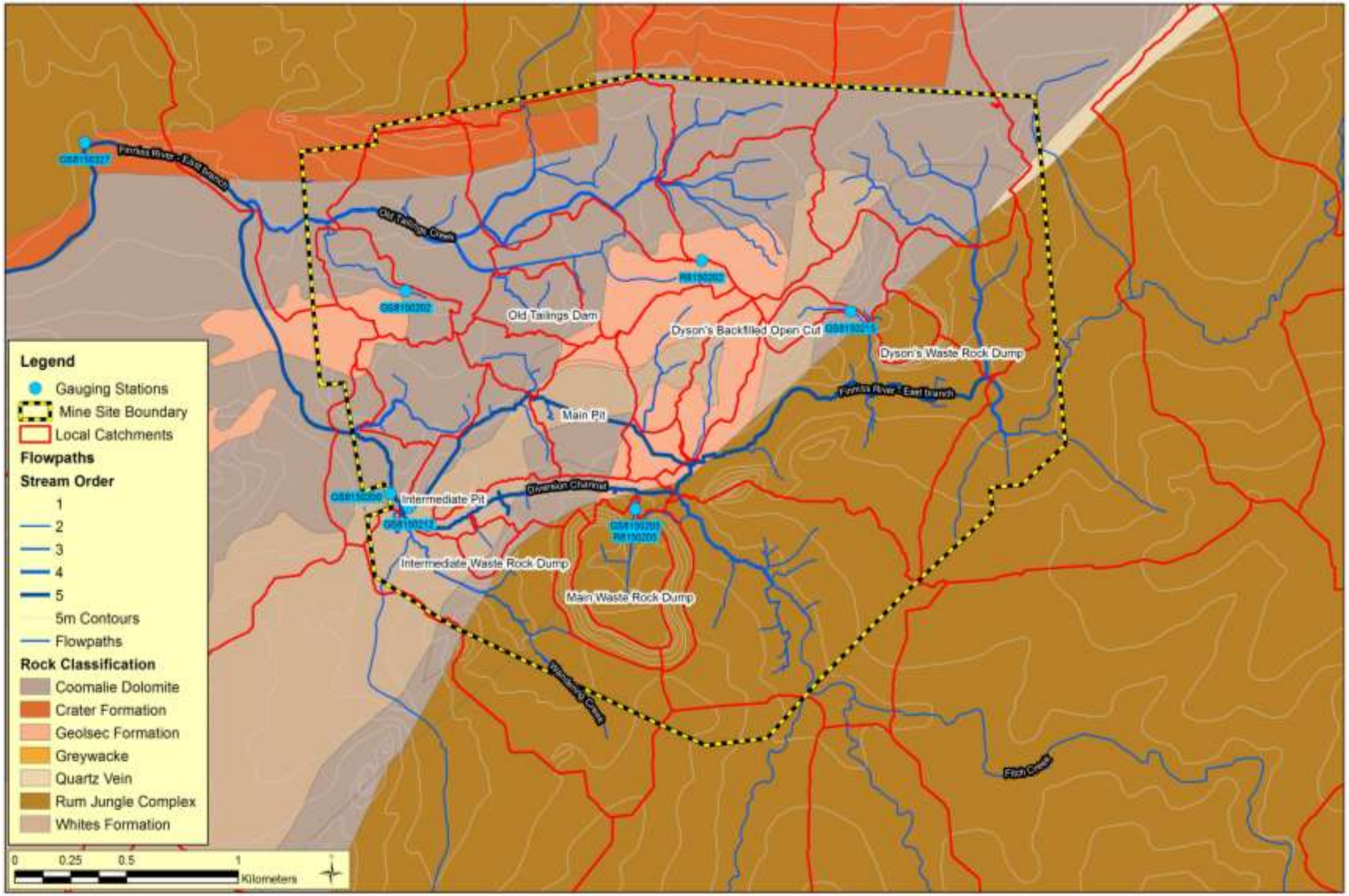


Figure 6-9 Current surface water catchments in Rum Jungle — geology map background

6.5.3. East Finniss River discharge behaviour

A daily rainfall–runoff model was developed for the East Finniss River catchment for flow response at gauging station GS8150097 (see Figure 6-10). This gauging station was chosen because it has a long record of data (January 1965–June 2012), which is considered to be reasonably reliable and accurate. The gauging station is located downstream of the down-slope boundary of the local aquifer under Rum Jungle. It captures all surface and groundwater flow in the catchment; there is no subsurface flow beneath the gauging station that is unaccounted for.

The model was calibrated initially against the available rainfall and streamflow (47 years) records and then run with historical rainfall data to provide a continuous 123-year estimated daily discharge estimate, covering a wide range of wet and dry years. Statistical analysis was then undertaken to provide monthly measures of streamflow probability. These results can be used in assessing rehabilitation options to look at different discharge rates from the Main and Intermediate pits.

Figure 6-10 shows the model results for January and April as examples of the mid and late wet season flows in the system. The X-axis shows the probability that a daily discharge will be equalled or exceeded. If a desired discharge probability is chosen (30 per cent in the example) then in January, there is a 30 per cent probability of a discharge of about 210 ML/day or greater. In April, the 30 per cent probability discharge is only about 25 ML/day.

As another example of the modelling results, if there is a desired discharge of 500 ML/day (e.g. as a minimum for dilution of pit water) then there is about a 12 per cent probability of this occurring on any one day in January, but only about a 3 per cent probability of it occurring on a day in April.

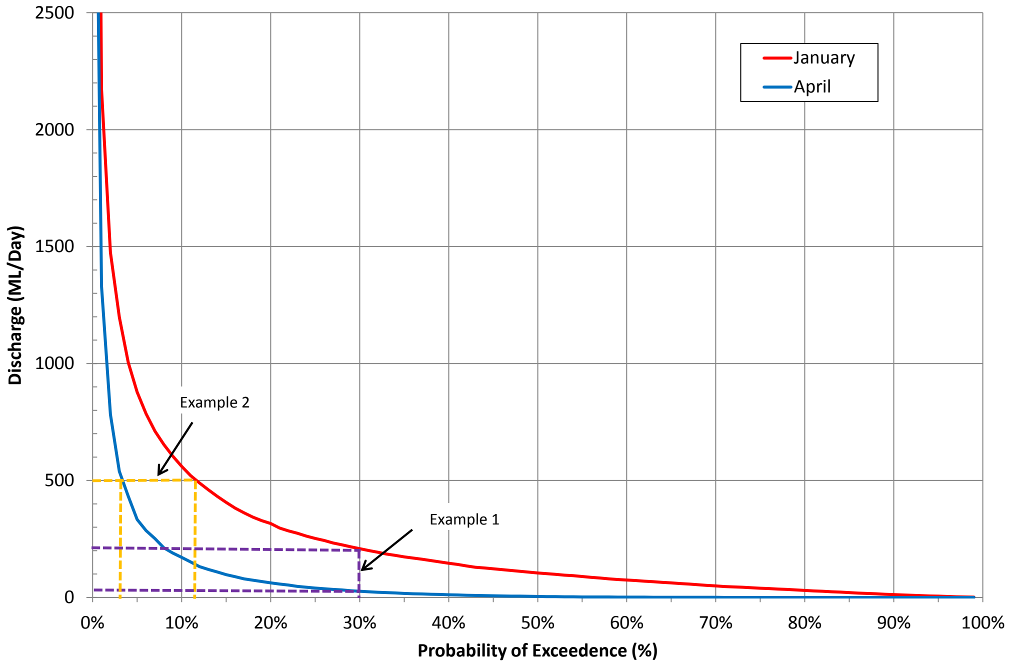


Figure 6-10 Daily flow exceedence curves for January and April for the East Finniss River at GS8150097

Table 6-7 shows the shows discrete values of daily streamflow exceedences for December to April.

Table 6-7 Daily flow exceedence for December–April for the East Finniss River at GS8150097 based on 123 years of modelled streamflow

Probability of exceedence (%)	Daily discharge (ML)				
	December	January	February	March	April
99.9	0	0	0	0	0
99	0	1	2	0	0
95	1	5	14	2	0
90	2	12	28	7	0
75	9	39	75	37	0
50	33	104	194	143	4
25	92	248	451	400	40
10	224	551	931	889	170
5	370	872	1275	1317	317
1	950	2209	2531	2550	1256
0.1	2948	6718	5743	5543	3826

Figure 6-11 shows, the average monthly rainfall from the SILO database and areal potential evapotranspiration from the BoM (2013).

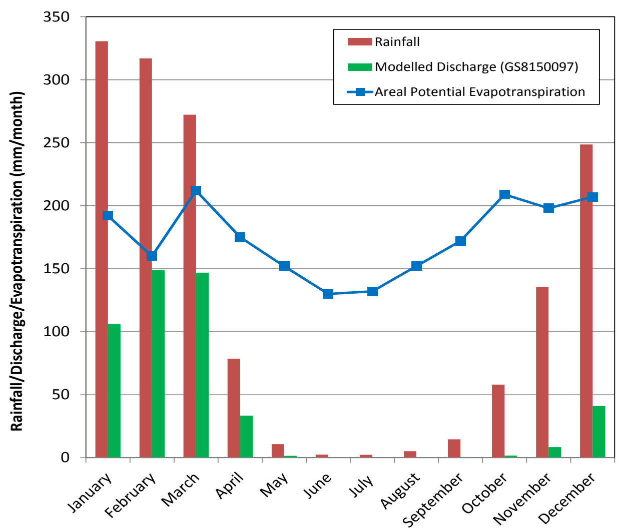


Figure 6-11 Average monthly discharge for the East Finniss River at gauging station GS8150097 together with average monthly rainfall and areal potential evapotranspiration for the Rum Jungle area

The mine site and its components, such as waste rock dumps, are small in area relative to the whole East Finniss River catchment. Therefore, any changes to the rainfall–runoff behaviour in the mine site area will not be detected at the gauging station downstream. However, changes to the site such as rehabilitation works are likely to alter the quality and other characteristics of surface runoff.

6.5.4. Waste rock dump infiltration estimates

Obtaining estimates of the current rates of infiltration into the mine landforms onsite are central to:

- determining how the landforms are performing against the original site rehabilitation objectives
- providing a baseline to quantify the improvements achieved by the rehabilitation strategy developed by the NPA.

Using rainfall–runoff modelling, two approaches were used to estimate net infiltration rates of the mine landforms across the Rum Jungle site: Water Technology and the Robertson Geoconsultants approach. The Water Technology approach was undertaken as part of a more extensive hydrological modelling exercise for the East Finniss system. The second approach by Robertson Geoconsultants was developed as part of their hydrogeological investigations and modelling. The results of the two approaches show substantial differences between the range of input data.

Approach 1 — Water Technology

The proportion of rainfall that infiltrates into the waste rock dumps was estimated using rainfall–runoff models, calibrated against surface runoff. This estimate was made at a local scale because the contribution of flow from these small footprint sources would be undetectable at catchment scale. Surface runoff was measured and the rainfall–runoff model was calibrated against the surface runoff to estimate infiltration.

Table 6-8 shows the historical surface water runoff monitoring undertaken on the waste rock dumps.

Figure 6-8 shows the location of the monitoring stations. Only the Main waste rock dump and Dysons backfilled pit were monitored. Both were monitored between 1985 and 1988, but only Dysons backfilled pit was monitored in 1997–98. Only limited data was available for modelling; in addition, data was not available for all monitoring periods at all sites.

Table 6-8 Waste rock dump runoff and rainfall monitoring data

Station			Monitoring period	Available data period
Number	Name	Type		
GS8150205	Main waste rock dump	Discharge	Feb 1985 – July 1988	Feb 1985 – May 1988
R8150205	Main waste rock dump	Rainfall	Aug 1984 – Feb 2011	Aug 1984 – Feb 2011
GS8150215	Dysons backfilled pit	Discharge	Dec 1997 – June 1998	Dec 1997 – May 1998
			Feb 1985 – July 1988	No data

Two separate rainfall–runoff models were used for the surface runoff from the Main waste rock dump and Dysons backfilled pit. The models recorded rainfall at the Main waste rock dump, calibrated against the available surface runoff monitoring data. The calibrated models were run with 123 years of historical rainfall and evaporation data (1889–2012) (SILO database, 2012) to provide a continuous 123-year estimated daily estimate of surface runoff and infiltration, covering a wide range of wet and dry years. The estimated infiltration rates from the rainfall–runoff modelling were:

- Dysons backfilled pit: 73 per cent of rainfall.
- Main waste rock dump: 67 per cent of rainfall.

The infiltration estimates are based on a very short data record: one year for Dysons backfilled pit and three years for the Main waste rock dump. Therefore, data should be collected on current conditions from the landforms at Rum Jungle, which should help to refine these estimates.

It is not possible to infer the fate of the infiltrated water (e.g. does it recharge the regional aquifer or does it report as seepage from the perimeter of the pit area) without seepage monitoring data. This data may become available in the future and can then be used to further refine the rainfall–runoff models.

Approach 2 — Robertson GeoConsultants Inc

Robertson GeoConsultants Inc (2012a), conceptualised groundwater recharge to represent a percentage of incident rainfall. Recharge to the Coomalie Dolostone was thought to represent 10–15 per cent of incident rainfall, whereas annual infiltration rates for the Whites Formation (5–10 per cent) and the Rum Jungle Complex (2 per cent) were lower. As part of this assessment, the waste rock dumps were conceptualised as areas of preferential recharge. Recharge was estimated to be about 25 per cent of annual rainfall. This percentage was based, in part, on an assessment of observed contaminant loads in the East Branch undertaken in 2011 (RGC, 2011a) and from information gained from experience at other abandoned mine sites in northern Australia.

The conceptual recharge model from RGC (2011b) did not explain the similar range in groundwater levels during the 2010–2011 and 2011–2012 wet seasons, despite disparate rainfall amounts (i.e. 2390 mm vs 1350 mm). Therefore, a revised recharge model was developed based on recharge rates estimated by the water table fluctuation method described by Healy and Cook (2002). This method uses short-term variations in groundwater levels to estimate recharge rates based on the premise that increases in groundwater levels in unconfined aquifers are due to infiltrating rainfall arriving at the water table.

Using the revised recharge method, recharge to the Coomalie Dolostone was estimated to be 20 per cent of annual rainfall in 2010–2011 and 2011–2012. Recharge to Rum Jungle Complex was more variable, as 10 per cent of rainfall in 2010–2011 was estimated to infiltrate to groundwater and 14 per cent of rainfall was estimated to infiltrate to groundwater in 2011–2012). Recharge could not be estimated directly because no reliable information on groundwater-level fluctuations within or beneath the waste rock dumps was available. Based on the conceptual model for the site, recharge was assumed to be twice as high as estimated recharge for Rum Jungle Complex (i.e. 20–28 per cent of rainfall) and a sensitivity analysis was conducted to evaluate potential uncertainty.

The sensitivity analysis simulated toe seepage from the Main waste rock dump using the updated numerical flow model. Two sensitivity runs were completed, with one run assuming recharge was equivalent to the estimated recharge for Rum Jungle Complex (i.e. 10–14 per cent) and another run assuming that recharge to the waste rock dump is three times higher than the estimated recharge (i.e. 30–42 per cent). Observed rates of toe seepage from the Main waste rock dump during the 2011–2012 wet season were comparable to simulated toe seepage for the low-recharge sensitivity run. These results suggest that recharge may be slightly over-estimated in the updated groundwater flow model and that recharge to the Main waste rock dump is likely to be less than 25 per cent of the annual rainfall for most years (RGC, 2013).

Comparison of infiltration estimates

There is a large difference between the infiltration estimates derived from the Water Technology approach and the Robertson Geoconsultants' approach. However, these estimate are preliminary based on the information available at the time this report was compiled. Once the consultants finalise their detailed reports, the reasons for the differences will be established and the need for any additional assessments determined.

6.6. Main and Intermediate open pit limnology

There was a need to understand the water quality profiles and bathymetry of the two water-filled pits on site in the Main and Intermediate areas. Significant water treatment activities during the 1980s rehabilitation works improved the water quality in the pits. However, more information was needed to determine the water quality in the pits from surface to depth and to develop bathymetry models of the pits themselves. The bathymetry data is important for developing the mine model to understand the available volumes for relocating waste material for the rehabilitation scenarios.

A study undertaken in 2008 to assess the limnology of the water bodies of the Main and Intermediate pits determined that water quality in the upper levels of both pits had significantly improved since the late 1980s and early 1990s (Boland, 2008). Small remnants (a few metres thick) of highly contaminated water were found at depth in both pits. The high density of this water, relative to the overlying water, suggests that the contaminated water is likely to be hydrodynamically stable. The study recommended further hydrodynamic modelling to better quantify the potential of this bottom water as a future pollutant source (Boland, 2008).

The study provided:

- bathymetric (surface topography) models and hypsographic curves for the two pits
- estimates of metal concentrations and total mass contained within the water columns of the two pits
- an improved measure of radiological activity remaining in the water column.

