RADIATION PROTECTION AND WASTE MANAGEMENT PLAN

Document No:	NRE-0000-H-PLN-H-0004 Rev 4
Project Name:	Nolans Rare Earths
Location:	Approximately 135 km northwest of Alice Springs, Northern Territory
Date of Plan:	19 March 2025
EPBC Approval:	EPBC 2015/7436
Proponent:	Arafura Nolans Project Pty Ltd
	(ABN: 88 118 158 900)
Proposed Action:	To construct and operate an open pit rare earths mine, intermediate processing facility using a phosphoric acid pre-leach process and associated support infrastructure, approximately 135 km northwest of Alice Springs, Northern Territory.

REVISION HISTORY

Date	Revision	Description	Prepared	Reviewed	Approved
March 2025	Rev 4	Issued to DCCEEW	Suitably qualified expert(s) listed in Section 2.0	Daniel Jordan Environment Manager	Tommie van der Walt Chief Project Officer
September 2024	Rev 3	Issued to DCCEEW	Suitably qualified expert(s) listed in Section 2.0	Tanya Perry Head of Sustainability & Env	Stuart Macnaughton Chief Operating Officer
November 2022	Rev 2	Issued to DITT	Michael Robinson ESG Manager	Michael Robinson ESG Manager	Stewart Watkins GM Projects
July 2022	Rev 1	Issued to DITT	Michael Robinson ESG Manager	Michael Robinson ESG Manager	Stewart Watkins GM Projects
October 2021	Rev 0	For DITT review	Michael Robinson ESG Manager	Brian Fowler Environmental MGR	Stewart Watkins GM Projects

DECLARATION OF ACCURACY

In making this declaration, I am aware that sections 490 and 491 of the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act) make it an offence in certain circumstances to knowingly provide false or misleading information or documents. The offence is punishable on conviction by imprisonment a fine, or both. I declare that all the information and documentation supporting this Management Plan is true and correct in every aspect. I am authorised to bind the approval holder to this declaration and that I have no knowledge of that authorisation being revoked at the time of making this declaration.

Declared	By
Signed:	
Name:	Tommie van der Welt
Position:	Chief Projects Officer
Organisation:	Arafura Rare Earths Limited
Date:	19 March 2025

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1.0 INTRODUCTION

The Arafura Rare Earths Limited (Arafura) Nolans Project (the Project) intends to mine and produce rare earth oxides for the market. The mineralisation is known to contain elevated concentrations of naturally occurring uranium and thorium. During the processing of the ore, the uranium and thorium will be separated from the rare earth elements and placed in the Residue Storage Facility (RSF).

The potential radiological impacts of the Project operations were investigated in detail in the Nolans Project Environmental Impact Statement (Arafura, 2016). This document is the combined Radiation Protection and Radioactive Waste Management Plan (collectively referred to as the RPRWMP) for the Project. It follows on from the EIS and will be implemented from the recommencement of construction activities at the Project site.

The content and structure of the document is based on the Australian Radiation Protection and Nuclear Safeguards Agency (ARPANSA) Code of Practice and Safety Guide for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing Radiation (ARPANSA, 2005).

Arafura engaged JRHC Enterprises Pty Ltd as a suitably qualified expert to assist in the development of this RPRWMP, in collaboration with Arafura personnel (see Section 2.0). It has been developed to reflect sound, accepted industry practices for radiation management and associated waste disposal. Arafura takes full responsibility for the RPRWMP's content, implementation and confirmation of compliance with the stated requirements.

This RPRWMP outlines the commitments that Arafura makes for radiation protection. The purpose is to define the process, systems and methods that will be used by Arafura through the phases of the Project to ensure that workers, the public, and the environment are protected from any harmful effects of radiation that may arise from Project activities. It is intended to be a working document and accessible by staff, workers and contractors.

The Nolans Bore rare earth ore deposit (in the mining area) exists in an area with naturally elevated concentrations of uranium and thorium, and therefore, has an elevated natural background radiation level. All other parts of the Project Area, inclusive of the proposed accommodation village, Process Plant, RSF and borefield sites exist where the natural background radiation level is lower than that in the mine area.

The EIS reported that the radiological impacts at the Project site would be low, with predicted mine worker doses less than 5mSv/y and Process Plant workers in the order of 1mSv/y. This was revised to 5mSv/y and 2.5mSv/y, respectively, following the publication of new dose factors by the International Commission on Radiological Protection (ICRP) in 2017. It was also concluded that doses during operations would be maintained As Low As Reasonably Achievable (ALARA) through effective design controls and administrative processes.

It is relevant to note that measures required for control of radiation in rare earth mining and processing are very similar to those required in mineral sands mining and processing and are well understood by the mining industry.

For ease of understanding the variable radiation risk profile of the Nolans Project and the associated controls that will be implemented commensurate with the levels of risk, the Project is described in this

RPRWMP in accordance with the aspects and description summaries provided below. Please note that detailed descriptions for these aspects and maps for reference are provided in Section 8.0.

1.1 Construction – Project Area, Excluding Mine Pit

Activities in the Project Area, outside of the mine pit footprint, are conducted in areas with no NORM containing mineralisation. Clearing and construction activities in these areas will not result in occupational radiation exposure levels that will require specific controls to be implemented.

1.2 Construction – Mine Pit

The Nolans Bore rare earth deposit is known to contain elevated uranium and thorium concentrations, resulting in the potential for occupational and environmental exposure above natural background exposure. Whilst the preliminary site preparation and construction activities in this area won't involve mining or disturbance of the radioactive ore or other material classified as NORM, some radioactive materials may be encountered, and Arafura will take a precautionary approach. From the commencement of clearing and construction in the Mine Pit area, it will be designated as a 'Radiation Supervised Area' and specified controls will be implemented for the commencement of activities.

1.3 Operations – Mining, Processing and Residue Storage

The radiation management controls implemented from the commencement of construction in the Mine Pit area will be reviewed and continue to apply through to actual mining operations. The full Mine Pit area will continue to be designated as a 'Radiation Supervised Area'.

Once ore mining commences, the Mine Pit area will be classified as a 'Radiation Controlled Area' and specified controls will be implemented for the commencement of mining.

Potential exposure to radiation will need to be managed throughout the Process Plant and the RSF – from the commencement of ore commissioning onwards. The Process Plant and RSF will be designated as a 'Radiation Supervised Area'. Key areas of the Process Plant will be designated as 'Radiation Controlled Areas', depending upon the projected radionuclide concentrations of process streams. These areas will be designated commensurate with the risk level and specified controls implemented.

1.4 Site Closure

The Project's final phase occurs when mining and processing is complete, and the Project enters the decommissioning and rehabilitation phase. This phase is characterised by plant and equipment decontamination, with a focus on clearance to a level that maximises recycling.

The RSF will be capped, and the NORM waste rock dumps covered with benign waste rock. Surface contouring will integrate the closed-out facilities into the existing landscape.

Radiological closure criteria have been developed. They focus on ensuring that the final landforms are safe and secure and that radiation levels are consistent with pre-operational levels. The member of public dose limit that has been set for the site closure is 1mSv/y, from all exposure pathways.

Acknowledging that radiation management can be a complex subject, Section 6.1 of this document provides an 'Introduction to Radiation', for information purposes.

2.0 PREPARATION OF THIS DOCUMENT

This document is the responsibility of the Arafura technical and environmental teams. It has been developed in conjunction with the Arafura consultant subject matter expert (SME) – radiation, Mr Jim Hondros of JRHC Enterprises (a resume is provided as APPENDIX A).

The Arafura team chose the SME based on the following aspects:

- 40 Years experience in mining in the areas of occupational health and safety, environment protection and community relations, with expertise in radiation protection.
- More than 10 years of experience providing advice to Arafura on occupational and environmental radiation protection, including co-authoring the radiation impact assessment, which was used as the basis of the radiation chapter of the EIS.
- Extensive national and international experience, including as a recognised expert of the International Atomic Energy Agency (IAEA) on Naturally Occurring Radioactive Materials (NORM).
- Extensive experience in radiological impact assessment and the development and practical implementation of radiation management plans for more than 20 operations with NORM.
- Certified Radiation Safety Adviser by the Australasian Radiation Protection Accreditation Board.

This RPRWMP has been prepared in accordance with the EPBC 2015/7436 Conditions of Approval and NT EPA Report 84 Recommendations for the Nolans Project. Table 2—1 provides a summary of the relevant EPBC 2015/7436 condition relating to radiation management and where it is addressed in this RPRWMP. The conditions current at the time of preparation of this RPRWMP are dated 24 October 2024.