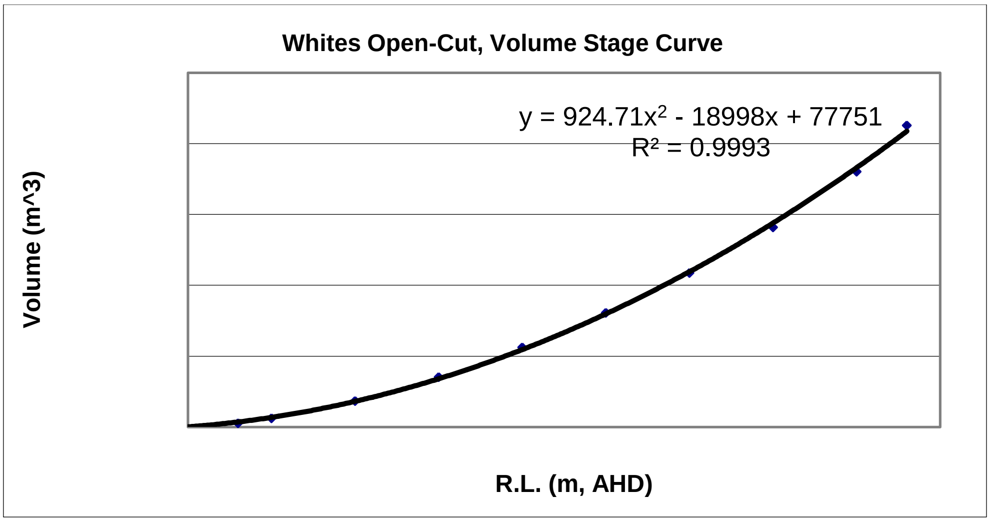
6.6.1. Bathymetry

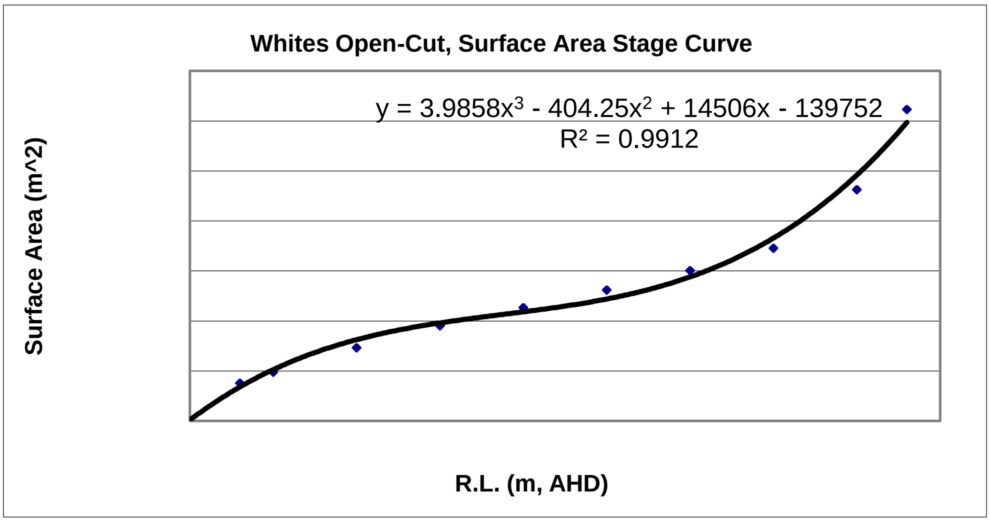
Boland (2008) developed hypsographic curves for both the Main and Intermediate pits and calculated volumes and surface areas for the water bodies up to the surface levels that were present in 2008 (Table 6-9 and Figure 6-12 and Figure 6-13). Extrapolation of these curves to full capacity levels could be undertaken without introducing significant inaccuracies. Full capacity levels are 60 metres elevation for the Main pit and 59 metres elevation for the Intermediate pit. These curves provide key information about the volume of water that would need to be removed from each pit before they could be backfilled with waste rock.

Table 6-9 Approximations of volume and surface area of water bodies in the Main and Intermediate pits based on maximum depths measured at the date of sampling

	Main (at 58 m RL)	Intermediate (at 57 m RL)
Max. depth	44.4	52
Volume (m^3)	2,100,000	750,000
Surface area (m^2)	120,000	56,000

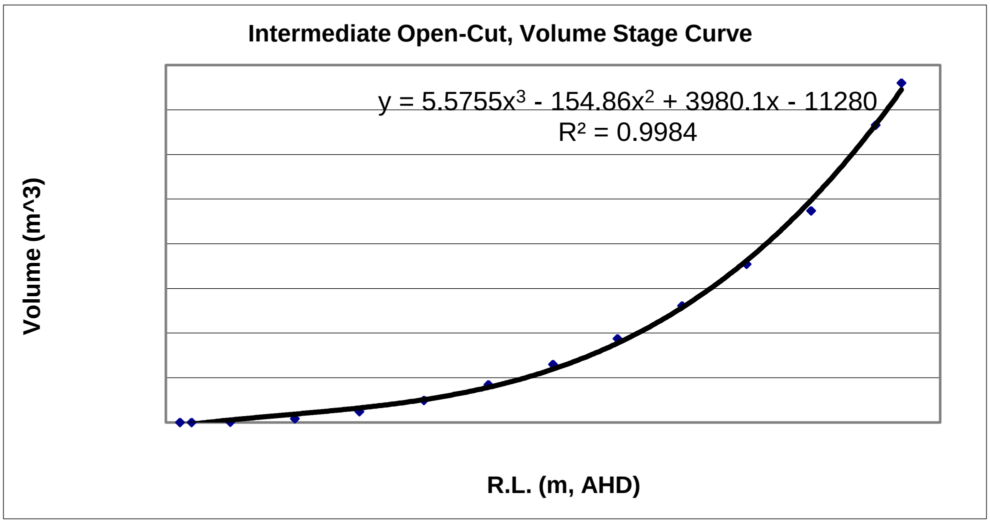
Source: Boland (2008)
Note: Sample dates: 25 June 2008 for the Main pit and 7 September 2008 for the Intermediate pit.

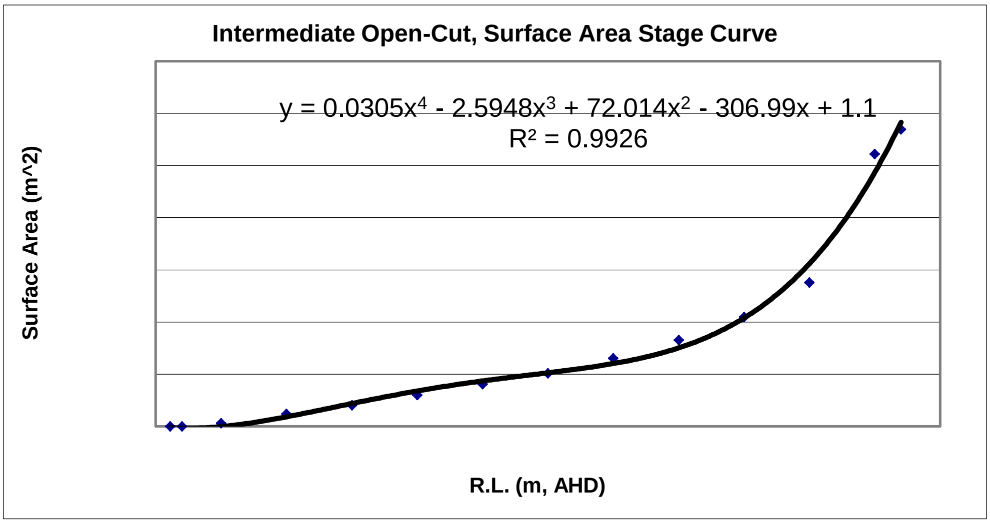




Source: Boland (2008)

Figure 6-12 Volume and surface area curves for the Main pit





Source: Boland (2008)

Figure 6-13 Volume and surface area curves for the Intermediate pit

Figure 6-14 and Figure 6-15 show the bathymetric contours for the Main and Intermediate pits.

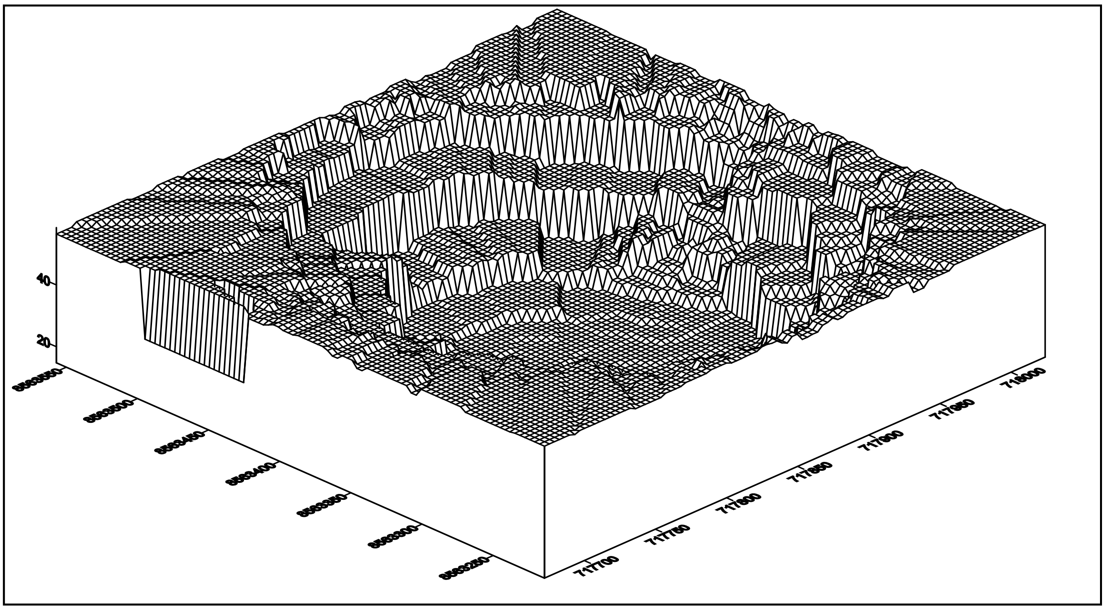


Figure 6-14 Wire-frame bathymetric approximation of the Main pit using the nearest neighbour method (Boland, 2008)

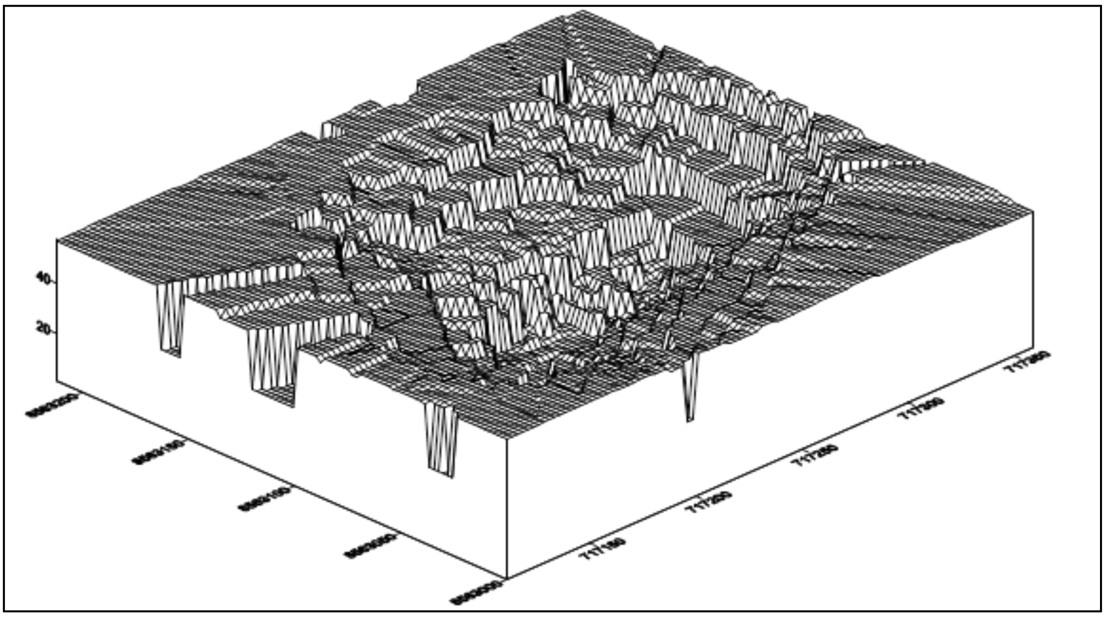


Figure 6-15 Wire-frame bathymetric approximation of the Intermediate pit using the nearest neighbour method (Boland, 2008)

6.6.2. Metal concentrations and mass

Boland (2008) found much lower concentrations of metals in the upper levels of the Main and Intermediate pits compared to data collected in 1998 and reported by Lawton and Overall (2002) (see Table 6-10). Knowing these concentrations is important for two reasons. Firstly they enable an assessment of the current potential of the pits as a source of contaminants to the Finniss River. Secondly, the concentration profile enables an assessment of the conditions under which water could be discharged from the pits if they were emptied before they are backfilled with waste rock.

Table 6-10 Comparisons of ranges of metal concentrations (mg/L) in the surface layers of Main and Intermediate pits in 1998 and 2008

Water body	Main		Intermediate	
Survey date	April 1998	May 2008	April 1998	Sept 2008
Depth (m)	0–32	0–36	0–35	0.5–40
Cu	0.10–3.10	0.095–0.120	0.20–1.10	0.064–0.071
Mn	0.30–17.00	0.72–0.82	0.37–9.75	0.493–0.518
Zn	0.04–0.42	0.05–0.10	0.02–2.01	0.032–0.036
Ni	0.06–1.01	0.07–0.08	0.08–1.83	0.074–0.077
Fe	0.46–0.87	0.44–0.74	0.02–25.00	0.160–0.380
Al	0.09–14.80	0.20–0.25		

Source: Boland (2008)

A 5.6 metre band of dense, highly contaminated and hydro-dynamically stable water overlies the bed of the Main pit (Table 6-11). From the water quality data through the water column, it was inferred that the vertical mixing of contaminants from depth with the upper levels of the water body was not as pronounced as in the mid-1990s. With the exception of iron, it appears that metal concentrations in this dense layer have not substantially changed since April 1998; however, the thickness of the layer appears to have substantially decreased. Although a wider 11.45 metre band of contaminated water is present at the base of the Intermediate pit, this water is of much better quality (almost two orders of magnitude) than the water found at the base of the Main pit.

Table 6-11 Total concentrations of selected metals in Main and Intermediate pits

Determinant	Al		Cu		Fe		Mn		Ni		Zn
UNITS	µg/L	mg/L	µg/L	mg/L	µg/L	mg/L	µg/L	mg/L	µg/L	mg/L	µg/L
Sampling depth	MAIN PIT										
Surface (~0.1m)	112	NA	95.2	NA	440	NA	729	NA	72.8	NA	23.9
5	163	NA	108	NA	700	NA	751	NA	74.1	NA	24.2
30	172	NA	110	NA	740	NA	756	NA	73.7	NA	23.9
36	214	NA	120	NA	1000	NA	823	NA	77.3	NA	25.7
41	>LWR	170	>LWR	38	>LWR	851	>LWR	219	>LWR	12.3	6200
43	>LWR	107	>LWR	26	>LWR	1160	>LWR	220	>LWR	10.4	5200
	INTERMEDIATE PIT										
0.5	49.2		64.4		160	NA	493	NA	76.4		35.5
20	65.4		71.3		280	NA	456	NA	73.8		31.8
40	112		70.1		380	NA	518	NA	76.7		32.2
47	30.4		70.6		>LWR	30.9	>LWR	12.5	349		35.5
51	25.9		64.6		>LWR	28.9	>LWR	12.6	343		33.6

Source: Boland (2008)
Note: Samples obtained 30 May 2008 and 7 September 2008 respectively. Cations and anions were analysed on filtered samples. '> LWR' denotes greater than Linear Working Range where concentrations were over measurement limits.

6.6.3. Radionuclide activity in pit water

The *Australian Drinking Water Guidelines* (NHRMC, 2004) and the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC, 2000b) for irrigation and livestock waters provide guideline values of 0.5 Bq/L for both gross alpha and beta activities (K^{40}-corrected)[5].

Boland (2008) found 'a significant decrease in overall radionuclide activity in the surface layer' of the Main pit between 1998 and 2008, with activity currently well below guideline values. Activity in the deep contaminated waters of the Main pit was also lower than in 1998, but radionuclide activity levels in this section of the water column remain orders of magnitude above the guideline values (Table 6-12). Radionuclide activity in the upper levels of the Intermediate pit is well below recommended guideline values, while levels in the deeper portion are above guideline values, but substantially less than the deep water in the Main pit.

Table 6-12 Radionuclide activity in samples taken from the Main and Intermediate pits in 2008

Sampling depth (m)	Alpha activity (Bq/L)	K40-corrected beta activity (Bq/L)
Main pit (30 May 2008)		
Surface (~0.1)	0.11 ± 0.01	0.19 ± 0.02
5	0.10 ± 0.01	0.26 ± 0.02
30	0.11 ± 0.01	0.15 ± 0.01
36	0.14 ± 0.02	0.23 ± 0.02
41	100 ± 10	120 ± 9
43	59 ± 6	72 ± 6
Intermediate pit (29 May 2008)		
Surface (~0.1)	0.08 ± 0.01	0.23 ± 0.02
15	0.08 ± 0.01	0.19 ± 0.02
31	0.11 ± 0.01	0.24 ± 0.02
Intermediate pit (7 Sept 2008)		
0.5	0.07 ± 0.01	<0.1
20	0.07 ± 0.01	<0.1
40	0.09 ± 0.01	<0.1
47	5.4 ± 0.9	0.18 ± 0.02
51	6 ± 1	0.24 ± 0.02

Source: Boland, 2008

[5] Total beta activity is corrected for the contribution of potassium-40, a natural beta emitter, which occurs in a fixed ratio to stable potassium. K is an essential element for humans ingested mainly from food, and is maintained at a constant level of intake. (NHMRC, 2011; NRMMC, 2011)

6.7. Hydrogeology

Early in the NPA process, it was clear from literature reviews and gap analysis that the data collation and knowledge of groundwater conditions at Rum Jungle stopped in 1988. Since then, no significant data collection or analysis of groundwater conditions has been undertaken. DME commissioned a detailed investigation into the groundwater conditions at the site. Given the complexity of this study, it was split into four discrete phases with each phase being informed by the outcomes of the preceding phase.

Rum Jungle features a network of 103 historic monitoring bores and 39 additional monitoring bores installed since 2010 (see Figure 6-16 and Figure 6-17 for drilling and final monitoring bore respectively). Most of the historic bores were installed during previous groundwater investigations, such as Appleyard (1983) and Salama (1985), and tend to be shallow and clustered together near the waste rock dumps.

Bores installed in 2010 are located mainly near the former copper extraction pad area or north of the central mine reach and were installed to delineate the extent of groundwater contamination across the mine site. Bores installed in 2012 are located near the East Finniss diversion channel and the copper extraction pad and are intended to:

- delineate the extent of highly contaminated groundwater related to historic heap leaching activities
- constrain the hydraulic characteristics of this area.

Figure 6-16 Drilling monitoring bore adjacent to East Finniss diversion channel

Figure 6-17 Monitoring bore adjacent to East Finniss diversion channel

Groundwater levels and groundwater quality conditions in a selection of bores are routinely monitored by the DME. Groundwater quality data is collected twice every year by the DME's Environmental

Monitoring Unit and groundwater levels are monitored monthly in the dry season and every two weeks during the wet season (see RGC, 2012b). The quality and flows of seepage from the waste rock dumps and Dysons backfilled pit are also regularly monitored.

The waste rock dumps and Dysons backfilled pit are the major sources of contaminants to groundwater and to the East Branch. The annual SO_4 load in the East Branch for 2010/2011 was about 3,400 tonnes (or about 10 per cent lower than the average SO_4 load in the mid-1990s). Annual loads of dissolved metals in the East Branch range from five tonne for copper and nickel to 24 tonne for manganese (see RGC, 2012a). The majority of these observed contaminant loads are explained by seepage from the waste rock dumps and from Dysons backfilled pit directly into the East Branch.

Substantial loads of contaminants are also delivered to shallow groundwater. Shallow groundwater near the waste rock dumps is, therefore, often characterised by high concentrations of SO_4 and dissolved metals. Dissolved metal concentrations further down-gradient of the mine site tend to be relatively low due to the high buffering capacity of the Coomalie Dolostone (see RGC, 2012b). The most impacted groundwater at Rum Jungle is under the former copper extraction pad between the Main and Intermediate pits. Groundwater in this area is characterised by very high metal concentrations that are thought to be derived from seepage (or 'liquor') lost during the copper extraction process (see RGC, 2012b).