The condition associated with this RPRWMP relates to recommendations from the NT EPA Assessment Report 84. These are described in Table 2—2 below.

Table 2—1 EPBC 2015/7436 Conditions Addressed in this Plan

Condition description		Section(s) within this RPRWMP	Demonstration of how this RPRWMP addresses condition requirements
Condition 7 EPBC 2015/7436	To ensure that radionuclides and radiation do not harm people and non-human biota, the approval holder must submit to the **department** for the **Minister's** for approval, a Radiation Protection and Waste Management Plan that meet requirements of: i. a) to b) of recommendation 15, and ii. g) of recommendation 16 of **Assessment Report 84**. The Radiation Protection and	▪ Entire RPRWMP. ▪ Table 2—2. ▪ Section 1.0. ▪ Section 6.3 refers to the primary ARPANSA Mining Code requirements.	▪ Entire RPRWMP. ▪ A brief resume for the suitably qualified expert is provided in Section 2.0. and a full copy is provided as APPENDIX A.

Condition description		Section(s) within this RPRWMP	Demonstration of how this RPRWMP addresses condition requirements
	Waste Management Plan must be developed by a **suitably qualified expert** based upon guidance material from **ARPANSA**. In association with the Radiation Protection and Waste Management Plan, the approval holder must commence **construction** of the action only in accordance with Condition 8 of this instrument.		

Table 2—2 NT EPA Assessment Report 84 Recommendations Addressed in this RPRWMP

Recommendation Description		Section(s) within this RPRWMP	Status
Recommendation 15. Approvals and decisions for the Project shall have conditions that require the Mine Closure Plan to progressively include:			
a)	Alternative risk-based rehabilitation options that identify a range of closure scenarios and strategies for the Waste Rock Dumps, Tailings Storage Facility, Residue Storage Facility and the pit and provide justification that the preferred closure option minimises environmental risks.	▪ Section 13.0.	This RPRWMP notes that radiological aspects are one component of the final decision on closure options. This RPRWMP only covers radiation risks associated with the Project. Non-radiation rehabilitation options are incorporated into the Mine Closure Plan for the Project.
b)	Identification and management of knowledge gaps relating to closure-specific technical information: including environmental baseline data, waste characterisation, pit lake characterisation, and review of monitoring data; to inform sustainable mine closure.	▪ Section 13.0.	This RPRWMP refers to ensuring that radiological aspects based on monitoring and characterisation are taken into account in closure decision making.

Recommendation Description		Section(s) within this RPRWMP	Status
Recommendation 16. Before approvals or decision are given or made for the Project, the Proponent or Operator shall provide to the relevant regulator a conceptual Mine Closure Plan that must be reviewed and updated every three to five years. The Mine Closure Plan must:			
e)	Include a commitment to ensure all landforms, including the pit lake, are safe and stable.	▪ Section 13.0.	This RPRWMP refers to the radiation related closure goals of the Project.
f)	Include an adaptive management approach in response to progressive rehabilitation performance monitoring results to ensure rehabilitation is successful	▪ Section 13.0.	This RPRWMP refers to the closure decision making processes and the consideration of radiological aspects.
g)	Establish ongoing monitoring and maintenance of the site post-mining in accordance with an approved monitoring and maintenance program until such time as the relevant regulator directs	▪ Section 13.0.	This RPRWMP notes that monitoring will be conducted post-closure (extent is to be defined during the operations phase) to ensure that closure goals for radiation are met.