Groundwater flow fields at Rum Jungle appear to have been significantly altered by the presence of the waste rock dumps and the flooded pits. The 'mounding' of groundwater levels near the Main waste rock dump are particularly interesting due to a combination of high recharge and the low-permeability Rum Jungle Complex under the Main waste rock dump and the lack of mounding near the Intermediate waste rock dump due to the permeable nature of the Coomalie Dolostone that underlies it (see RGC, 2012b). Another significant feature of local groundwater flow fields is the interaction between groundwater and the pits, which tends to act as a source of water to the bedrock aquifer in the dry season and sinks for groundwater during the wet season. These and other aspects of site hydrogeology are closely simulated by the numerical groundwater flow developed for Rum Jungle (see RGC, 2012b for more details).

6.8. Cover design

The performance of the covers constructed on the waste rock dumps during the 1980s to limit water and oxygen ingress has declined substantially over time (Taylor et al., 2003). This decline in performance is primarily the result of inadequacies in the original design. Current understanding of leading practice in cover system designs indicates that the layer thicknesses used in the 1980s' works were substantially less than what is required for sustainable long-term performance. Without intervention, performance of the existing covers will continue to decline over time and the contaminant loads emanating from the existing waste rock dumps will continue to have an unacceptable and adverse impact on the downstream environment. In addition, results from the mine model confirmed that the volumes of waste material onsite require an aboveground waste rock dump, even if both pits are selectively backfilled with waste with the highest potential to generate contaminants.

DME commissioned O'Kane Consultants Pty Ltd (OKC) to design conceptual cover and landform systems for waste rock dumps at Rum Jungle, including determining the availability of sufficient quantities of suitable construction materials within economic haul distances to construct the conceptual design.

Large quantities of borrow material were excavated from the site for the 1980's rehabilitation works, therefore it is unlikely suitable quantities of borrow material are available on site. As a result DME advised OKC to focus their search for cover material on adjacent land with potentially suitable geology. Approval to access land adjacent to Rum Jungle to determine the availability or otherwise of suitable construction materials could not be secured to date. As a result OKC was unable to characterise and quantify suitable construction materials as part of this study. The development of the conceptual cover and landform designs was therefore progressed based on the properties of materials available at other sites nearby with which OKC has had experience (e.g. Woodcutters rehabilitation). Is it important to emphasise that due to the lack of site-specific data, the designs and recommendations presented are conceptual.

Soil-plant-atmosphere numerical modelling was completed to evaluate performance of four cover system designs. The modelling was carried out to clarify the following aspects of cover performance:

- net percolation through the cover system; and
- emission of radon gas from a point source in the waste material to the surface of the cover system.

Each of the four cover systems evaluated were found to generate very different net percolation (NP) rates and will result in different contaminant loadings, which will affect downstream target concentrations. The seepage and contaminant transport modelling being undertaken as part of the site hydrogeology project (see section 6.7) will determine this final target net percolation rate and allow a single cover design to be selected. However, until suitable quantities of borrow material have been identified and characterised, the most likely design will still carry some uncertainty.

What could currently be concluded by OKC is that a full range of net percolations can be achieved based on materials that may potentially be available on site. The four cover systems evaluated were:

- Cover System #1 - 0.3 coarse surface material over 2 m non-compacted growth medium over waste rock material;
- Cover System #2 - 0.3 coarse surface material over 2 m non-compacted growth medium over 0.5 m compacted clay (poorly compacted or sub-optimal clay material) over waste rock material;
- Cover System #3 - 0.3 coarse surface material over 2 m non-compacted growth medium over 0.5 m compacted clay (quality controlled compaction of optimal clay material) over waste rock material; and
- Cover System #4 - 0.3 coarse surface material over 2 m non-compacted growth medium over GCL synthetic over 0.5 m compacted clay (quality controlled compaction of optimal clay material) over waste rock material.

The simulation results presented here represent a relatively flat area such as the plateau of a waste rock dump (WRD). Additional simulations are still to be completed to examine performance of a cover system on a sloping surface (OKC, 2013). The results of the modelling of the above cover designs over a 100-year climate database showed:

- Cover System #1 – High NP net percolation is predicted to range from 25% - 30% of average annual rainfall.
- Cover System #2 – Moderate NP net percolation is predicted to range from 10% - 20% of average annual rainfall.
- Cover System #3 – Low NP the net percolation is predicted to range from 5% - 10% of average annual rainfall
- Cover System #4 – Very Low NP is predicted to be <5% of annual average rainfall.

It was noted that the low and very low NP cover systems were modelled on a relatively flat surface were at a high saturation condition during the wet season. In order for these NP values to be valid, a robust, efficient drainage system would be required for the entire cover system landform to manage the high runoff rates (OKC, 2013).

Based on the current results of the numerical modelling, OKC (2013) could not recommend a single preferred conceptual cover design. However, based on OKC knowledge designing similar cover systems and taking current knowledge (or what is not known) into consideration; OKC expect the most likely suitable cover system to be Cover System #3. It should be noted that as more site specific data and design parameters become available, (specifically contaminant target concentrations and material characteristics) it is possible that the modelling may identify Cover System # 2 or #4 as the preferred design.

If the acceptable contaminant target concentrations are set at a low level or if the site specific materials are not suitable for cover system construction it will be more likely that modelling and risk assessment will indicate that Cover System #4 will be required. It should be noted that if target contaminant concentrations are set very low they may still not be achievable even with Cover System #4. However, if suitable site specific materials are available that could limit net percolation and manage gas transport to meet contaminant target concentrations (higher levels acceptable) then Cover System #2 could be sufficient.

Two options were considered for the final landform alternatives for WRDs. The first option would be to leave or construct landforms with appropriately armoured 1:1.5 (vertical:horizontal) side slopes at a maximum vertical height of 21 m. Erosion modelling undertaken by OKC identified that WRDs with 1:1.5 outer embankment slopes would require an armouring layer of a material with median diameter of 100 mm for long-term stability of batter slopes. To use finer-textured materials (such as topsoil) on the surface of the batters would require reshaping to reduce the slopes to either 1:3 or 1:4 depending on the site specific materials used for rehabilitation.

A revegetation plan was developed for Rum Jungle waste rock covers based on the development of self-sustaining native woodland comprising species found in analogous local undisturbed environments. Additionally, a conceptual performance monitoring plan was developed for the rehabilitated landforms.

6.9. Mine model

A mine model was required to determine the volumes of voids, waste dumps, water, and volumes of cover material needed as part of evaluating rehabilitation scenarios and providing cost estimates.

The objectives of the mine model were to:

- quantify the volumes of voids, waste dumps, water held in storages, and volumes of cover material required for rehabilitation scenarios
- accommodate different haul routes, transport, and distance options
- simulate the relocation of waste from existing locations to backfill voids or to consolidate to a single location
- identify the most efficient methods for material movement (e.g. loader, truck, conveyor)
- calculate excavation volumes and transport distances (including haul profiles) for movement of waste and cover materials
- calculate water movements and disposal to facilitate backfilling of voids.

Five rehabilitation scenarios were modelled as part of the mine model project. The details of each scenario are discussed in Section 7.

Key outcomes of the modelling were to verify volumes of waste stored onsite, as well as verify available volume of voids. The accuracy of the volumes of materials and voids is critical, because the rehabilitation scenarios rely heavily on the accuracy of this information for developing cost estimates of earthmoving.

Table 6-13 shows the volumes of waste rock and capacity of the voids (pits). New or re-shaped waste rock dumps onsite are required under all rehabilitation scenarios.

Table 6-13 Volumes of waste material and voids

Feature	**Area, ha**	**Volume, Mm^3**
Total waste rock volume, 5.41 Mm^3		
Main waste rock dump	31.5	3.24
Main North waste rock dump	3.9	0.03
Intermediate waste rock dump	8.4	0.56
Dysons waste rock dump	8.8	1.12
Dysons (backfilled) open pit*	6.0	0.46
Pit capacity, 2.57 Mm^3		
Main open pit	8.5	1.97
Intermediate open pit	3.0	0.60

* 0.9 Mm^3 of tailings in Dysons (backfilled) open pit are not included in this table, nor is the 0.9 Mm^3 of tailings in the Main open pit.

This modelling has allowed DME to take the rehabilitation scenarios from ideas through to concepts with a better understanding of the actual volumes required to backfill voids or to relocate waste to new locations, and the amount of borrow material required for new cover systems. The modelling has also helped to develop conceptual costing of the scenarios and detailed visualisations of the rehabilitation scenarios to simulate the landforms post-rehabilitation. A key attribute of the mine model is that it can be adapted and modified by DME to account for changes in rehabilitation scenarios.

6.10. Environmental values

A study of the environmental values downstream of Rum Jungle was commissioned in late 2012 to:

- describe the current condition of the downstream receiving environment's key ecological and geomorphic attributes
- identify environmental values
- propose water quality objectives in accordance with the ANZECC/ARMCANZ (2000b) methodology.

A review of available literature, a site visit, and discussions with relevant stakeholders, including the traditional Aboriginal owners representing both the Rum Jungle site and the downstream Finniss River system concluded that, while a substantial amount of environmental monitoring data had been collected over the years, there were also substantial data gaps.

This component of the baseline studies is a very important project because the water quality objectives could, if they are formally adopted, set the benchmark for extent of improvement in water quality that must be achieved by future site remediation works.

A monitoring program was also scoped to support application of the proposed environmental values and water quality objectives and to enable future development of locally derived water quality trigger values. A broad-brush impact assessment was also undertaken, involving a desktop data review, data from wet season (2012) snapshot sampling of waters and sediments, and proposals for longer-term monitoring programs and surveys. This impact assessment also incorporated feedback from stakeholders obtained during field consultation.

6.10.1. Current condition of environmental values

The East Branch and Finniss River have dynamic flow and sediment processes, including monsoonal and season rainfall, high rates of sediment delivery from an eroding mine landscape, a sand-bearing geology, and high groundwater connectivity. The rainfall record showed that the region has become wetter over recent decades. Combined with climate change and the proliferation of gamba grass, this higher rainfall indicates that rates of erosion and sediment transport have probably increased and may increase further with particular implications for large stores of sand in the lower East Branch river channel.

Water and sediment quality on the mine site have been relatively well studied and the rehabilitation of the mine site in the 1980s greatly improved the quality of discharges downstream and reduced contaminant loads delivered to the East Branch by factors of three to seven per annum. However, water quality in the East Branch was still above levels that could cause environmental impact as late as the 2000s. Sediments along the East Branch have contaminant concentrations above the ANZECC/ARMCANZ (2000b) sediment quality guidelines. There has been no reporting of the trends in continuing water quality monitoring data since reviews in the mid-2000s.

Notable studies of aquatic ecosystems were undertaken during the 1990s, which documented the status and recovery of water quality and aquatic organisms after rehabilitation started in 1983. But few studies reference riparian vegetation either during baseline studies, during the mine's life, or in the post-rehabilitation period. This lack of information makes quantitative impact assessment difficult, although massive dieback is known to have occurred. Despite ecological recovery in the East Branch, elements of the ecosystem remain highly impacted; condition is better in the Finniss River. A range of terrestrial fauna species, including threatened species, has been recorded in the area. Downstream, the Finniss River flows through the Finniss River Coastal Floodplain Site of Conservation Significance, which supports a number of listed threatened species.

6.10.2. Environmental values and water quality objectives

The full range of relevant environmental values needed to be identified for the Finniss system, using the ANZECC/ARMCANZ (2000b) framework. Cultural values were discussed with traditional Aboriginal owners. The traditional Aboriginal owners from both Rum Jungle and downstream, participated in this process and willingly gave their time to identify the cultural values of most importance to them. The health of the river, its ability to flow freely, the abundance and well-being of Totem and other culturally and spiritually significant organisms, and traditional foods are all particularly important cultural values to the traditional Aboriginal owners.

To help assign environmental values and water quality objectives, the Finniss system was divided into nine discrete zones based on geomorphic type, habitat, ecological condition, and extent of disturbance. The nine zones included four in the East Branch (between upstream of the mine and the Finniss River confluence) and five in the Finniss River (from upstream of the East Branch confluence to the estuary, including the site of conservation significance). The condition, environmental values, recovery potential, and, therefore, targets are variable along the river system.

The suite of identified environmental values are:

- aquatic ecosystems
- wildlife habitats
- primary recreation
- secondary recreation
- visual recreation
- cultural and spiritual values
- industrial use
- aquaculture
- drinking water
- irrigation
- stock water
- farm supply.

Not all values are relevant to each zone, except aquatic ecosystems and cultural and spiritual values, which are significant for every zone. The defined river zones and environmental values for each zone are in Appendix 3. Water quality objectives were developed for each zone, for each water quality parameter, by selecting the lowest ANZECC/ARMCANZ (2000) default trigger value identified for any environmental value in that zone. Trigger values were defined for water, sediment, soil quality, radiation parameters, and selected radionuclides. Water quality trigger values for copper, manganese, and zinc, which are characteristic of the site's metal solute fingerprint, are in Appendix 4.

6.10.3. Monitoring program to support environmental values and water quality objectives

A monitoring program has been designed to support development of locally derived water quality trigger values. The proposed monitoring program focuses on water quality; aquatic biota; tetrapoda (vertebrates other than fish); channel processes; riparian vegetation; and aquatic macrophytes. The program will encompass both upstream (reference) and downstream sites within each river zone that have previously shown some aquatic or riparian ecosystem impacts. Monitoring will extend to a point downstream where impacts have not been detected historically nor would be expected to occur into the future as rehabilitation progresses (River Zone 7). The monitoring program focuses on both compliance with the assigned water quality objectives and an assessment of the ecosystem status. Details of the proposed monitoring program are in Appendix 5. Implementation of this program is dependent on future funding.

Reporting and review is important to measure ecosystem response to progressive rehabilitation and, ideally, enable the extent of the program to be reduced as ecosystem conditions improve post-remediation.

6.10.4. Impact assessment

To address the more immediate concerns of stakeholders, a preliminary environmental impact assessment has been commissioned. This is a three-stage study consisting of:

1. a desktop review of environmental datasets to assess the suitability of existing data to use for the impact assessments
2. a 2012–13 wet season snapshot survey of water and sediment quality
3. a longer-term flora, fauna, and bush foods surveys.

The 2012–13 wet season sampling was initiated because a desktop review revealed a lack of recent data for aquatic ecosystem impact assessment for the river system downstream of the mine and also a lack of filterable metals (the most bioavailable fraction) data at key sites. The sampling program will collect a range of water quality parameters at reference and impact sites.

6.11. Flora and fauna

Following a literature review and gap analysis, a lack of contemporary site-specific data on flora and fauna was identified. Flora and fauna is an important consideration for rehabilitation planning as the presence of any endangered or protected species can influence the way in which rehabilitation is implemented and the environmental assessment processes needed before rehabilitation works can start.

Before 2002, knowledge of the flora at Rum Jungle and the surrounding Bachelor area was limited to landscape-scale mapping such as bioregions (Thackway and Cresswell, 1995); 1:1,000,000 scale vegetation units (Wilson et al., 1990); and old land resource surveys (Christian and Stewart, 1953). Broad-scale vegetation mapping was conducted in 2002 for the Browns Oxide Project, which included the Rum Jungle site (Metcalfe, 2002). This survey was repeated in 2005, but with a smaller study area excluding Rum Jungle (Egan, 2005). These two studies are the most detailed undertaken within and adjacent to Rum Jungle. The combined studies identified 327 species across 14 major vegetation communities (Metcalfe, 2002; Egan, 2005). Within Rum Jungle, eight vegetation types form the dryland communities, monsoon forests, and drainage areas (Table 6-14). Across both surveys, 33 introduced plant species were recorded, including significant weeds such as gamba grass (*Andropogon gayanus*); mission grass (*Pennisetum polystachion*); horehound (*Hyptis sauveolens*); sida (*Sida acuta, S. cordifolia*); mimosa; senna (*Senna obtusifolia*); and snakeweeds (*Stachytarpheta spp.*). Metcalfe (2002) recorded the protected plant *Cycas armstrongii* (recently accorded 'vulnerable' status), and suggests *Helicteres* sp. 'Glenluckie Creek' has the potential to occur, but requires seasonal surveys. Another threatened species, *Acacia praetermissa*, may also occur in the border area.

In a literature review of the area, Low (2001) lists several fauna studies in the greater region, dating back to the 1980s and focusing on other mines and pastoral resources. More recent datasets include surveys in Litchfield National Park and other regional pastoral stations. However, before 2002, few records are available for Rum Jungle. Most recently, the Browns Oxide Project included a broad fauna survey in the 2002 dry season, with a smaller study repeated in the 2005 wet season (EMS, 2005). The 2002 study included a selection of habitats within Rum Jungle and targeted terrestrial and semi-aquatic fauna.

Table 6-14 Major vegetation communities in the Rum Jungle study area

Vegetation community	Description
Eucalyptus tetrodonta/ E. miniata Open woodland	Open woodland to open forest with grassy understoreys and sparse mid-stratum layer occurring on shallow, gravelly soils on gentle side slopes and low hills.
Acacia auriculiformis communities Woodland to open forest	Woodland areas with *Acacia auriculiformis* dominant, including degraded or recovering monsoon vine-forest.
Eucalyptus tetrodonta/ E. miniata/ Erythrophleum chlorostachys Tall open forest to woodland	Dense, well-developed open forest and woodland with co-dominant to dominant Ironwood with Eucalyptus species, on deeper soils in upland areas.
Riparian corridor Woodland to open woodland	Narrow linear band of riverbank species on small incised drainage lines. Typically fringed by alluvial flats with sparse trees amongst dense grassland. Larger drainage lines with dense tree layer and mid-stratum of riparian species, with terraced banks and sandy levees merging with paperbark areas and extensive floodplain habitat.
Lophostemon communities Open woodland to grassland	Highly variable formation structurally and floristically. Varies from dense mono-specific stands of *Lophostemon lactifluus* fringing minor creeks to open woodlands with *Lophostemon* dominant on broad drainage ways. Occurs in association with *Melaleuca* (Paperbark), riparian species and scattered Eucalyptus.
Eucalyptus papuana/ Corymbia foeslcheana/ Melaleuca spp. Open woodland to grassland	Open woodland community on drainage ways and floodplain areas including degraded areas from previous mining and rehabilitation. *Eucalyptus papuana* common throughout with variable co-dominant canopy species.
Paperbark communities Woodland to open woodland	Paperbark communities dominated by *Melaleuca* spp. in seasonally wet areas.
Disturbed areas	Including old mines, borrow pits, rehabilitated areas and other exploration activities.

Source: As mapped by Metcalfe (2002)

At the time of the EMS surveys, the Browns Oxide site had similar vegetation communities to Rum Jungle (Metcalf, 2002; Egan, 2005) and it could be expected that similar fauna would also occur across the two sites. Over the two survey years, EMS (2005) documented 18 amphibians, 38 reptiles, 120 birds, and 33 mammal species. Introduced species included the cane toad (a recent arrival in 2005), domestic dog, feral pig, and feral cat. Seven threatened species were recorded in the area: Northern quoll (*Dasyrus hallucatus*); Partridge pigeon (*Geophaps smithii*); Red goshawk (*Erythrotriorchis radiatus*); Brush-tailed phascogale (*Phascogale pirata*); Black-footed tree rat (*Mesembriomys gouldii*); Pale field-rat (*Rattus tunneyi*); and Floodplain monitor (*Varanus panoptes*). Other species of conservation significance in the area are the migratory birds: Fork-tailed swift (*Apus pacificus*); Cicadabird (*Coracina tenuirostris melvillensis*); Swinhoe's snipe (*Gallinago megala*); White-bellied sea eagle (*Haliaeetus leucogaster*); White-throated needletail (*Hirundapus caudacutus*); Rainbow bee-eater (*Merops ornatus*); and Rufous fantail (*Rhipidura rufifrons*). It is expected that since the EMS (2005) report, the cane toad has had a significant impact on its predators, especially the Northern quoll and Floodplain monitor.

6.12. Data and information deficiencies and knowledge gaps

Identifying knowledge gaps is an important part of the rehabilitation planning process. Some high-priority knowledge gaps have been identified and articulated in commissioned consultancy projects. Many of these gaps have come to light as a result of the findings from the projects commissioned under the current NPA. This section identifies key knowledge gaps that require further work.

6.12.1. Flora and fauna

A study has been scoped for a detailed flora and fauna survey. This study is important for understanding both the impacts of further disturbance to the site, managing existing disturbed and regenerating areas, and for understanding the characteristics of sustainable, undisturbed ecosystems in the surrounding environment. The outputs from this work will inform the development of indicators of success for re-establishing the biological assemblages on the site, and providing the metrics for assessing the success of the biological component of the remediation program. A comprehensive flora and fauna survey may be needed if the proposed remediation program triggers an assessment under Commonwealth or Northern Territory Government environmental legislation. Initiation of this work is contingent on approval for Stage 2 of the NPA.

6.12.2. Aquatic impact assessment and local water quality guidelines

Stage 2 of the study investigating environmental values (Stage 1 is complete) must be implemented to develop locally derived water quality guidelines. Stage 2 should also include a downstream impact assessment to refine the rehabilitation designs so that environmental values are protected in the long term.

6.12.3. Gathering infiltration data on waste rock dumps

Substantially different infiltration estimates for the waste rock dumps and the backfilled pit have been detailed in this report. Rehabilitation planning requires better infiltration data to both assist with the design of covers for new dumps, as well as providing a baseline against which to assess the success of future remediation works. Water balances for proposed new landforms are also needed to predict the relative proportions of runoff versus infiltration to minimise the volume of contaminated seepage from these structures and also to minimise the surface erosion of covers.

The locations and volumes of suitable borrow materials will need to be identified. These parameters will be determined from the outcomes of the current cover design project, the mine model, and the optimisation process to choose the preferred rehabilitation option.

6.12.4. Revegetation plan

The proposed revegetation strategy will need to address how to establish resilient ecosystems so that threatening processes (fire, weeds, feral animals, and pests) do not lead to unsustainable groupings of vegetation on the proposed new landforms. A post-remediation monitoring and review process will be required to ensure that vegetation is sustainable. This post-remediation assessment will need to detect and rectify any sub-standard areas of revegetation as early as possible, so that appropriate intervention methods can bring them back on target. The revegetation plan, incorporating monitoring programs, will substantially draw on new knowledge from the (yet to be commissioned) flora and fauna study.

6.12.5. Weed control

Further trials will be required to develop effective and sustainable eradication or control programs for specific weeds that threaten sustainability of revegetation and the stability of the new landforms. A specific weed eradication trial has been initiated during the 2012 dry season to eradicate weed species (primarily Gamba grass) within the 20 hectare Borrow Area 5. The trial consist of repeated weed spraying over at least two seasons followed by direct seeding with native species of which seed collection has already commenced.

6.12.6. Radiological management plan

A radiological management plan will be required to guide and prioritise the reclamation and placement of material from the existing waste dumps when the preferred strategy is implemented. The plan will ensure higher radiation sources are buried deep in new repositories, as well as ensuring an appropriate level of protection for the onsite workforce.

6.12.7. Land uses

A review of land uses will be required as the design is finalised to bring together traditional Aboriginal owners' land use objectives for the rehabilitated landform and the practical implications of these objectives based on the information gathered for this document, the *Conceptual Rehabilitation Plan*.

6.12.8. Finalisation of the preferred remediation strategy

The preferred rehabilitation strategy identified by the NPA will require some fine-tuning as it moves from the concept stage through to detailed design. This fine-tuning will include drainage design, engineering, and geomorphic landform design because conceptual planning assumes certain slope angles. As planning for rehabilitation moves toward implementation, detailed design will need to address the long-term drainage stability aspects of new landforms. It will be important to determine where water will be directed off these landforms and how can the design ensure long-term stability. Cost estimations will also need to be refined as more precise design enables more accurate cost estimations. Trends in inflation and the availability of equipment and human resources will also need to be considered. These works are detailed in the proposed scope for Stage 2 of the NPA.

6.12.9. Employment for traditional Aboriginal owners

Future stages of the rehabilitation project will consider opportunities for employment for traditional Aboriginal owners that cannot be adequately addressed by the current conceptual stage of planning.

6.13. Knowledge management

6.13.1. Knowledge management principles

Knowledge is the key resource of most organizations in today's world. Managing knowledge effectively requires understanding of and attention to the concept of organizational knowledge rather than just the traditional notion of individual-centered knowledge. This shift can be addressed through the utilization of organizational core competencies that have proven themselves to be of value within many Member State (MS) organizations. (IAEA, 2006)

While the IAEA guidelines on knowledge management emphasise collection of data from active uranium mining operations, there are many principles that are relevant for legacy sites such as Rum Jungle. Also, the knowledge gained from this project is likely to be applied to other abandoned mine rehabilitation projects in Australia and elsewhere. The key knowledge management principles cover the dimensions of complexity, cost, timescale, cooperation, and education and training.

Complexity

In Australia, information about the rehabilitation of abandoned mines is very limited or hard to find. Comprehensive information about radiological condition is especially scarce owing to the multi-pathway exposure assessment required as part of the rehabilitation planning process. The physical, chemical, radiological, and biological interactions of materials, as well as sociological, economic, and political interactions must all be considered as a whole.

Cost

Largely due to complexity, creating a repository of well-documented and substantiated rehabilitation knowledge about the dual radiological and AMD issues at a site such as Rum Jungle is costly, as well as requiring substantial multi-disciplinary inputs.

Timescale

The period of time between the creation of knowledge and the use of that knowledge can be considerable. For example, the time between mining at Rum Jungle, the first rehabilitation project in the 1980s, and more recent site management and rehabilitation planning process has spanned many decades. Project information and the ability to access, interpret, and understand it must be been maintained to ensure consistency in community safety and ecological protection in line with project objectives.

Cooperation

Many individuals, organisations, and governments can legitimately contribute to and access the site's knowledge base. The information and data used, and the experiences, skills, and insights applied must be carefully monitored to guarantee robustness.

Education

Education and training are essential to create new knowledge and to apply it to emerging challenges. These challenges may be at Rum Jungle, elsewhere within the Northern Territory, or in other jurisdictions in Australia. There is also a global interest in what is happening at Rum Jungle from those working in rehabilitation and closure disciplines, given the iconic status that this site has occupied in the remediation field over many decades.

6.13.2. Knowledge management for the Rum Jungle rehabilitation project

To date, good historical management by both the Northern Territory and Commonwealth Governments has enabled the findings and original data from past projects and investigations to be re-visited and re-assessed as part of the current NPA planning process. Also, individuals with familiarity of the site's history and key stakeholders have been engaged early in the project planning process to provide an additional valuable perspective. Table 6-15 describes how knowledge is currently being managed to ensure it will be available for current and future planning, implementation, site management, and monitoring programs. It also needs to be a format that is suitable for communication of the findings and outcomes to the broader community. This comprehensive suite of components fits well within the IAEA framework for effective corporate knowledge management.

Table 6-15 Overview of knowledge management systems

Type of knowledge	Knowledge management
Historic reports	Electronic filing system and hardcopy
	Endnote database for all references material held by DME
Consultants reports	Electronic filing system and hardcopy
	Any GIS component is provided to DME as an ESRI-compatible project
Imagery	All hardcopy maps and images are digitised
	Historic aerial photography is digitised and mosaicked to form a single image
	Large images are stored electronically and uploaded to the web-based GIS platform
	Water quality information: HYDSTRA database – hydrological and weather information Oracle database – surface and ground water quality
Multimedia	Photographs stored digitally in electronic filing system
	High resolution video footage stored digitally in electronic filing system
	Web-based GIS: Site imagery from 2010, 1977,1963, 1954 and 1952 Administrative layers including site boundaries, cadastre and place names Aboriginal sacred sites and historic features Digital Elevation Model – 0.5m contour 2011 Weed distribution and density Vegetation and land Systems Roads and watercourses Site photographs with orientation, altitude and description www.coffeyspatial.com/rumjungle/
Website www.rumjungle.nt.gov.au	All project reports are accessible via the DME internet site
	Historic documents and images of significance
	Site maps, project plans, photographs and contact details
Meetings	All minutes digitised and stored in an electronic filing system
Email	All appropriate correspondence and email attachments stored in TRIM document management system

6.13.3. Succession planning

The Rum Jungle rehabilitation project is continuing to engage a range of consultants and expertise to ensure knowledge is shared by a large pool of experts. This process supports the ongoing knowledge base for the project, as well as taking succession planning into account. Within DME, there is a strategic overlap of key aspects of roles in the NPA so if key personnel are unavailable at any one time, the program of activities can continue. The involvement of key Commonwealth personnel also ensures knowledge is gained, maintained and communicated at that level of government.

7. Rehabilitation scenarios

7.1. Overview of options for the Conceptual Rehabilitation Plan

Chapter 1 details the objectives of the Conceptual Rehabilitation Plan. The plan encompasses objectives that fall into three main groups:

1. objectives set by Commonwealth and Northern Territory Governments embodied in the NPA
2. objectives set by the rehabilitation requirements for the site
3. objectives set by the traditional Aboriginal owners and the community.

The objectives are the basis for identifying and scoping of technical investigations, the design and execution of specific monitoring programs, and the focus for specification and assessment of potential options for rehabilitation work. The results of the technical studies detailed in Chapter 6 and a review of current leading practice rehabilitation methods in Australia and overseas were used to define five potential rehabilitation scenarios:

1. Scenario 1—Re-cover waste rock dumps in situ
2. Scenario 2—Backfill Intermediate and Main pits then consolidate remaining waste rock into the Main waste rock dump
3. Scenario 3—Backfill the Intermediate and Main pits and consolidate remaining waste rock into Dysons waste rock dump
4. Scenario 4—Backfill Main and Intermediate pits and consolidate waste rock in former tailings dam area
5. Scenario 5—Backfill Main Pit and leave the Intermediate pit as a lake.

In reviewing and comparing the various scenarios, it is useful to have a visual base map of the current layout and contours of the site. Figure 7-1 shows the current site conditions. Section 5.5 provides more details about the current site condition.

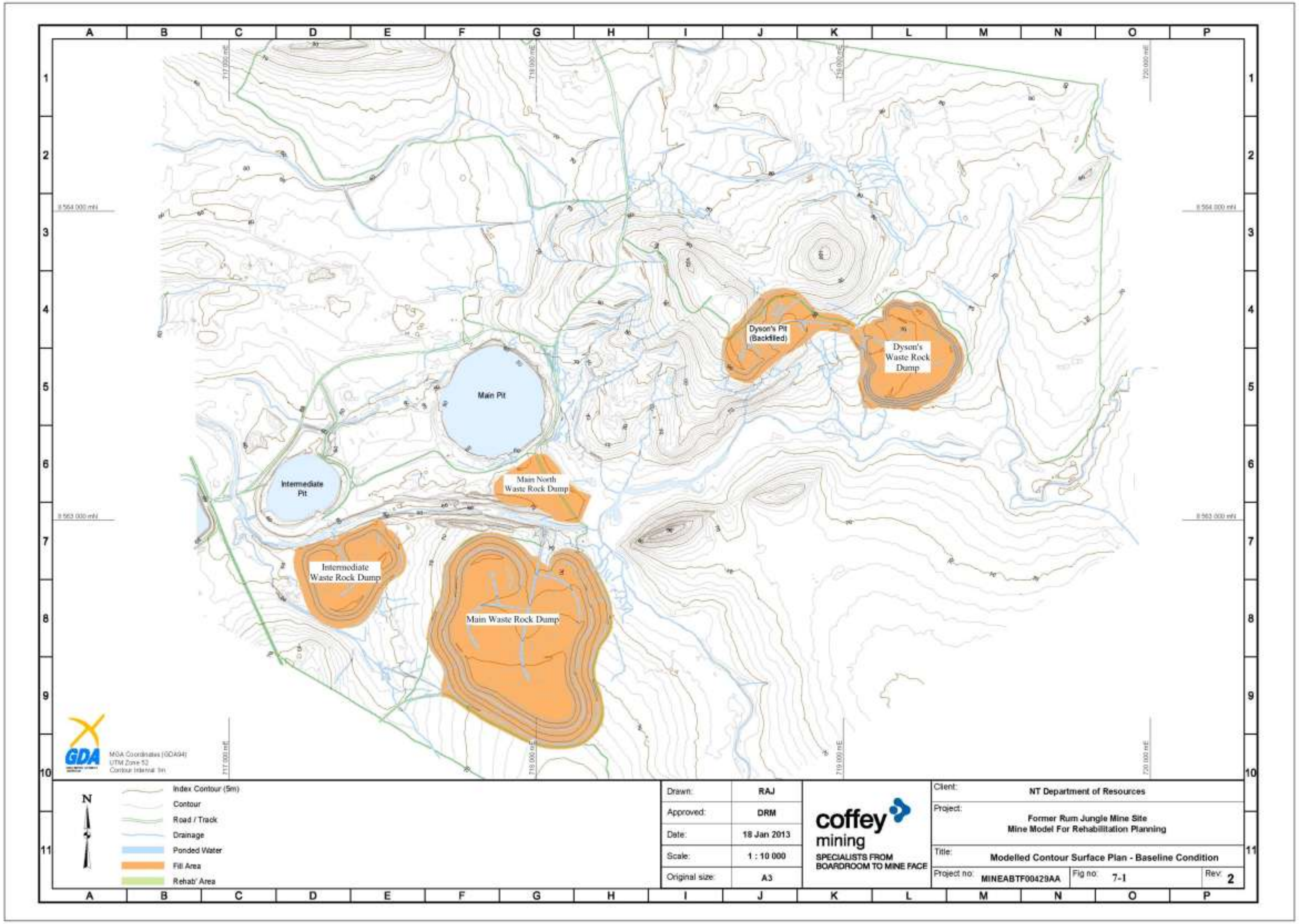


Figure 7-1 Current site conditions

7.2. Scenario 1—Re-cover waste rock dumps in situ

7.2.1. Description of Scenario 1

Scenario 1 focuses on constructing new cover systems over the existing waste landforms and does not involve any major relocation of waste materials. The primary objective of the new cover system is to reduce infiltration into the waste landforms to a pre-determined amount, reducing contaminated seepage. This scenario also includes clean-up of contaminated land. Figure 7-2 details Scenario 1.

7.2.2. Rationale for Scenario 1

The performance of the covers constructed on the waste rock dumps during the 1980s to limit water and oxygen ingress has declined substantially over time. This decline in performance is primarily the result of inadequacies in the original design. Current understanding of leading practice in cover system designs indicates that the layer thicknesses used in the 1980s' works were substantially less what is required for sustainable long-term performance. Without intervention, performance of the existing covers will continue to decline over time. As a minimum, the covers need to be repaired or replaced. The batter slopes of Dysons waste rock dump were not covered during the previous rehabilitation program, leaving reactive waste exposed. Scenario 1 includes completing the covers on the batters (slopes) of Dysons waste rock dump.

The following factors were considered in developing Scenario 1:

- If a waste rock dump is located close to a watercourse, the toe is cut back at least 25 metres to ensure that waste materials are not exposed to stream and flood flows. It is assumed that cut back material from Main and Intermediate waste rock dumps is consolidated into each waste rock dump.
- The batters of Dysons waste rock dump are cut back to reduce the batter angle, which is currently too steep to efficiently construct a cover system. The cut-back material is consolidated into the waste rock dump.
- The Main North waste rock dump is consolidated into the Main waste rock dump.[6]
- Leading practice designs for landform shape and covers are developed and implemented.
- A clean up of any residual contaminated soils on site is undertaken, with contaminated soil consolidated to the Main waste rock dump and the contaminated diversion drain cleaned up.
- The potential to use passive water treatment systems, including passive reactive barriers and wetlands to intercept and treat residual seepage, is investigated.

[6] As a general rule, any waste material less than 10 metre thick will be relocated due to the much higher unit costs associated with in situ rehabilitation of small contaminant sources.