3.0 CODES AND STANDARDS

Table 3—1 International Codes and Standards

Reference	Details
ARPANSA 2005	The Code of Practice and Safety Guide for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing Radiation Protection Series. Canberra. RPS 9
ARPANSA 2010	Environmental Protection: Development of an Australian approach for assessing effects of ionising radiation on non-human species. Technical Report Series No. 154
ARPANSA 2011	Safety Guide for Monitoring, Assessing and Recording Occupational Radiation Doses in Mining and Mineral Processing
ARPANSA 2015	Guide for Radiation Protection of the Environment, Radiation Protection Series G-1
ARPANSA 2019	Code of Practice for the Security of Radioactive Sources
ARPANSA 2019b	Code of Practice for the Safe Transport of Radioactive Material RPS C-2
ARPANSA 2020	ARPANSA Code for Radiation Protection in Planned Exposure Situations
ARPANSA 2022	ARPANSA Updates Radiation Dose Conversion Factors 4 July 2022
DMP 2010	WA Govt, 2010, 'Managing Naturally Occurring Radioactive Material (NORM) in mining and mineral processing guideline', Government of Western Australia DMP, Monitoring NORM - Airborne radioactivity sampling
ERICA 2023	http://erica-tool.com/ (accessed July 2024)
ICRP 1977	Recommendations of the ICRP, Publication 26. Ann. ICRP 1 (3)
ICRP 2007	The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103. Ann. ICRP 37 (2-4)
ICRP 2017	ICRP, 2017. Occupational Intakes of Radionuclides: Part 3. ICRP Publication 137. Ann. ICRP 46(3/4)
IAEA 2014	Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards. General Safety Requirements Part 3 No. GSR Part 3 — Vienna: International Atomic Energy Agency
UNSCEAR 2000	Annex B: Exposures from natural radiation sources, United Nations Scientific Committee on the Effects of Atomic Radiation, New York
UNSCEAR 2000b	UNSCEAR 2000 Report to the General Assembly, with Scientific Annexes UNITED NATIONS New York, 2000 VOLUME I: SOURCES

4.0 ABBREVIATIONS AND DEFINITIONS

Table 4—1 Abbreviations and Definitions

Abbreviation	Meaning
Arafura / ARU	Arafura Resources Limited
ALARA	As Low As Reasonably Achievable (social & economic factors taken into account)
AMAD	Activity Median Aerodynamic Diameter
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
ERICA	Environmental Risk from Ionising Contaminants
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
LOM	Life of Mine
MMAD	Mass Median Aerodynamic Diameter
MCP	Mine Closure Plan
NHB	Non-human biota
NORM	Naturally Occurring Radioactive Material
OSLD	Optically Stimulated Luminescence Dosimeter
PTW	Permit to Work
RPRWMP	Radiation Protection and Radioactive Waste Management Plan
REE	Rare Earth Elements
ROM	Run of Mine
RP Act	Radiation Protection Act
RPP	Radiation Protection Plan
RSF	Residue Storage Facility
Statutory RSO	Statutory Radiation Safety Officer
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
WI	Work Instructions
Bq/cm^2	Becquerel per square centimetre
m^3/h	Cubic meters per hour
mSv/y	Millisievert per year
µJ	Microjoule
mJ	Millijoule

5.0 PROJECT OVERVIEW

Arafura proposes to develop and operate the Nolans Project, a rare earth mine located approximately 135 kilometres (km) north-northwest of Alice Springs in the Northern Territory. The Project is situated approximately 10km west of Aileron Roadhouse. The main access to the Project site will be from the Stuart Highway, 5km south of Aileron Roadhouse and south of the Alyuen community.

The majority of the Project site is situated on the Aileron Perpetual Pastoral Lease (PPL 703), with the exception of the western part of the borefield area, which is situated on the Napperby Perpetual Pastoral Lease (PPL 747/748), and the very northern portion of the Kerosene Creek diversion (ML 32416) which is located on the Pine Hill Perpetual Pastoral Lease (PPL 1030).

The Project comprises an open pit mine at Nolans Bore, an associated concentrator and Process Plant, with ancillary facilities including waste rock dumps (WRD) and Residue Storage Facility (RSF) for the beneficiation tailings and waste streams from the Process Plant. There will also be a water supply borefield, clean-up area for radioactively contaminated waste materials, gas-fired power plant and accommodation village.

The ore body is an REE-P-U deposit with mineralisation-characterised veins of REE-rich apatite with grades from 5-10% Total Rare Earth Oxide (TREO). Mining will be open pit with all material to be mined, drilled and blasted. Mining will be a conventional excavator-truck operation with the ore requiring selective mining with tight geological control. The plan is to commence mining an average of 1.0 Mtpa of ore, increasing to 1.5 Mtpa later in mine life and together with approximately 5 Mtpa of other materials (low grade ore and waste), with staged increases to 8 and 12 Mtpa. Ore will be stockpiled on the ROM pad and ore blends will be loaded onto trucks, for delivery to the Process Plant, 8.5 km to the south.