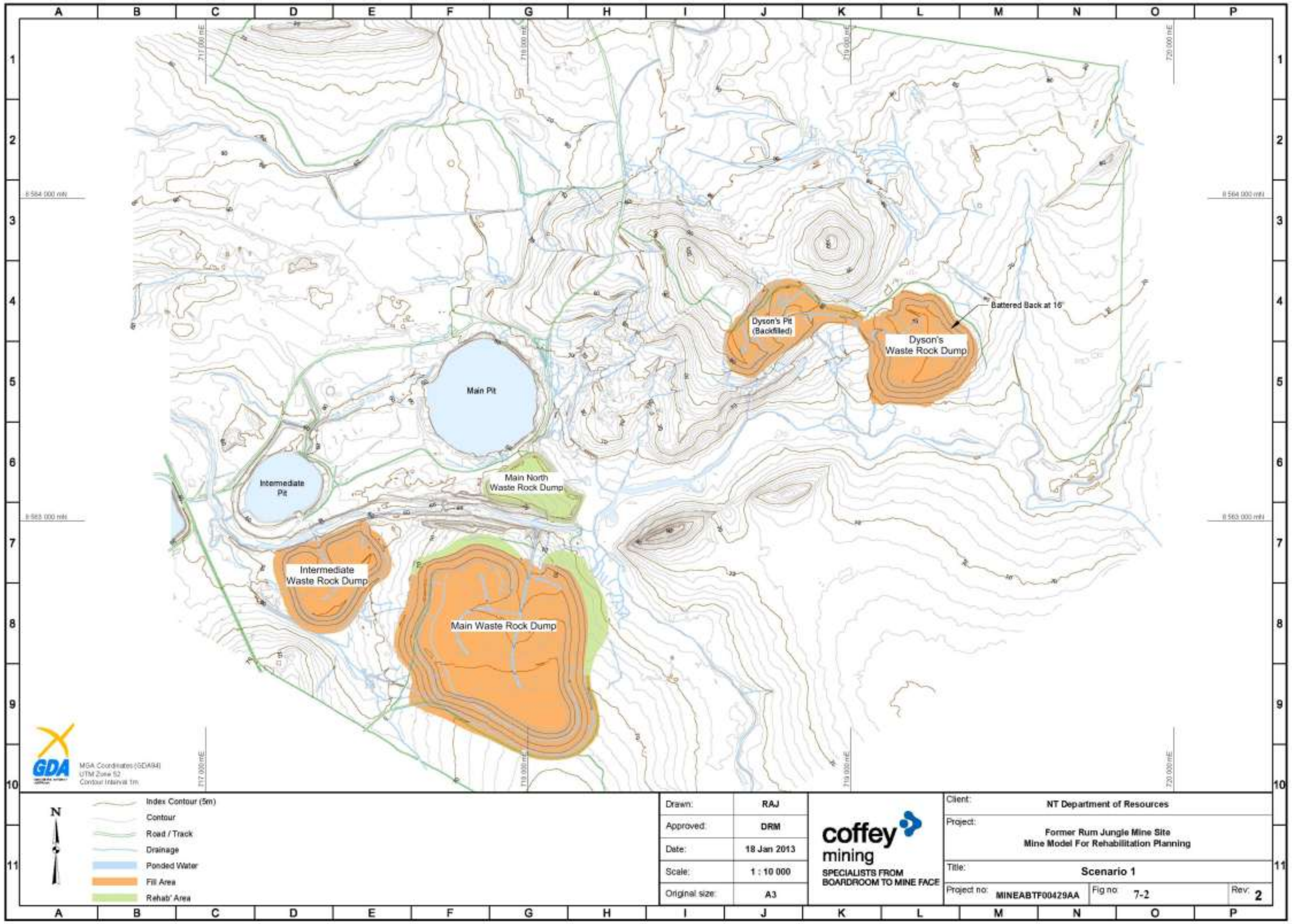


Figure 7-2 Scenario 1

7.3. Scenario 2—Backfill the Intermediate and Main pits and consolidate remaining waste rock into the Main waste rock dump

7.3.1. Description of Scenario 2

Scenario 2 involves backfilling the Main and Intermediate pits and consolidating and re-covering all residual waste rock into the Main waste rock dump. The key outcome of Scenario 2 is to substantially reduce the amount of waste rock stored at the surface. Figure 7-3 details Scenario 2.

7.3.2. Rationale for Scenario 2

Reactive sulfidic waste is currently stored on the surface. Relocating it back into the pits provides a secure, long-term storage option, based on leading practices applied elsewhere (Ayres, B.K. et al. 2007). Consolidating the remaining waste in a single location has the combined benefit of reducing the footprint of the surface landforms and minimising long-term management, maintenance, and monitoring by reducing the number of waste rock dumps.

The following factors were considered in developing Scenario 2:

- Refilling the two pits with relocated waste rock with the highest potential to generate contaminants (top of Dysons backfilled pit, Intermediate waste rock dump and some of the waste contained within the Main waste rock dump). This represents 48 per cent of the total volume of waste rock currently stored on the site.
- Lime is incorporated into the waste as it is backfilled into the pits. No further contamination of metals in groundwater is expected as a result of the incorporated lime. However, modestly elevated levels of SO_4 are expected in groundwater downgradient.
- It may be necessary to treat water pumped out when the pits are dewatered before they are backfilled. The layer of highly contaminated water at the bottom of the Main pit will be taken into consideration.
- The toe of the Main waste rock dump is cut back 25 metres, as a minimum, from watercourses (Fitch Creek and the diversion drain).
- The footprint of disturbance of the Main waste rock dump is increased to accommodate waste from Dysons waste rock dump and the Main North waste rock dump.
- Leading practice landform and cover designs are developed and implemented for the back-filled pits (Main, Intermediate and Dysons) and waste rock dumps. The landforms and cover design may include shallow-water covers for the back-filled Main and Intermediate pits. Revegetation of all covers follows leading practice principles. For example, the cover systems for the Main and Intermediate pits could be:
  - Shallow-water cover, which is a wetland or lake created through diverting creek flow across the surface of the backfilled pit. This option is dependent on the outcome of hydraulic modelling and may require diverting high flows through the diversion drain.
  - Dry cover, which is flush with the ground surface, or slightly mounded initially, with all catchment water flowing through the diversion drain.
  - Dry cover with a drainage line through the top of the cover, with high flows through the diversion drain.
- Landform design also accounts for the important cultural aspects of the landscape at Rum Jungle and, wherever possible, protects and reinstates them.

- Any residual contaminated soils located on the site are cleaned up, with the contaminated soil consolidated to the Main waste rock dump, including cleaning up the currently contaminated diversion drain.
- The potential to use passive water treatment systems, including passive reactive barriers and wetlands post-rehabilitation is investigated.

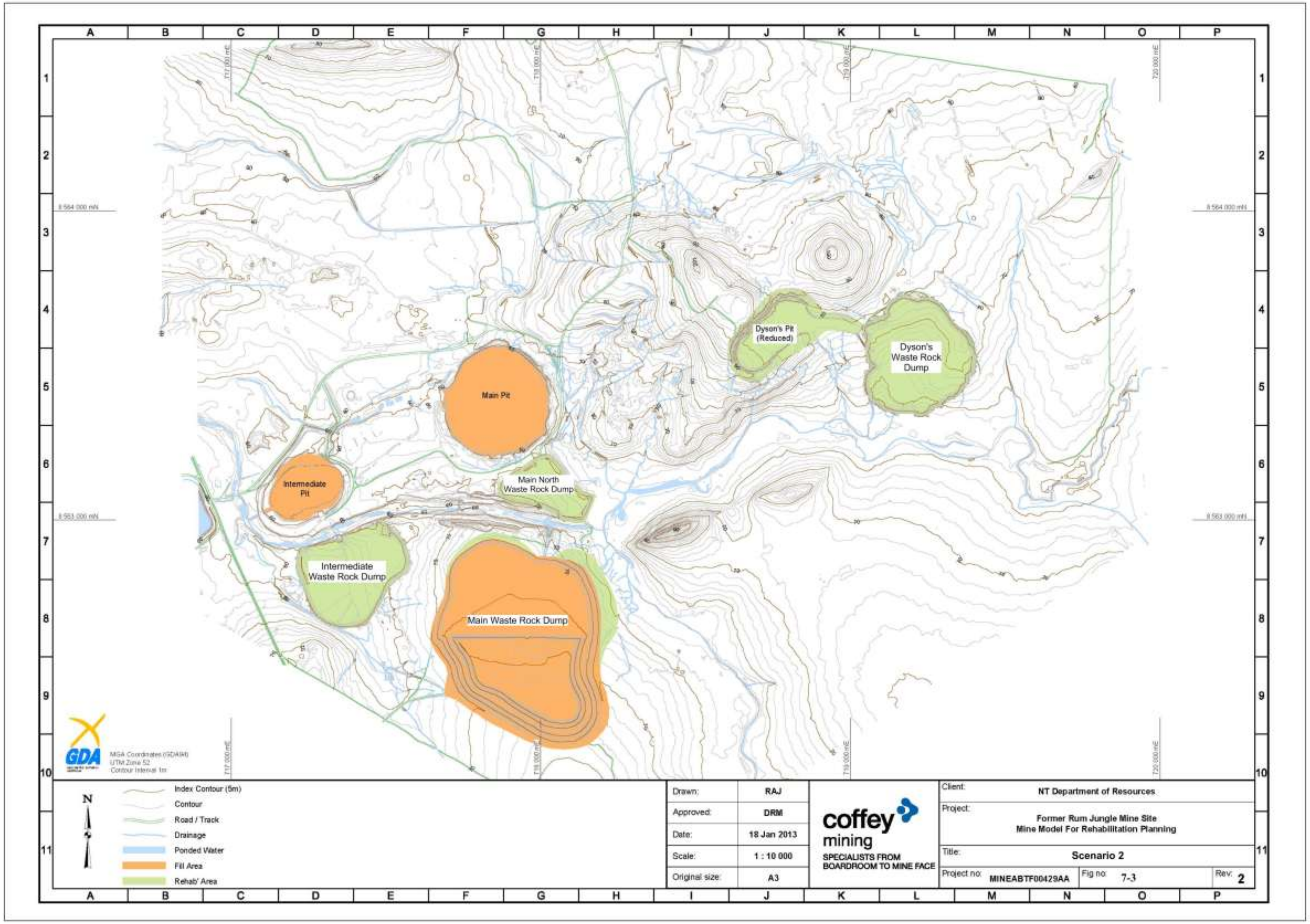


Figure 7-3 Scenario 2

7.4. Scenario 3—Backfill Intermediate and Main pits and consolidate remaining waste rock into Dysons waste rock dump

7.4.1. Description of Scenario 3

Scenario 3 involves the backfilling of Main and Intermediate pits and consolidating all remaining waste rock into Dysons waste rock dump and constructing a cover system over the waste rock dump. This approach is similar to Scenario 2; however, in Scenario 3, waste material from the Main waste rock dump is moved and consolidated into the Dysons waste rock dump area. Figure 7-4 details Scenario 3.

7.4.2. Rationale for Scenario 3

Reactive sulfidic waste is currently stored on the surface. Relocating it back into the pits provides a secure, long-term storage option, based on leading practices applied elsewhere (Ayres, B.K. et al. 2007). Consolidating the remaining waste in a single location has the combined benefit of reducing the footprint of the surface landforms and minimising long-term management, maintenance, and monitoring by reducing the number of waste rock dumps.

Relocating the residual Main waste rock dump material to the Dysons area removes the major contaminated seepage source, which is close to the diversion drain. However, due to the topology of this area, this scenario creates a large landform in the Dysons catchment, which may mitigate some of the benefits of this scenario.

The following factors were considered in developing Scenario 3:

- Refilling the two pits with relocated waste rock with the highest potential to generate contaminants (top of Dysons backfilled pit, Intermediate waste rock dump and some of the waste contained within the Main waste rock dump). This represents 48 per cent of the total volume of waste rock currently stored on the site.
- Lime is incorporated into the waste as it is backfilled into the pits. No further contamination of metals in groundwater is expected as a result of the incorporated. However, modestly elevated levels of SO_4 are expected in groundwater downgradient.
- It may be necessary to treat water pumped out when the pits are dewatered before they are backfilled. The layer of highly contaminated water at the bottom of the Main pit will be taken into consideration.
- The batters of Dysons waste rock dump are cut back to reduce the batter angle, which is currently too steep to efficiently construct a cover system. The cut-back material is consolidated into the waste rock dump. Where necessary, the toe of the waste rock dump is cut back 25 metres, as a minimum, from watercourses.
- The footprint of disturbance of Dysons waste rock dump is increased to accommodate waste from the Main waste rock dump and the Main North waste rock dump.
- Leading practice landform and cover designs are developed and implemented for the back-filled pits (Main, Intermediates and Dysons) and the waste rock dump. Landform and cover designs may include shallow-water covers for Main and Intermediate pits. Revegetation follows leading practice principles.
- Cover systems for the Main and Intermediate pits could be:

    - Shallow-water cover, which is a wetland or lake created through diversion of creek flow across the backfilled pit. This option is dependent on the outcome of hydraulic modelling and may require diverting high flows through the diversion drain..

  - Dry cover is flush with the ground surface, although it may be slightly mounded initially, with all catchment water flowing through the diversion drain.
  - Dry cover with a drainage line through the top of the cover with high flows through the diversion drain.

- Landform design also accounts for the important cultural aspects of the landscape at Rum Jungle and, wherever possible, protects and reinstates them.
- Any residual contaminated soils located on the site are cleaned up, with the contaminated soil consolidated to the Dysons waste rock dump, including cleaning up the currently contaminated diversion drain.
- The potential to use passive water treatment systems, including passive reactive barriers and wetlands post-rehabilitation is investigated.

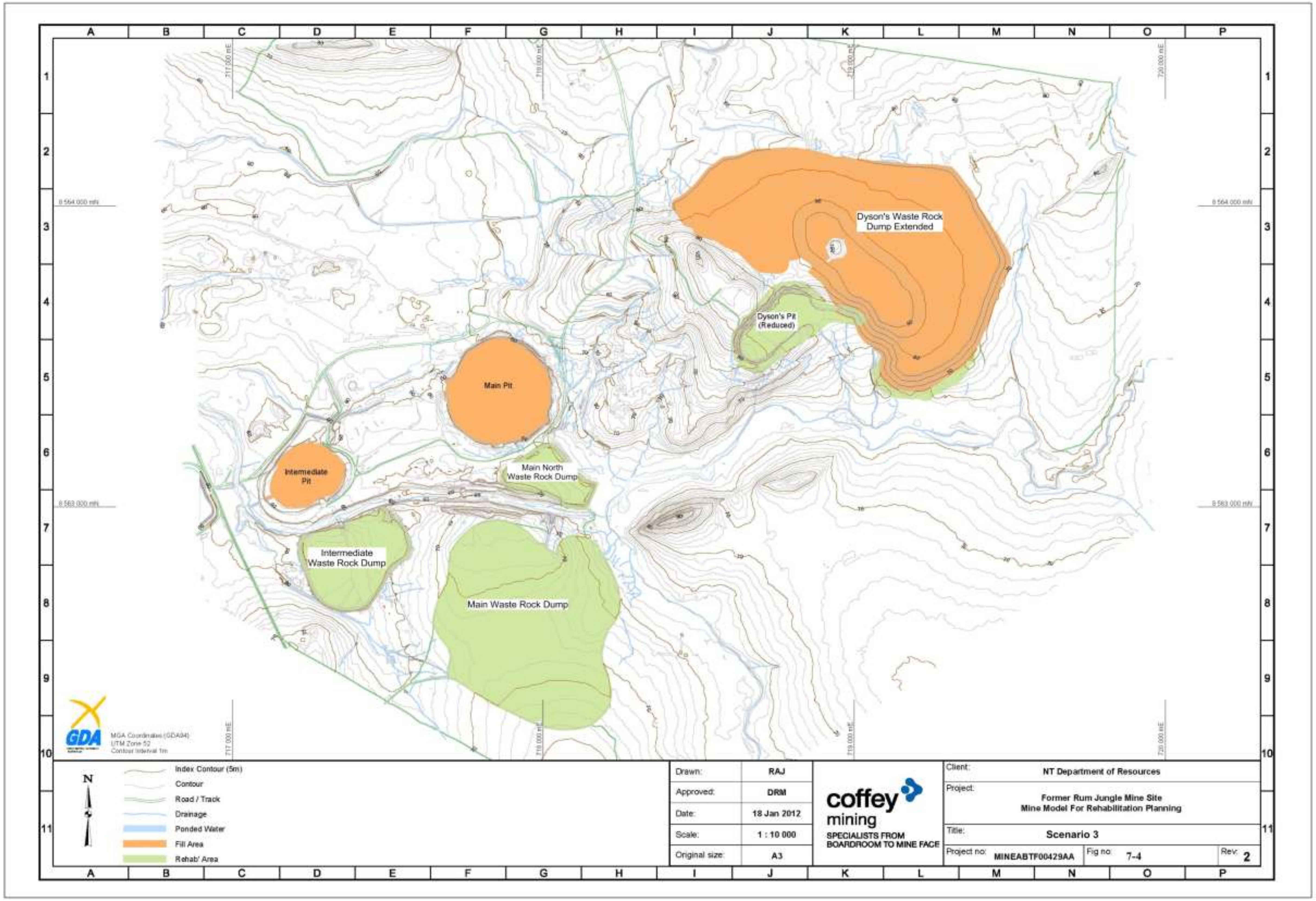


Figure 7-4 Scenario 3

7.5. Scenario 4—Backfill the Main and Intermediate pits and consolidate waste rock in former tailings dam area

7.5.1. Description of Scenario 4

Scenario 4 involves backfilling the Main and Intermediate pits and consolidating the remaining waste rock to a new facility constructed in the old tailings dam area north of Main Pit. Figure 7-5 details Scenario 4.

7.5.2. Rationale for Scenario 4

Reactive sulfidic waste is currently stored on the surface. Relocating it back into the pits provides a secure, long-term storage option, based on leading practices applied elsewhere (Ayres, B.K. et al. 2007). Consolidating the remaining surface waste in a single, new, purpose-built location reduces the number of landforms required, which reduces the amount of material and cost required to construct cover systems. Scenario 4 also minimises the long-term maintenance, management, and monitoring requirements. The traditional Aboriginal owners' desire to return the site, wherever practical, to its pre-mining topography is more fully accommodated by this scenario.

The following factors were considered in developing Scenario 4:

- Refilling the two pits with relocated waste rock with the highest potential to generate contaminants (top of Dysons backfilled pit, Intermediate waste rock dump and some of the waste contained within the Main waste rock dump). This represents 48 per cent of the total volume of waste rock currently stored on the site. The remaining waste rock is then consolidated into a new purpose built waste rock dump.
- Lime is incorporated into the waste as it is backfilled into the pits. No further contamination of metals in groundwater is expected as a result of the incorporated. However, modestly elevated levels of SO_4 are expected in groundwater downgradient.
- It may be necessary to treat water pumped out when the pits are dewatered before they are backfilled. The layer of highly contaminated water at the bottom of the Main pit will be taken into consideration.
- Leading practice landform and cover designs are developed and implemented for the in-filled pits and the waste rock dump, including an assessment of the type of liner system that may be required for the base of the new waste rock dump. Revegetation follows leading practice principles.
- Cover systems for the Main and Intermediate pits could be:
  - Shallow-water cover, which is a wetland or lake created through diversion of creek flow across the backfilled pit. This option is dependent on the outcome of hydraulic modelling and may require diverting high flows through the diversion drain..
  - Dry cover is flush with the ground surface, although it may be slightly mounded initially, with all catchment water flowing through the diversion drain.
  - Dry cover with a drainage line through the top of the cover with high flows through the diversion drain.
- Scenario 4 also accounts for the important cultural aspects of the landscape at Rum Jungle and, wherever possible, protects and reinstates them. Of the five scenarios considered, this one most comprehensively addresses the cultural aspects of the site.
- Any residual contaminated soils located on the site are cleaned up, with the contaminated soil consolidated to the new waste rock dump, including cleaning up the currently contaminated diversion drain.