The ore will be processed through a conventional crushing-milling and flotation circuit to produce an apatite rich rare earth concentrate. The concentrate will be treated in the Process Plant using a complex hydrometallurgical flowsheet. The process will extract the REE and phosphate from the apatite from the concentrate while rejecting impurities, including radionuclides. The REE will be separated to produce ~5000 tpa of rare earth oxides for sale. The impurities, radionuclides and low value REE such as Lanthanum (La) and Cerium (Ce) will be neutralised and disposed of in a lined cell within the RSF. The phosphate that is recovered from the apatite in the feed will be converted into approximately 144,000 tpa of merchant grade phosphoric acid for export.

The Project site includes the following main areas, linked by access roads and pipelines:

- Mine Area.
- Process Plant.
- Residue Storage Facility.
- Explosives magazine.
- Accommodation village.
- Borefield.
- Site access roads.

6.0 BACKGROUND

6.1 Introduction to Radiation

All matter is made of atoms. Atoms are made up of a nucleus that contains protons and neutrons and is orbited by electrons. Some atoms are unstable and breakdown, giving off energy from the nucleus in the form of radiation. These are known as radioactive atoms or radionuclides.

Different radionuclides emit radiation at different rates. The breakdown (or decay) of radionuclides reduces the number remaining, so that the amount of radiation emitted continually reduces. The time taken for one half of the radionuclides to decay away is known as the half-life. Each radionuclide has its own half-life that can range from less than one-thousandth of a second to billions of years.

When a radionuclide decays, the new atom formed may itself be radioactive, which might in turn decay to another radionuclide. This can continue until a stable element is reached. When this occurs, the chain of radioactive decays is called the decay series or decay chain.

Radionuclides are ubiquitous and naturally occurring, existing everywhere in the environment - in food, air, water, soils and rocks. For example, uranium is a naturally occurring heavy metal and is widespread in the Earth's crust, having an average concentration of about three parts per million (ppm). Since radionuclides essentially exist naturally in all materials, it is usual to only define a material as radioactive when the concentration of a radionuclide in the material exceeds a prescribed level.

Radiation emitted from radionuclides is known as ionising radiation because it ionises material through which it passes. This means that radiation produces charged particles called ions as it passes through matter.

There are three types of radiation emitted by naturally occurring radionuclides:

- *Alpha radiation* consists of alpha particles (two neutrons and two protons) and has a very short range in air (a few centimetres), depositing their energy quickly. They are unable to penetrate the outer skin layer but can be hazardous when inhaled or ingested.
- *Beta radiation* is a negatively charged particle, similar to electrons. They have moderate penetration, typically about one metre in air and a few millimetres in water or tissue.
- *Gamma radiation* is not a particle but an electromagnetic wave, like X-rays, but of much higher energy. Gamma rays are generally able to penetrate up to several centimetres of metal or 10 cm of concrete.

Exposure to radiation can only occur when there is an exposure pathway between the radioactive material and the person exposed. This can occur in two ways: through external exposure (where the source of radioactivity is outside the body) and through internal exposure (where the source of radioactivity is inside the body – for example, in inhaled air).

Radiation and radioactivity can be described in a number of ways. The most common way refers to the amount of radioactivity in a material (or how radioactive it is). This is described by its 'activity' and is measured in the unit of becquerel (Bq), which is the amount of radioactive material that produces one radioactive decay per second. The 'activity concentration' is the amount of radioactivity in a unit mass (or volume) of material and is measured in becquerels per gram (Bq/g) or per litre (Bq/L).

Another way of describing radioactivity is by the radiation 'exposure'. Exposure refers to the amount of radiation received at a point or by a person. Radiation 'dose' is then a standardised measure of the effect (or detriment) of exposure to the radiation and is measured in the units of sieverts (Sv). The unit of dose considers different types of radiation and different exposure situations. The sievert is a large unit of measure, and doses are usually expressed in millisieverts (mSv) (thousandths of a sievert).

Due to radiation being very common in nature, everyone is exposed to natural radiation throughout their life. This radiation comes from the rocks and soil of the earth, the air we breathe, the water and food we consume, and from cosmic radiation from space. Natural background concentrations can vary considerably in different places in the world. While the world average dose is 2.4 mSv/y, the typical range is quoted as 1–10 mSv/y (UNSCEAR 2000).

In addition to natural background exposure, some people around the world are regularly exposed to radiation in their work and from leisure activities (such as flying) and in medical procedures. Table 6—1 shows the average annual dose for a range of different jobs.

Table 6—1 Occupational Radiation Exposures (in addition to natural background levels)

Source practice	Average effective dose from internal and external exposure above natural background (mSv/y)
Industrial uses of radiation	0.5
Medical uses of radiation (doctors/nurses)	0.3
Air crew (from cosmic radiation)	3.0
Nuclear fuel cycle	1.8
Mining (other than coal)	2.7
Coal mining	0.7

Source: UNSCEAR 2000 Report Vol. I Sources and Effects of Ionising Radiation

A major source of radiation exposure to the general public is medical exposure. Radiation is used extensively for diagnosis (such as x-rays) and treatment of disease. The average annual radiation dose from diagnostic medical procedures in developed countries is approximately 1.2 mSv/y (UNSCEAR 2000).

The acute health effects of radiation exposure (both internal and external) are well known. At high doses (several sieverts), significant numbers of cells may be killed, leading to the breakdown of the organ or tissue and possibly resulting in death. The doses required for these effects are similar to those received by Chernobyl fire-fighters. These dose levels are in the magnitude of hundreds of times higher than those expected at the Nolans Project

At lower doses, chronic health effects may arise from cells that are damaged by the radiation but not killed. This may be the initiating event for development of a cancer.

Several studies have found an increased risk of cancer among people exposed to moderate doses of radiation (UNSCEAR 2000). The studies show that the risk increases as the radiation dose increases.

In general, none of the studies have been able to measure increases in cancer risk from exposures to low doses of radiation (below about 50 to 100 mSv); however, it is conservatively assumed that an increased risk does exist. This is called the linear non-threshold hypothesis.

The studies and their results form the basis of radiation standards for the exposure of workers and the general public.

The effective annual dose limits are 20mSv/y for a radiation worker and 1mSv/y for a member of the public.

6.2 Approach to Radiation Protection

Radiation and its effects have been well documented and studied for more than 100 years, and there is international consensus on its effects and controls. The main organisations that oversee radiation and radiation protection and provide guidance and standards are:

- The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) provides a consolidated overview of the effects of radiation by regularly reviewing research and publishing summaries. UNSCEAR provides the scientific basis for radiation protection.
- The International Commission on Radiological Protection (ICRP) is recognised as the pre-eminent authority on radiation protection and has developed the philosophy for radiation protection and publishes recommendations on radiation protection. ICRP provides the philosophical basis for radiation protection.
- The International Atomic Energy Agency (IAEA) develops and publishes standards and guides and provides advice on basic safety precautions for both industry and regulators when dealing with radiation. The IAEA develops operating standards.

The standards and guidelines established at an international level are adopted in Australia as National Standards and Codes of Practice through the work of the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA). The national standards are then adopted by Australian States and Territories as necessary and enacted in legislation or enforced through licence conditions.

The basis of radiation protection regulation is outlined in ICRP Publication number 26 [ICRP 1977], in which the ICRP first recommended the *system of dose limitation*. This is recognised as the internationally accepted approach to radiation protection and is universally adopted as the basis of legislative systems for the control of radiation. It is made up of three key elements:

- Justification – this means that a practice involving exposure to radiation should only be adopted if the benefits of the practice outweigh the risks associated with the radiation exposure.

- Optimisation – this means that the protection mechanisms for radiation protection have been optimised so that doses are *As Low As Reasonably Achievable*, taking into account economic and social factors. This is also known as the *ALARA* principle.
- Limitation – this means that individuals should not receive radiation doses greater than the prescribed dose limits.

The ALARA principle is generally regarded as the most important and effective of these elements for controlling and managing radiation.

While the ALARA principle is the foundation for radiation protection, radiation dose limits have been established to provide an absolute level of protection. The limits apply only to the radiation dose received as a result of *practice* and exclude natural background radiation. The limits are:

- 20 mSv/y for a worker (whilst at work).
- 1 mSv/y for a member of the public (total year).

Radiation protection is regulated in the Northern Territory under the Radiation Protection Act (RP Act) (2004) and Regulations (2007) and the requirements of the *Environment Protection Legislation Amendment Act 2023* and *Work Health and Safety (National Uniform Legislation) Act 2011*. Arafura has committed, through the EIS (Arafura 2016) to abiding by Territory, National and International standards for radiation protection.