- The potential to use passive water treatment systems, including passive reactive barriers and wetlands post-rehabilitation is investigated.

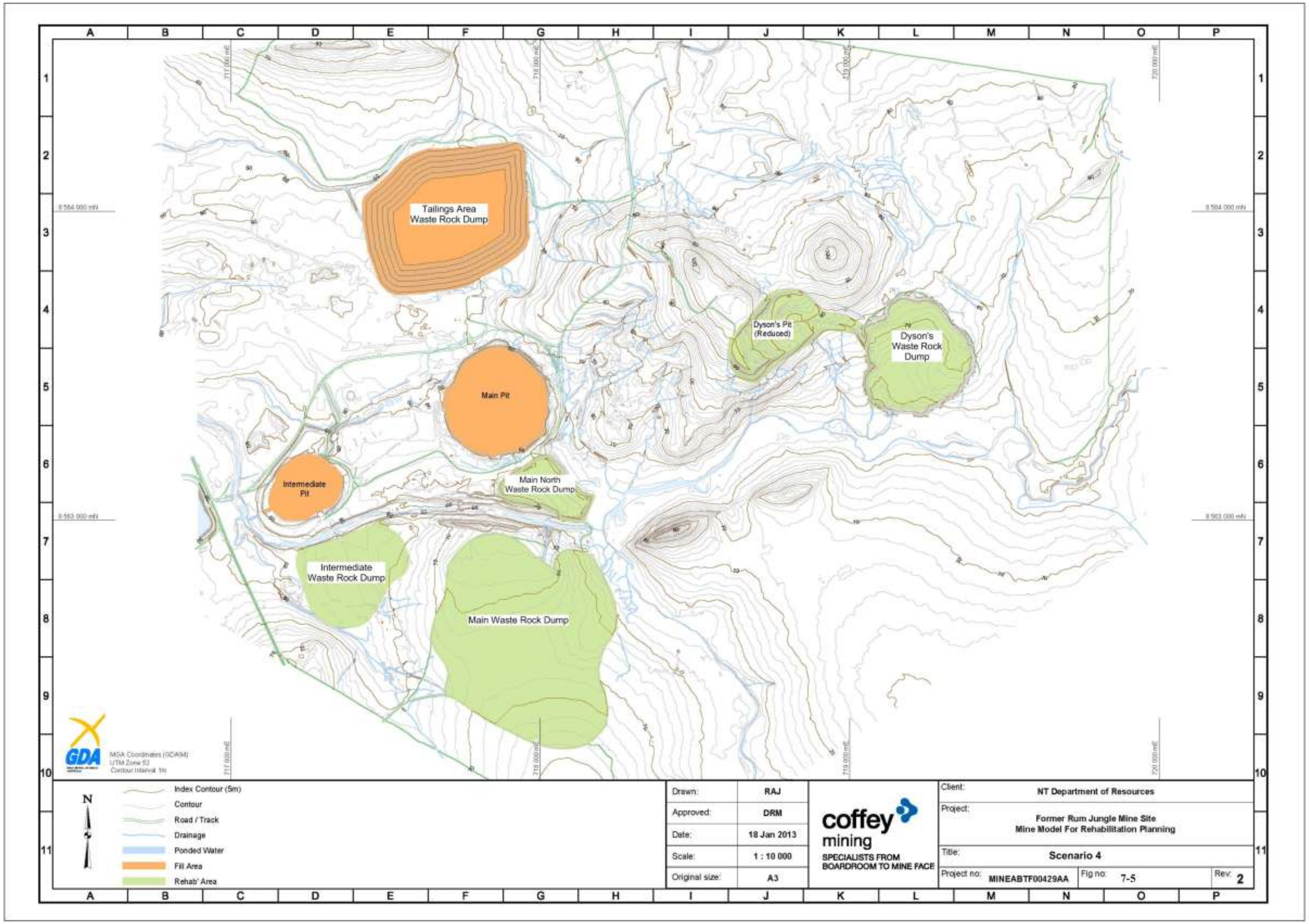


Figure 7-5 Scenario 4

7.6. Scenario 5—Backfill the Main pit and leave the Intermediate pit as a lake

7.6.1. Description of Scenario 5

Scenario 5 involves backfilling the main pit, leaving Intermediate pit as a lake and consolidating residual waste rock to the Main waste rock dump. Figure 7-6 details Scenario 5.

7.6.2. Rationale for Scenario 5

Scenario 5 reduces the volume of waste rock stored at the surface, but not by as much as in the scenarios where both pits are filled. Consolidating the remaining surface waste in a single location reduces the number of landforms, which reduces the amount of material required and the cost of constructing cover systems. Consolidating the surface waste also minimises the long-term maintenance, management and monitoring requirements.

As in Scenario 4, Scenario 5 also relocates some of the waste currently contained in waste rock dumps to the Main pit. However, in this scenario, the Intermediate pit remains as a water-filled void and more waste remains on the surface. The technical benefit of this scenario is that the water-filled void is a more effective buffer for diluting the first flush of contaminants at the start of each wet season. The void also provides a buffer for the lateral migration of contaminants into groundwater from the backfilled Main pit, and from the residual plume in the copper extraction area between the pits. The Main waste rock dump is then used as the consolidation location for the remaining waste rock on the site.

The following factors were considered in developing Scenario 5:

- Refilling only the Main pit with relocated waste rock with the highest potential to generate contaminants (top of Dysons backfilled pit, Intermediate waste rock dump and a small amount of the waste contained within the Main waste rock dump). This represents approximately 38 per cent of the total volume of waste rock on site.
- Lime is incorporated into the waste as it is backfilled into the pit. No further contamination of metals in groundwater is expected as a result of the incorporated. However, modestly elevated levels of SO_4 are expected in groundwater downgradient.
- It may be necessary to treat water pumped out when the main pit is dewatered and before they are backfilled. The layer of highly contaminated water at the bottom of the Main pit will be taken into consideration.
- Leading practice landform and cover designs are developed and implemented for the backfilled pits and the waste rock dump. Revegetation follows leading practice principles.
- The cover system for the Main pit could be:
    - Shallow-water cover, which is a wetland or lake created through diversion of creek flow across the backfilled pit. This option is dependent on the outcome of hydraulic modelling and may require diverting high flows through the diversion drain.
    - Dry cover is flush with the ground surface, although it may be slightly mounded initially, with all catchment water flowing through the diversion drain.
    - Dry cover with a drainage line through the top of the cover with high flows through the diversion drain.

- The important cultural aspects of the landscape at Rum Jungle are taken into account and, wherever possible, protects and reinstates them.
- Any residual contaminated soils located on the site are cleaned up, with the contaminated soil consolidated to the Main waste rock dump, including cleaning up the currently contaminated diversion drain.
- The footprint of disturbance of the Main waste rock dump will accommodate any residual waste material from Main North waste rock dump.
- The Dysons waste rock dump will be re-covered in situ.
- The potential to use passive water treatment systems, including passive reactive barriers and wetlands post-rehabilitation is investigated.

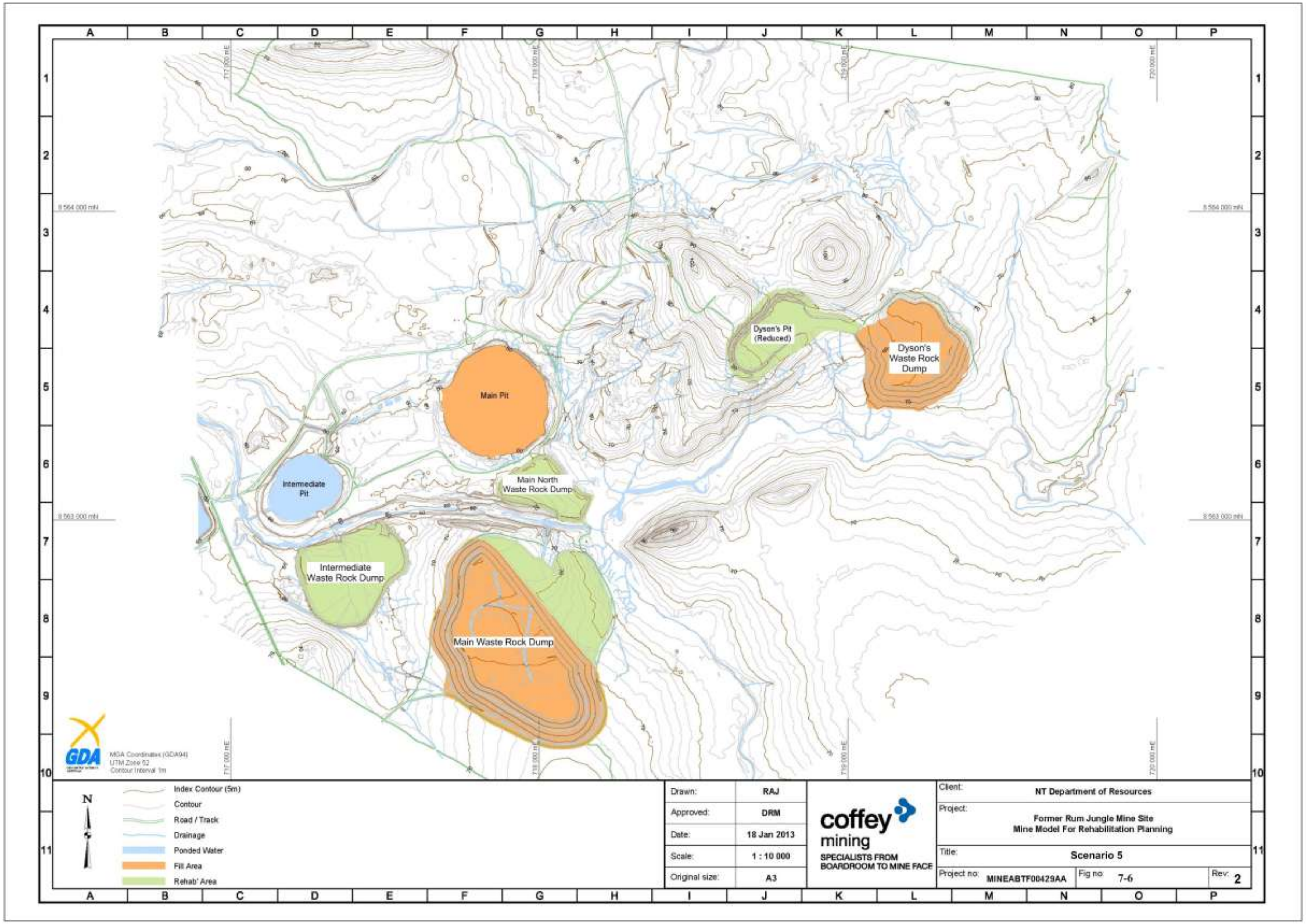


Figure 7-6 Scenario 5

7.7. Multiple Accounts Analysis results and preferred rehabilitation scenario

The proposed rehabilitation scenarios were evaluated using Multiple Accounts Analysis (MAA). MAA is a tool for evaluating different options or alternatives for a project, or specific components of a project, by weighing the relative benefits and costs (or losses) of a variety of independent factors (Shaw, et al. 2001). MAA is particularly useful when socio-economic considerations are a major component of a rehabilitation planning exercise, as well as technical and environmental dimensions. In the case of Rum Jungle, findings from a large number of multi-disciplinary and many single-discipline projects have to be considered, alongside diverse stakeholder perspectives. MAA is open and transparent and stakeholders can provide input to alternatives and to evaluate the alternatives in an objective and systematic way.

The MAA evaluation process was undertaken over five days in February 2013. Robertson GeoConsultants Inc. led the process, with input from the RJPT, the Rum Jungle Working Group, and traditional Aboriginal owners. The evaluation process focused on four key categories. The MAA process calls categories ‘accounts’:

- Predicted Environmental Performance Account
- Cultural Considerations Account
- Technical Feasibility Account
- Financial Cost to Implement the Scenarios Account.

Each account had a number of sub-accounts called ‘issues’. For example, minimising the potential for AMD is an issue relating to the Predicted Environmental Performance Account. Each issue was then further broken down into specific ‘indicators’ that clearly described the impacts of each issue. The performance of each scenario against every indicator was scored on a scale from 1–9, with 9 assigned the best performer and the remaining items scored relatively. However, the worst performing scenario was not necessarily assigned a value of 1. Each level of the MAA (account, issues, and indicator) was assigned a weighting (from 1–9), with the highest score of 9 assigned to the aspect judged by the group to be the most important contributor to a successful rehabilitation outcome.

The accounts, issues, and indicators were initially developed by consultation between DME and Robertson GeoConsultants. The accounts, issues, and indicators were further refined by the Rum Jungle Working Group and traditional Aboriginal owners as the workshop progressed through each account. An average was calculated for each issue. Table 7-1 shows the format of the MAA calculation spreadsheet.

Table 7-1 Format of Multiple Accounts Analysis

Accounts		Assessment Criteria				Alternative Rehabilitation Scenario					
Account	Account Weight	Issue	Issue Weight	Indicator	Indicator Weight	0 No Rehabilitation	#1 Re-Cover WRDs & Dyson's Landform	#2 Backfill the pits (consolidate to Main WRD)	#3 Backfill the pits (consolidate to Dyson's Area)	#4 Backfill the Main Pit (consolidate to Old Tailings Dam area)	#5 Backfill the Main Open Pit & re-cover *in situ*
Environmental	9	Minimization of Affected Areas	6	Additional contamination due to the re-location of WRDs	9						
				Removal of contaminated materials from affected areas	9						
				New borrow areas (for cover materials)	5						
				Issue Score:		0.0	0.0	0.0	0.0	0.0	0.0
		Minimization of AMD Potential	9	Overall effectiveness of control measures	9						
				Environmental impact sensitivity/assimilative capacity	5						
				Contaminant re-mobilization due to re-locating WRDs	7						
				Issue Score:		0.0	0.0	0.0	0.0	0.0	0.0
		Improvement in Surface Water Quality Conditions	9	Localized conditions within the rehabilitated mine area	6						
				Conditions in the East Branch of the Finniss River downstream	9						
				Potential for first flush exceedances	7						
				Issue Score:		0.0	0.0	0.0	0.0	0.0	0.0
		Increased Habitat Availability & Re-Vegetation	6	Aquatic habitat in creeks & water bodies (assuming water covers)	9						
				Improvement in downstream riparian & aquatic habitat	8						
				Re-vegetation by native species	7						
				Issue Score:		0.0	0.0	0.0	0.0	0.0	0.0
		Minimization of Groundwater Contamination	8	Contaminant loading to groundwater	9						
				Potential migration of groundwater from heap leach area	5						
				Issue Score:		0.0	0.0	0.0	0.0	0.0	0.0
				Account Score:		0.0	0.0	0.0	0.0	0.0	0.0
Cultural	9	Meets TO Land-Use Aspirations	7	Cultural use of aquatic resources	9						
				Reclaimed land for cultural use	9						
				Issue Score:		0.0	0.0	0.0	0.0	0.0	0.0
		Protects Culturally-Sensitive Areas	9	Locations & heights of the WRDs (female perspective)	9						
				Locations & heights of the WRDs (male perspective)	9						
				Issue Score:		0.0	0.0	0.0	0.0	0.0	0.0
		Improves Site Aesthetics	6	Overall appearance of the rehabilitated landscape	9						
				Issue Score:		0.0	0.0	0.0	0.0	0.0	0.0
		Maximizes Capacity & Opportunities for TO Employment	8	Employment & training opportunities during rehabilitation	9						
				Community infrastructure & long-term employment opportunities	9						
				Issue Score:		0.0	0.0	0.0	0.0	0.0	0.0
				Account Score:		0.0	0.0	0.0	0.0	0.0	0.0
Technical	7	Minimization of the Burden on Society	9	Long-term active management (based on residual footprint area)	9						
				Future risk	7						
				Issue Score:		0.0	0.0	0.0	0.0	0.0	0.0
		Technical Feasibility of Solution	9	Lime treatment during backfilling process	3						
				Seepage collection	9						
				Issues & feasibility of cover construction	9						
				Issue Score:		0.0	0.0	0.0	0.0	0.0	0.0
		Flexibility & Availability of Mitigation Strategies to Adaptive Management	4	Flexibility of solution to adaptive management after rehabilitation	9						
				Issue Score:		0.0	0.0	0.0	0.0	0.0	0.0
				Account Score:		0.0	0.0	0.0	0.0	0.0	0.0
				MAA Score:		0.0	0.0	0.0	0.0	0.0	0.0
				Overall Ranking:		6	5	3	4	1	2
Financial	-	Initial Capital Costs	-	Re-locating waste rock to another WRD	-	-					
				Re-locating waste rock to pits		-					
				Collection of contaminated soils (0.6 Mm³ assumed)		-					
				Installing cover system on the above-ground waste units	-	-					
				Construction of SIS (or liner)	-	-					
				Construction of water treatment plant	-	-					
				Lime costs	-	-					
				Project Management (assuming 30% of total capital costs)	-	-					
		Long-Term Monitoring and Maintenance Costs	-	Water treatment costs (for 30 yrs)	-	-	-	-	-	-	-
				Cover maintenance & repairs (for 30 yrs)	-	-	-	-	-	-	-
				Total Cost (in millions $AUS)		-	$0	$0	$0	$0	$0

7.7.1. Predicted Environmental Performance Account

The Predicted Environmental Performance Account considered issues including future potential for AMD generation, the impacts of AMD, and the assimilative capacity of the receiving environment. Improvements to water quality for both surface water and groundwaters, revegetation, and aquatic eco-systems and habitat availability were also considered. The Predicted Environmental Performance Account was assigned a weighting of 9, given the high value placed on addressing environmental issues as part of the rehabilitation planning process. Key findings for each scenario from MAA process for the Predicted Environmental Performance Account are summarised.

- Scenario 4 received a score of 8 out of 9 and was ranked the highest of the proposed scenarios. This scenario was considered particularly effective for improving surface water quality in the East Branch, limiting further generation of AMD, and minimising further groundwater contamination. Scenario 4 achieves these environmental outcomes by consolidating waste rock further away from the water courses than existing waste rock dumps, in a potentially lined facility in the old tailings dam area, and by treating seepage collected by the liner system. Furthermore, the site has a high assimilative capacity of AMD as it is underlain by neutralising dolostone resulting in reduced contaminant loading to the local groundwater aquifer.

- Scenario 2 scored a 6.6 and Scenario 5 scored a 6.9. Both these scenarios backfill one or both of the currently flooded pits and either consolidate and cover all waste on the Main waste rock dump (Scenario 2) or re-cover the residual waste rock in situ (Scenario 5). These scores were lower than Scenario 4 because of the likelihood of ongoing, albeit significantly reduced, contamination of groundwater and surface water from the existing unlined waste rock dumps.

- Scenario 1 and Scenario 3 scored less than 4.5. Scenario 1 installs new covers on the existing waste rock dumps and backfilled pit in the Dysons area. Scenario 3 backfilled the pits and consolidated and covered residual waste rock in the Dysons area. These scenarios scored poorly for environmental performance because they have a higher likelihood of ongoing contamination to surface water and groundwater due to the waste rock dump being unlined and located close to watercourses. Both the location and the unlined dumps create greater opportunities for ongoing AMD to the East Branch. Scenario 3, which consolidates waste rock in the Dysons area, was considered to be particularly problematic due to the very large footprint over several drainage lines, making any adaptive management strategy with seepage interception extremely difficult to implement.

7.7.2. Cultural Considerations Account

Addressing cultural issues and the post-rehabilitation land-use aspirations of the traditional Aboriginal owners are critical aspects that will contribute to the overall success of rehabilitating the site. After considerable discussion with the traditional Aboriginal owners during the MAA process, the Cultural Considerations Account was valued at a score of 9, the same score as the Predicted Environmental Performance Account. This weighting aligns with the high value DME placed on addressing cultural issues as part of the rehabilitation planning process. Key findings for each scenario from MAA process for the Cultural Considerations Account are summarised.

- Scenarios 1, 2, 3, and 5 that leave a residual waste rock dump near Fitch Creek, in the vicinity of the current Main or Intermediate waste rock dumps or relocated waste rock to the Dysons waste rock dump area were not well received by the traditional Aboriginal owners and were given scores of 5 or less. Under these scenarios, the waste rock dumps remain close to the most culturally sensitive areas onsite.

- Scenario 4 was overwhelmingly preferred by traditional Aboriginal owners, with a score 8.1 because waste rock was removed from, or not re-located to, the most culturally sensitive areas of the site and because implementing Scenario 4 would substantially improve surface water quality in the East Branch. The traditional Aboriginal owners had a very strong preference for restoring the pre-mining aesthetics of the land, including reinstating the original course of the East Branch by directing the river through a water cover or wetland system over the backfilled pits. Backfilling the Main pit was considered an absolute requirement of rehabilitation by the traditional Aboriginal owners, whereas backfilling the Intermediate pit is not a high priority.

7.7.3. Technical Feasibility Account

The Technical Feasibility Account considered elements of technical feasibility, engineering implementation and performance issues, and the future burden of the site on society (e.g. site stewardship, legacy management, and maintenance issues). Scenario 4 was ranked the highest with a score of 7.3. All the other scenarios scored 5.7 or less. The high score for Scenario 4 reflects the relatively small footprint a single waste rock dump would have in the old tailings dam area, and the expected ease that seepage could be captured and treated, if necessary. The long term risk of Scenario 4 is much reduced compared with other scenarios as a result of the capacity for ongoing adaptive management of mitigation strategies.

7.7.4. Financial Cost to Implement the Scenarios Account

In Financial Cost to Implement the Scenarios Account, the costs were estimated from the waste rock and pit volumes generated from the mine model (section 6.9) and estimates of current industry unit rates for major earthworks, such as re-locating waste rock and installing new covers. Lime costs for in-pit placement of waste rock and the cost of a liner for any new facility were also considered.

The potential need for a long-term water treatment plant was also considered. However, because the scenarios have only been developed to a conceptual level, further detailed work is required before a decision about water treatment can be made. One of the key technical components of Stage 2 of the NPA will be to determine whether there is a requirement for long term water treatment to reduce to acceptable levels the ongoing environmental risk posed by residual release of contaminants. Potential costs for seepage collection and treatment and long-term monitoring and maintenance costs have not been taken into account in the MAA.

7.7.5. Outcome of the Multiple Accounts Analysis

Based on the MAA, the preferred rehabilitation strategy needs to include backfilling of one or both pits with waste currently stored at the surface and consolidate the remaining waste into a single landform located as far away as practically possible from water courses. The conceptual rehabilitation strategy that addressed these requirements best is Scenario 4 which:

- backfills the Main and Intermediate pits
- relocates remaining waste rock from the Main and Dysons waste rock dumps to a new facility in the old Tailings dam area.
- The estimated capital cost of Scenario 4 is $109 million (in $AUD 2013) as outlined in Table 7-2.

Table 7-2 Summary of MAA Results for Rum Jungle

Account	Score or ranking	Alternative Rehabilitation Scenarios					
		0 No Rehabilitation	#1 Re-Cover WRDs & Dyson's Pit	#2 Backfill the pits (re-cover *in situ*)	#3 Backfill the pits (consolidate to Dyson's Area)	#4 Backfill the Main Pit (consolidate to Old Tailings Dam area)	#5 Backfill the Main Open Pit & re-cover *in situ*
Environmental (W=9)	Account Score	3.3	4.3	6.6	4.4	8.0	6.9
Cultural (W = 9)	Account Score	1.3	2.3	4.6	5.0	8.1	3.9
Technical (W = 7)	Account Score	4.3	3.9	5.4	3.3	7.3	5.7
Overall	MAA Score	2.9	3.5	5.5	4.3	7.8	5.5
	Ranking	-	5	3	4	1	2
Total Cost (in millions $AUS)		n/a	$64	$100	$113	$109	$79

Note: Scenarios are scored on a scale of 1 (worst) to 9 (best) for each account and then the scenarios are ranked based on the MAA score
W = account weight used to determine the MAA score

7.8. Context and limitations of the preferred rehabilitation scenario

The objective of Stage 1 of the NPA is that, 'through this Agreement, the Commonwealth and Northern Territory commit to improved management of the former Rum Jungle mine site consistent with the interests of stakeholders, particularly traditional Aboriginal land owners'.

The key outcomes of the NPA have been:

1. improved understanding of the current state of the environment
2. improved site management
3. development of an improved rehabilitation strategy for the site.

These key outcomes have been achieved through comprehensive technical studies, developing an understanding of traditional Aboriginal owner requirements, and investigating current leading practice rehabilitation methods.

The output of this three-year process is selection of a preferred conceptual rehabilitation strategy—Scenario 4—as the option that best meets the NPA and rehabilitation objectives. Selecting a preferred rehabilitation strategy has relied on the current state of knowledge about environmental processes and some key assumptions about water quality performance targets. The assumptions about water quality performance targets are based on a stepped process. Step one was to identify default water quality trigger values (ANZECC, 2000). Step two is the development of site-specific water quality trigger values. If required, step three is the development of trigger values based on ecotoxicological testing. Step one of this process has been completed (see Hydrobiology, 2013). However, step two (planned for Stage 2 of the NPA) will provide a much clearer understanding of the future water quality targets that will need to be achieved in the receiving environment. Finalising these targets will feed back to the level of performance needed from the engineering design elements of the waste rock dump and backfilled pits.

The cost estimates in this report have a substantial level of uncertainty. Detailed design work needs to be undertaken on the landform, cover, and liner systems for any waste rock dump facility to refine cost estimates to a sufficiently high level of confidence for formal budgeting.

There is a reasonably high level of confidence in the costs assumed for onsite movement of material. However, until the sources of material to construct the cover systems are identified and permissions and authorisations obtained, there is a lower level of confidence about the costs assumed for this component.

Acknowledging these cost caveats, sufficient information is available to frame the preferred rehabilitation strategy at a conceptual level, with a very clear plan to take this concept through to more detailed specification and design in Stage 2 of the NPA.

7.9. Ongoing site management and maintenance requirements

The current NPA expires on 30 June 2013; however, the site will continue to require a level of ongoing maintenance and monitoring regardless of any future remediation activities. A number of activities are needed to maintain the site and continue the collection of critical environmental data. Maintenance of the site in its current condition will not prevent the continuing decline in the performance of waste rock dump covers and the consequent increase in the pollutant load leaving the site.

The projected costs for the 2013/14 financial year for monitoring and site maintenance at Rum Jungle are estimated at $550,000, comprising three elements detailed in Table 7-3:

- site maintenance activities—$150,000
- environmental monitoring—$350,000
- traditional Aboriginal owner and other stakeholder consultation—$50,000.

The main site maintenance activities undertaken will be maintenance of access roads, repair of erosion control earthworks, and weed management.

An extensive network of monitoring and sampling equipment and data loggers is installed onsite, including an automated weather station. This equipment requires regular maintenance and data downloading. Environmental monitoring activities at Rum Jungle include surface and groundwater sampling and a recently implemented sampling program to determine water quality objectives, which includes sediment, biological, and geomorphological sampling (see Section 6.10.2). These monitoring activities will provide comprehensive baseline information to fill gaps in current knowledge and to refine the trigger values for each discreet river zone identified by the environmental values project.

Ongoing consultation with traditional Aboriginal owners and other stakeholders is a key component of the success of any future site management. The identified budget will allow an appropriate level of consultation to ensure maintenance and monitoring programs meet expectations and deliver suitable outcomes.

Table 7-3 Projected annual costs of ongoing management requirements after the National Partnership Agreements ends

Activity	Frequency
Site maintenance ($150,000)	
Earthworks, erosion control, and road maintenance	As needed (usually following the Wet Season)
Security, signs, and fences	As needed
Infrastructure maintenance and repair	As needed
Weed control of gamba grass and mimosa	Bi-annual
Fire management	Bi-annual
Environmental monitoring ($350,000)	
Groundwater (water quality)	Bi-annual
Groundwater (standing water level)	Fortnightly/Monthly (Wet/Dry Season respectively)
Gauge station—hydrology, physico-chemical, meteorological, telemetry (maintenance, sample collection, and data management)	Continuous
Run-off Monitoring – to determine infiltration estimates for current waste rock dump structures (maintenance, data collection and management).	Continuous
Water quality—gauge stations	Wet season
Water quality—grab samples for routine monitoring	Monthly during wet season
Water quality—grab samples for water quality objectives project	Monthly during wet season
Sediment, biological, geomorphology sampling	Bi-annual
Consultation ($50,000)	
Traditional Aboriginal Owner and other stakeholder consultation	Quarterly

7.10. Next steps for detailed design

Stage 2 of the NPA is the detailed design and construction documentation phase for the preferred rehabilitation strategy, Scenario 4. The proposed key components for Stage 2 include:

- detailed engineering design works, including supporting investigations
- scheduling arrangements including project management oversight
- preparation of detailed procurement packages
- ongoing site maintenance and monitoring.

Key aspects of the Stage 2 works are detailed in Table 7-4.

Table 7-4 Activity for Stage 2 of the National Partnership Agreement

Description	Timeframe
Engineering design including detailed drawings and specifications for the development of tender ready packages	
Dewatering voids	2013–14 to 2014–15
Upgraded diversion channel and water hydraulics modelling	2014–15 to 2015–16
Cover systems	2013–14 to 2015–16
Landform and erosion modelling	2014–15 to 2015–16
Contaminated soils clean up	2013–14
Passive/reactive barriers/wetlands and seepage interception systems	2015–16
Water treatment plant evaluation	2015–16
Geochemistry and lime supply analysis	2014–15 to 2015–16
Borrow Pit/s and material movement/sequencing	2015–16
Survey and photography	
Update aerial photography and DTM	Continuous
Update GIS	Continuous
Final design and construction surveys	2015-16
Management plans and approvals	
Flora and fauna surveys	Continuous
Conservation management plan	2013-14 to 2014–15
Radiation management plan	2013-14 to 2014–15
AAPA certificate for upcoming works	Continuous
Commonwealth & Northern Territory environment approvals	Continuous
Stakeholder engagement	

Description	Timeframe
Liaison Committee	Continuous
Rum Jungle Working Group	Continuous
Rum Jungle Stakeholder Advisory Committee	Continuous
Downstream traditional Aboriginal owners	Continuous
Groundwater	
Groundwater load balance calculations	Continuous
Hydrogeological assessment in old tailings area	2013–14 to 2014–15
Delineation of groundwater contamination in the copper extraction pad area	2014–15
Surface water including development of locally derived water quality guidelines	
Surface water monitoring of all sites	Continuous
Collection of 'first flush' data	Continuous
Biota sampling	Continuous
Rum Jungle Creek South	
Assessment of existing cover system	Continuous
Design of any remediation works, including detailed engineering drawings	2014–15 to 2015-16
Mount Burton and Mount Fitch	
Contaminated soil assessment and radiation survey	2013-14
Site maintenance	
Site management and maintenance works (security, fire)	Continuous
Weed management	Continuous
Revegetation trials of Borrow Area 5	Continuous
Upgrading of site access	Continuous

The proposed deliverables for Stage 2 are:

- detailed engineering design and construction scheduling for the preferred remediation option
- tender-ready procurement packages for the remediation works (Stage 3)
- any required environmental approvals for the proposed remediation works
- other relevant approvals including Aboriginal Areas Protection Authority, radiation safety, workplace health and safety plans
- locally derived water quality triggers representative of specific site conditions
- ongoing collection of critical environmental monitoring data including surface water, ground water, biota, and sediments
- improved understanding of the current state of the environment at Mount Burton and Mount Fitch
- revegetation trials of former Borrow Area 5, that will provide a pilot test for the works that will need to be conducted across the whole site
- site security and maintenance.

Continued engagement with key stakeholders, including the traditional Aboriginal owners of the site, downstream traditional Aboriginal owners, the Rum Jungle Working Group, and the Rum Jungle Stakeholder Advisory Committee will be maintained throughout Stage 2 to ensure the outcomes of the program meet technical and social objectives.

The activities outlined for Stage 2 need to be completed to determine the costs of the preferred rehabilitation strategy to a level of accuracy sufficient to be able to implement it with a high level of fiduciary confidence (Stage 3) and to ensure the environmental performance objectives will be met, consistent with stakeholder and regulatory expectations. The projected costs for Stage 2 are estimated at $11,288,000 over 3 years.

8. Conclusions

As part of the 2009-10 budget, the Commonwealth Government committed over $7 million over a four-year period for the environmental management of Rum Jungle (Commonwealth Government, 2009). To manage this commitment, the Northern Territory Government and the Commonwealth of Australia entered into NPA. This agreement sets out the objectives for site management and maintenance as well as the development of a *Conceptual Rehabilitation Plan*.

8.1 Conceptual Rehabilitation Strategy

The conceptual rehabilitation strategy presented in Chapter 7 is the culmination of all the technical investigations and stakeholder engagement activities undertaken to date.

Five potential rehabilitation scenarios for the Rum Jungle site were developed and assessed to evaluate how each scenario addressed the key rehabilitation objectives. These key rehabilitation objectives were developed through a comprehensive process of internal analysis of technical requirements and extensive consultation with stakeholders, including the two traditional Aboriginal owner groups. In summary the rehabilitation process should create a landscape which:

- is safe for people and wildlife
- is physically, chemically, and radiologically stable
- has a significantly reduced contaminant load (associated with AMD) travelling beyond the boundaries of the site
- supports sustainable land uses by traditional Aboriginal owners of the area with few, if any, limitations
- encourages beneficial alternative post-rehabilitation land uses.

The five scenarios evaluated ranged from re-covering the existing waste rock dumps and the Dysons backfilled pit in situ, to backfilling the two existing water-filled pits and relocating and consolidating the remaining surface material in a new waste rock dump. The five scenarios were evaluated using a formalised tool called Multiple Accounts Analysis (MAA). The MAA incorporates four major components that address the environmental, technical and engineering feasibility, socio-economic (including cultural aspects), and cost dimensions of each issue associated with the site. Each of the individual components contributing to these issues was scored on its relative perceived performance against relevant remediation objectives, and then weighted on its perceived importance in contributing to a successful remediation outcome. The MAA is an open and transparent framework for professional judgements and opinions to be discussed and debated along a path to achieving a consensus.

The outcome of the MAA was a clear preference for Scenario 4. The key components of Scenario 4 are: backfilling Main and Intermediate Pits and consolidating residual waste rock within a new facility constructed in the old tailings dam area north of Main pit. This scenario will substantially reduce the volume of waste rock stored above ground, with the remaining above ground waste contained in a new purpose-built facility at an optimised location. This scenario achieved the highest score for the environmental, technical, and stakeholder components of the MAA.

8.2 The next steps

The key outcomes of the NPA are: improved management and maintenance of the site, continuation and enhancement of the monitoring program, and the development of a preferred conceptual rehabilitation scenario. To progress from the conceptual scenario delivered by this report through the NPA into a package of works that is ready for implementation will require substantially more work. It is proposed that this additional work is carried out through an extension of the current NPA, referred to as Stage 2.

Activities undertaken during Stage 2 will advance the technical studies completed to date to the level of detail required to underpin the specifications for the rehabilitation program. Appropriate environmental approvals will also be obtained and detailed engineering design and costing completed to bring the proposed works to a tender-ready stage.

During Stage 2, the water quality objectives will be defined. This is the critical step required to specify the level of performance required by the engineering design elements of the waste rock dump and backfilled pits. The full program of works proposed for Stage 2 is presented in Section 7.10. Stage 2 includes provision for ongoing site management and maintenance works that will need to continue to ensure that the site at least maintains its current condition while detailed design progresses.

Completion of Stage 2 will deliver a rigorously designed and fully costed rehabilitation program ready for implementation during the construction phase. The projected costs Stage 2 is estimated at $11,288,000 over three years.

9. References

Chapter 1

Commonwealth of Australia. 1981. *Finniss River Land Claim – Report by the Aboriginal Land Commissioner*, Parliament of the Commonwealth of Australia, Parliamentary Paper No. 130/1981, 22 May.

Commonwealth Government. 2009. *Budget—Australia's Federal Relations Budget Paper No. 3 2009–2010*, May, Canberra.

Northern Territory Government Gazette. 1989. No. G40. 11 October.

Taylor, G. Spain, A. Nefiodovas, A. Timms, G. Kuznetsov, V. Bennett, J. 2003. *Determination of the Reasons for Deterioration of the Rum Jungle Waste Rock Cover*, July 2003.

Chapter 2

ARPANSA. 2002. *Recommendations for Limiting Exposure to Ionizing Radiation* and *National Standard for Limiting Occupational Exposure to Ionizing Radiation.* Radiation Protection Series No. 1. Accessed from: http://www.arpansa.gov.au/pubs/rps/rps1.pdf.

ARPANSA. 2005. *Code of Practice & Safety Guide Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing.* Radiation Protection Series No. 9. Accessed from: http://www.arpansa.gov.au/pubs/rps/rps9.pdf.

Chapter 3

GEP. 2010. *Rapport Final du Grpupe d'Expertise Pluralilste*. Access at: http://www.gep-nucleaire.org/gep/sections/travauxgep/rapports/.

IAEA. 2002. IAEA Safety Report 27 Monitoring and surveillance of residues from the mining and milling of uranium and thorium.

IAEA. 2003. IAEA Safety Requirement WS-R-3, Remediation of Areas Contaminated by Past Activities and Accidents.

IAEA. 2005. RPS No. 9 — Code of Practice and Safety Guide, Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing.