6.3 Radiation Management Requirements

Arafura uses recognised industry standards to ensure that technologies and methodologies for mining, mineral processing and waste management enable the protection of people and the environment.

Arafura recognises that the contents of this RPRWMP must comply with the structure outlined in the ARPANSA Mining Code (ARPANSA 2005). The overriding objective of the Mining Code is to provide a framework for the protection of workers, members of the public and the environment from any harmful effects of radiation exposures arising from mining, mineral processing and waste management. It relates to potential impacts from current, planned and future activities.

The key components of the ARPANSA Mining Code Requirements for radiation protection and waste management, together with where they are addressed in this RPRWMP are presented in Table 6—2 below.

Table 6—2 Radiation Protection and Waste Management Requirements

ARPANSA Mining Code Requirement	Section of this RPRWMP
A description of the operations and the measures that are intended to be taken to control the exposure of employees and members of the public to radiation.	Sections 5.0 – Project Overview, 8.0 – Radiation Exposure and Management, 11.0 – Occupational Radiation Monitoring and 12.0 – Environmental Monitoring.
An outline of the processes generating radioactive waste and a description of the radioactive waste generated.	Section 8.1 – Radiological Characteristics of the Project.

ARPANSA Mining Code Requirement	Section of this RPRWMP
A description of the system for radioactive waste management.	Section 9.0 - Radioactive Waste Management.
Demonstrated access to appropriate professional expertise in radiation protection and details of appropriate equipment, staffing, facilities and operational procedures.	Throughout Section 8.0 – Radiation Exposure and Management. Section 8.4.2.5 – Radiation Safety Officer.
A plan for monitoring radiation exposure and for assessing the doses received by workers and the public.	Section 11.0 – Occupational Radiation Monitoring.
A program for monitoring the concentration of radionuclides in the environment.	Section 7.0 describes baseline radiation levels. Section 12.0 – Environmental Monitoring.
Details of induction and training courses.	Throughout Section 8.0 – Radiation Exposure and Management.
A plan for dealing with incidents, accidents and emergencies involving exposure to radiation.	Section 16.0 – Accident, Incident and Emergency Response.
Circumstances which might lead to an uncontrolled release of radioactive material to the environment and contingencies for mitigating / managing the release.	Section 13.0 – Site Closure. Section 16.0 – Accident, Incident and Emergency Response.
Details of record keeping and reporting, including personal dose monitoring and a schedule for reporting on the operation and results of monitoring and assessments required by this plan. Records will be kept in accordance with regulatory requirements.	Section 14.0 – Record Keeping.
A system of periodic assessment and review of the adequacy and effectiveness of procedures.	Section 17.0 – System of Review.

6.4 Requirements of Northern Territory Radiation Protection & Control Act & Regulations

The *Radiation Protection Act 2004* and Regulations 2007 (in force as of 2012) outline the requirements for radiation protection in the Northern Territory. The requirements for the transport of radioactive materials are outlined in the *Radioactive Ores and Concentrates (Packaging and Transport) Act 1980*, and Regulations 1980.

The Arafura mine and Process Plant are subject to the requirements of the Act and Regulations, requiring a licence and an approved Radiation Protection Plan. Arafura will seek a licence in accordance with Part 3 of the *Radiation Protection Act 2024* and provide this RPRWMP as part of the approval process. It is noted that other licences will be required, including:

- licences for radiation sources.
- registration of radiation sources.

- registration of place where a radiation source will be used or stored.
- disposal of radioactive waste, including general contaminated waste and tailings.
- operators' licences for XRF equipment, licences for any radiation apparatus, including XRF equipment and radiation density gauges.

This RPRWMP incorporates the requirements of the following:

- The Northern Territory Radiation Protection Act 2004 and Regulations 2007.
- The ARPANSA Mining Code.

7.0 LOCAL ENVIRONMENT AND RADIOLOGICAL CHARACTERISTICS

Arafura has completed comprehensive studies and environmental and social impact assessments for the Nolans Project, as presented in the Environmental Impact Statement (EIS). The full EIS is available on the Arafura website at: https://www.arultd.com/projects/nolans/environmental-impact-statement/

Arafura has a long history of radiation monitoring in the region, with levels presented in the EIS and supplement. The key findings from these extensive environmental radiation studies are as follows:

- The mine area is radiologically determined by the extensive geological exploration and drilling of this sparsely outcropping orebody.
- The local region has locally defined elevated gamma radiation levels.
- Some areas with elevated levels of uranium and thorium characterise the broader area.
- There is locally elevated radon and thoron in the region due to the outcropping areas of elevated uranium and thorium.
- Radon and thoron concentrations in the air vary by up to 2 to 3 orders of magnitude.
- The EIS also reported that the findings are similar to those found in the vicinity of other near-surface undeveloped uranium and rare earth mineralisation.