IAEA. 2009. *Establishment of Uranium Mining and Processing Operations in the Context of Sustainable Development*. Accessed from: http://www-pub.iaea.org/books/IAEABooks/8082/Establishment-of-Uranium-Mining-and-Processing-Operations-in-the-Context-of-Sustainable-Development/.

IAEA. 2010. Best Practice in Environmental Management of Uranium Mining (IAEA, 2010).

IBA-SEE. 2009. *Internationale Bauausstellung (IBA) Fürst-Pückler-Land, 2000–2010 project,* SEE Conference, September, Grossraeschen, Germany.

OECD. 2002. Environmental Remediation of Uranium Production Facilities.

Paul, M., Mann, S., and Jakubick, A. 2009. *Environmental clean-up of the East German uranium mining legacy: The WISMUT remediation program*, presented at 8th ICARD June, Sweden.

Paul, M. 2012. *The Wismut Program—state and challenges*, presented at UMREG, Uranium Mining Rehabilitation Environmental Group, meeting Vienna, October (unpublished report).

Paulka, S. 2009. Nabarlek-Legacy Environmental Challenges for Brownfield Exploration. *AusIMM International Uranium Conference 2009*, 10–11 June, Darwin. AusIMM. Melbourne *(Powerpoint and abstract only)*

Pearman, G. 2009. *101 things to do with a hole in the ground*, Eden Project Post-Mining Alliance.

RET. 2011. A guide to leading practice sustainable development in mining, leading practice sustainable development program for the mining industry, 2011. Accessed on 16 March 2013 from: http://www.ret.gov.au/resources/Documents/LPSDP/guideLPSD.pdf
SSD. 2010. *2009–2010 SSD Annual Report.*

Turner, K., Jones, D., & Humphrey, C. 2009. *Changes in water quality of Rockhole Mine Creek associated with historic mining activities.* Internal Report 560, June, Supervising Scientist, Darwin. Unpublished paper.

UMREG. 2011. The Uranium Mining Remediation Exchange Group Selected Papers 1995–2007.

UNDP, UNEP, OSCE, & NATO. 2005. *Mining for Closure, Policies and Guidelines for Sustainable Mining Practice and Closure of Mines.*

Unger, C. 2010. *The James Love Churchill Fellowship to study leading practice abandoned mine rehabilitation and post-mining land use projects.* Accessed from: http://www.churchilltrust.com.au/site_media/fellows/UNGER_Corinne_2009.pdf.

Waggitt, P. W. 1996 Hazard reduction works in the upper South Alligator valley. Proceedings of the SPERA Specialist Workshop *Radiological aspects of the rehabilitation of contaminated sites (RARCS),* Jabiru NT 20–22 June.

Waggitt, P.W. 2000. Nabarlek uranium mine: From EIS to decommissioning, in *Proceedings, URANIUM 2000—International Symposium on the Process Metallurgy of Uranium*, Saskatoon, Canada 9–15 September 2000. Pub. Canadian Institute of Mining, Metallurgy and Petroleum, Montreal, Canada.

Waggitt, Peter W. (2004) Uranium mine rehabilitation: the story of the South Alligator Valley intervention. *Journal of Environmental Radioactivity, Volume 76, Issues 1-2, 2004, Pages 51-66.*

Waggitt, P. and Fawcett, M. 2008a. Uranium mine rehabilitation in the Gunlom Land Trust, Northern Territory. *The AusIMM Bulletin*, May/June 2008, Australasian Institute of Mining and Metallurgy, Melbourne.

Waggitt, P (2009). Uranium Stakeholder engagement in Northern Australia, in proceedings *International Symposium on Uranium Raw Material for the Nuclear Fuel Cycle - Exploration, Mining, Production, Supply & Demand, Economics and Environmental Issues (URAM–2009),* 22–26 June, IAEA, Vienna.

Wismut (2011). *Remediation of Uranium Mining and Processing Sites-Sustainability and Long-Term Aspects.* Proceedings of a seminar (WISSYM 2011), 25–26 May, Gera, Germany. Pub. Wismut GmbH, Chemnitz.

Chapter 4

Ahmad, M., Lally, J.H. and McCready, A.J. 2006. *Geology and Mineral Deposits of the Rum Jungle Mineral Field*, Report 19, Northern Territory Geological Survey.

Australian Bureau of Statistics, 31 July 2012, 3218.0 Population Estimates by Local Government Area, 2001 to 2011, Estimated Resident Population, Local Government Areas, Northern Territory, accessed 14 November 2012 from:
http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/3218.02011?OpenDocument

Bastin, G. and ACRIS Management Committee. 2008. *Rangelands 2008 — Taking the Pulse*. Published on behalf of the ACRIS Management Committee by the National Land and Water Resources Audit, Canberra.

Bollhöfer, A., Doering, C., Fox, G., Pfitzner, J., & Medley, P. 2012. *Assessment of the radiological exposure pathways at Rum Jungle Creek South (Rum Jungle Lake Reserve)—Batchelor*. Environmental Research Institute of the Supervising Scientist, Department of Sustainability, Environment, Water, Population and Communities, Darwin, NT.

Bureau of Meteorology. 2012. *Online Climate Data from the Australian Bureau of Meteorology*. Accessed from: www.bom.gov.au/climate.

Bureau of Meteorology. 2012a. *Climate Classification Maps*. Accessed on 5 December 2012 from: http://www.bom.gov.au/jsp/ncc/climate_averages/climate-classifications/index.jsp.

Bureau of Meteorology. 2012b. *Climate change in Australia*. Accessed on 4 December 2012 from: http://www.climatechangeinaustralia.gov.au/nttemp34.php.

Coomalie Community Government Council, 2012, History, accessed 14 November 2012 from: http://www.coomalie.nt.gov.au/index.php/our-community/history

CSIRO and Bureau of Meteorology. 2012. *State of the Climate 2012*. Accessed on 4 December 2012 from: http://www.csiro.au/State-of-the-Climate-2012.

Davy, D. R. 1975. *Rum Jungle Environmental Studies*, Australian Atomic Energy Commission report. September.

Department of Lands, Planning and Environment. 2000. *Coomalie Planning Concepts and Land Use Objectives*, NT Government, Darwin.

Government Gazette. 1973. *Commonwealth Government Gazette,* No. 143, 3. 11 October 1973.

Harrison, L., McGuire, L., Ward, S., Fisher, A., Pavey, C., Fegan, M. and Lynch, B. 2009. *An inventory of sites of international and national significance for biodiversity values in the Northern Territory*. Department of Natural

Kvasnicka, J. 1986. *Rum Jungle Creek South Uranium Mine: present radiological impact and rehabilitation proposal*. Northern Territory Department of Mines and Energy, Darwin, Northern Territory.

Kvasnicka, J, Li C-C & Robinson R 1992. Rum Jungle Creek South abandoned uranium mine: uranium fields before, during and after the site rehabilitation. Environmental Technical Report 92/2, Mines Environment Directorate, Northern Territory Department of Mines and Energy, Darwin NT.

McCready, A. J. and Stumpfl, E.F. 2004. Polymetallic Mineralization at the Browns Deposit, Rum Jungle Mineral Field, Northern Territory, Australia. *Economic Geology,* Vol. 99, pp. 257–277.

North Australian Fire Information website. 2012. Northern Territory Government, Charles Darwin University, Geoscience Australia, Landgate, Bushfires Northern Territory. Accessed on 30 November 2012 from: http://www.firenorth.org.au/nafi2/.

NRETAS. 2008. *Weed all about it*. NT Government newsletter, Issue 7, November 2008.Resources, Environment, The Arts and Sport, Darwin, Northern Territory.

Department of Natural Resources, Environment, the Arts and Sport. 2011. *Information for the Public, Guidelines for Preparation of an Environmental Impact Statement, Area 55 Oxide Project*, HNC (Australia) Resources Pty Ltd. Accessed 14 November 2012 from:

http://www.nretas.nt.gov.au/__data/assets/pdf_file/0017/14714/draft_eis_guidelines_area_55_part_a.pdf.

NT NRM Infonet website. 2012. *Territory Natural Resource Management.* Charles Darwin University, Natural Heritage Trust, Northern Territory Government. Accessed on 30 November 2012 from: http://infonet.cdu.edu.au/nrm.

Price, O. and Baker, B. 2003. *A natural resource strategy for Coomalie sub-region – draft for public comment.* A report to the Coomalie Community Government Council by the Department of Infrastructure, Planning and Environment, Darwin.

Chapter 5

Allen C.G., and Verhoeven T.J. 1986. *The Rum Jungle Rehabilitation Project Final Project Report*, prepared by the Northern Territory Department of Mines and Energy for the Commonwealth Department of Resources and Energy.

Barrie, D. R. 1982. *The Heart of Rum Jungle: the History of Rum Jungle and Batchelor in the Northern Territory of Australia.* The Dominion Press, Maryborough.

Berkman, D.A. 1968. The geology of the Rum Jungle uranium deposits. In: *Uranium in Australia. Symposium* (editors Berkman, D.A., Cuthbert R.H., & Harris I.A.). Rum Jungle, June 1968. Proceedings Australasian Institute of Mining & Metallurgy; 12–31.

Commonwealth of Australia. 1980, *Code of Practice on Radiation Protection in the Mining and Milling of Radioactive Ores*, AGPS, Canberra ACT.

Davy, D. R. 1975. *Rum Jungle Environmental Studies*, Australian Atomic Energy Commission report. September.

Earth Sea Pty Ltd. (2011). Heritage assessment of the former Rum Jungle Mine site, Northern Territory. A report prepared for the Department of Resources, NT. Darwin, NT.

Fawcett, M. N. R. and Rider, M. C. 2010. The Rum Jungle Project. *AusIMM Bulletin.* Issue no. 2, April 2011, pp. 16–19. Fawcett,

Kraatz, M. and Applegate, R.J.M. eds 1992. *Rum Jungle Rehabilitation Project Monitoring Report 1986–88*, Conservation Commission of the Northern Territory, Technical Report Number 51.

Kraatz, M. ed. 1998. *Monitoring Report 1988–1993 Rum Jungle Rehabilitation Project*, Northern Territory Department of Lands, Planning and Environment, Technical Report Number R97/2.

Kraatz, M. 2002. 'Management and monitoring: A discussion of issues affecting future land use, management and monitoring' in Pidsley, S. ed. 2002. *Rum Jungle Rehabilitation Project Monitoring Report 1993–1998*, Northern Territory Department of Infrastructure, Planning and Environment, Technical Report Number 01/2002.

Kraatz, M. 2004. *Rum Jungle Rehabilitation Site Scoping Study – Environmental Issues and Considerations for Future Management*, report to the Department of Industry Tourism and Resources, February.

National Archives of Australia, 1962/1824.

Pidsley, S. (ed) 2002. *Rum Jungle Rehabilitation Project Monitoring Report 1993–1998*, Northern Territory Department of Infrastructure, Planning and Environment, Technical Report Number 01/2002.

Reserve Bank of Australia. 2013. *Reserve Bank of Australia Inflation Calculator*. Accessed 18 January 2013 from: http://www.rba.gov.au/calculator/annualPreDecimal.html.

Richards RJ, Applegate RJ and Ritchies AIM (1996), 'The Rum Jungle Rehabilitation Project' in *Environmental Management in the Australian Minerals and Energy Industries, Principles and Practices*, edited by DR Mulligan, UNSW Press in association with the Australian Minerals and Energy Environment Foundation: 530–553.

Ritchie, I. 1985. 'The Rum Jungle experience — a retrospective view'. *Australian Science Magazine*, 4, pp. 22–30.

Senate Uranium Mining and Milling Committee. 1997. *Uranium Mining and Milling in Australia,* Reported 15 May 1997. Accessed on 14 May 2013 from: http://www.aph.gov.au/Parliamentary_Business/Committees/Senate_Committees?url=uranium_ctte/report/index.htm.

Wikipedia. 2013. Combined Development Agency. Accessed 16 March 2013 from: http://en.wikipedia.org/wiki/Combined_Development_Agency.

Wildman Land Management. 2011. *Rum Jungle Mine Site 5 Year Weed Management Plan 2011*. Humpty Doo, Northern Territory: Wildman Land Management.

Chapter 6

ANZECC. 2000a. *ANZECC Stock Water Quality Guidelines.*

ANZECC. 2000b. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, ANZECC/ARMCANZ, Canberra, ACT.

Appleyard, S. 1983. *Groundwater investigations at Rum Jungle April to December 1983*. Water Division, Department of Transport and Works.

Australian Standards. 2005. *Australian Standard 4482. 2005 Australian Standard: Guide to the investigation and sampling of sites with potentially contaminated soil, Part 1: Non-volatile and semi-volatile compounds.*

Boland, K. 2008. *Water quality profile & bathymetric survey of Whites and Intermediate open cuts, Rum Jungle 2008*, Tropical Water Solutions PL, Darwin.

Bollhöfer, A., Pfitzner, K., Ryan, B., Esparon, A., and Brazier, J. 2008. *Radiological assessment of rum Jungle Mine, Northern Territory*, report by the Environmental Research Institute of the Supervising Scientist, Supervising Scientist Division, Department of Environment and Water Resources, prepared for Northern Territory Department of Natural Resources, Environment and the Art and the Commonwealth Department of Industry, Tourism and Resources, amended January.

BoM. (2013). *Average annual and monthly evapotranspiration*. Access 17 January 2013 from: http://www.bom.gov.au/jsp/ncc/climate_averages/evapotranspiration/index.jsp?maptype=3&period=an#maps

Christian, G. S. and Stewart, G. A. 1953. *General report on survey of the Katherine-Darwin Region, 1946*. Land Research Series, No.1, CSIRO, Melbourne.

Egan, J. 2005. *Browns Oxide Project: Flora Characterisation and Impact Assessment*. Prepared for Enesar Consulting Pty Ltd and Compass Resources NL.

EMS. 2005. *Browns Oxide Project: Fauna Report*. Prepared for Enesar Consulting Pty Ltd and Compass Resources NL. Ecological Management Services Pty Ltd.

Healy, R. W., and Cook, P.G. 2002. Using groundwater levels to estimate recharge. *Hydrogeology Journal* 10(1):91-109. IAEA. 2006. Knowledge Management for Nuclear Industry Operating Organizations. Accessed from: http://www-pub.iaea.org/MTCD/publications/PDF/te_1510_web.pdf.

ICRP. 1999. *Protection of the Public in Situations of Prolonged Radiation Exposure.* Publication 82 of the International Commission on Radiological Protection. Pergamon Press, Oxford.

ICRP. 2005. *Assessing dose of the representative person for the purpose of radiation protection of the public and the optimisation of radiological protection.* Publication 101 of the International Commission on Radiological Protection. Pergamon Press, Oxford.

Lawton MD and Overall R (2002), 'Water Quality in Whites and Intermediate Open Cuts' in *Rum Jungle Rehabilitation Project Monitoring Report 1993-1998*, Pidsley SM (editor), ISBN 0724548211, pp. 74-92.

Lindsay-Park, Karl & Margereson, Andrew. 2011. *Rum Jungle Mine site: Results of Soil and Fluvial Zone Sampling & Assessment.* Report for the Dept. of Resources, Northern Territory. Report no. R167.2011.

Low, W. A. 2001. *Flora and Fauna of the Browns Project Region, N.T.: A desk top assessment of information available and required for environmental impact assessment of Browns Polymetallic Project.*

Metcalfe, K. 2002. *Flora Assessment Study for Environmental Impact Statement, Browns Polymetallic Project, Batchelor NT.* For Compass Resources NL and NSR Environmental Consultants Pty Ltd.

NHMRC. 2004. *Australian Drinking Water Guidelines.*

Robertson Geoconsultants Inc. 2011a. *Phase 2 Report — Detailed water quality review and preliminary contaminant load estimates, Rum Jungle Mine Site, Northern Territory.* Consultant's report to the Northern Territory Government.

Robertson Geoconsultants Inc. 2011b. *Phase 3 (Stage 1 Report) — Development of Conceptual Flow Model for the Rum Jungle Mine Site.* Consultant's report to the Northern Territory Government.

Robertson Geoconsultants Inc. 2012a. *Phase 3 (Stage 2) Report: Groundwater Flow Model for the Rum Jungle Mine Site,* April 2012.

Robertson Geoconsultants Inc. 2012b. *Phase 3 (Stage 3) Report: Contaminant Load Assessment and Surface Water Quality Assessment for the Rum Jungle Mine Site*, May 2012.

Robertson Geoconsultants Inc. 2013. Forthcoming report.

Salama R. 1985. *Preliminary interpretation of Rum Jungle Monitoring Data.* Water Resources Division, Department of Mines and Energy.

SILO (database). 2012. *SILO climate data database*, Queensland Government. Accessed from: http://www.longpaddock.qld.gov.au/silo/.

SRK Consulting (Australasia) Pty Ltd. 2012. *Geochemical characterisation of waste at the former Rum Jungle Mine Site.*

Taylor, G. Spain, A. Nefiodovas, A. Timms, G. Kuznetsov, V. Bennett, J. 2003. *Determination of the Reasons for Deterioration of the Rum Jungle Waste Rock Cover*, July 2003.

Thackway, R. and Cresswell, I.D. eds. 1995. *An Interim Biogeographic Regionalisation for Australia: a framework for establishing the national system of reserves, Version 4.0*, Australian Nature Conservation Agency, Canberra.

Wilson, B. A., Brocklehurst, P. S., Clark, M. J., and Dickinson, K. J. M. 1990. *Vegetation Survey of the Northern Territory, Australia,* Technical Report No 49, Conservation Commission of the Northern Territory.

Chapter 7

Ayres, B.K., Lanteigne, L., Smith, Q., and O'Kane, M. 2007. *Closure planning and implementation at CVRD Inco's Whistle Mine, Ontario, Canada.* In proceedings of Mine Closure 2007, October 16-19, 2007, Santiago, Chile.

Shaw, S.C., Maehl, W.C., Kuipers, J., Haight, S. 2001. *Review of the Multiple Accounts Analysis Alternatives Evaluation Process Completed for the Reclamation of the Zortman and Landusky Mine Sites*, National Association of Abandoned Mine Lands Annual Conference, August 19-22, 2001, Athens, Ohio.

Appendix 3

Hydrobiology. 2012. *Environmental Values Downstream of the Former Rum Jungle Mine Site—Phase 1 Final Draft Report*, Consultant's report to the Northern Territory Government.

Appendix 4

Hydrobiology. 2012. *Environmental Values Downstream of the Former Rum Jungle Mine Site—Phase 1 Final Draft Report*, Consultant's report to the Northern Territory Government.

Appendix 5

Hydrobiology. 2012. *Environmental Values Downstream of the Former Rum Jungle Mine Site—Phase 2 Draft Report*, Consultant's report to the Northern Territory Government.