These findings, however, are not dissimilar to those found in the vicinity of other near-surface undeveloped uranium and rare earth orebodies.

The physical environment of the Project setting is described in detail in:

- Nolans Project, Environmental Impact Statement (EIS), Arafura Resource Ltd, February 2016 (GHD, 2016).
- Nolans Project, Environmental Impact Statement (EIS) – Supplementary Report, October 2017 (GHD, 2017).
- Arafura Resources Ltd, Nolans Project Section 14A Notification, June 2019 (GHD, 2019).

A summary of the key environmental attributes of the Project site is provided below, copied from relevant sections of EIS Chapter 12 - Radiation.

7.1 Landforms and Vegetation

Vegetation communities and associated landforms have been described and mapped for the Project area within the EIS. Baseline surveys indicated there are no threatened ecological communities present within or surrounding the Project area; however, some are considered sensitive vegetation communities and/or provide suitable habitat for threatened species known to occur in the area.

The mining area is characterised as red earth plains, alluvial plains, rocky hills and several moderate sized drainage features (Kerosene Camp Creek and associated tributaries). The red earth plains support a Mulga shrubland over either tussock grassland or spinifex grassland. The alluvial plains support a mixed open woodland over tussock grasses, with the occasional calcareous low rise that supports Senna shrubs.

Several rock hills and outcrop areas are present, which support an open shrubland of Acacia or mallee (*Eucalyptus spp.*) over spinifex. The larger drainage channels are typically lined with River Red Gum (*Eucalyptus camaldulensis*) over tussock grasses (including the weed Buffel Grass *Cenchrus ciliaris*).

The Process Plant and RSF areas are characterised as flat red earth plains that support Mulga shrubland/low woodland over tussock grasses. The northern part of the Process Plant footprint is characterised as alluvial plains, gravel rises and containing some isolated low rocky hills.

The accommodation village is situated on flat alluvial plains and red earth plain that either support a Mulga shrubland or mixed woodland over either tussock grass or spinifex grass. Some low rocky hills on the eastern side of the accommodation village support Acacia shrubland over spinifex.

There are several planned extractive areas located off the main access road, which will be used for extracting gravel. These areas support rocky hills, gravel or rocky rises, alluvial plains and red earth plains.

The borefield occurs within an extensive spinifex sandplain (flat to gently undulating) that supports open shrubland (various species) over spinifex (*Triodia basedowii*). There is local variation in structure and species within this vegetation community, which is mostly likely to be associated with the fire regime.

Further to the west is the Day Creek alluvial floodplain, which supports low gravel rises (with either Mulga or Witchetty Bush) that transition into an alluvial plain and a large drainage channel (Day Creek) lined with River Red Gum.

7.2 Local Environment – Radiation

A detailed description of the radiological characteristics of the Project Area is provided in the following sections of the EIS:

- Chapter 3: Project Description.
- Chapter 12: Radiation.
- Appendix P: Radiation Report.

The information provided in the following sections of the RPRWMP draws directly from these sections.

Chapter 12 of the EIS provides an overview of the radiological environment of the Project, including a summary of the natural levels of background radiation in the region and potential impacts from Project activities on workers, the public and the environment.

To understand the existing environment of the Project from a radiological perspective, Arafura undertook comprehensive baseline radiological studies of the site and the region, including environmental and occupational radiation sampling and monitoring in 2005. Monitoring locations are shown in Figure 7—1. These studies are referred to in the EIS and considered the following:

- Environmental gamma monitoring
- soil and sediment sampling

- vegetation sampling
- groundwater sampling
- dust sampling and dust concentration in air
- passive radon and thoron
- real-time radon and thoron monitoring.

Following the publication of the EIS, Arafura has collected additional radionuclides in dust and groundwater data as part of ongoing baseline environmental monitoring. A summary of the monitoring and results is described in Section 7.3 below.

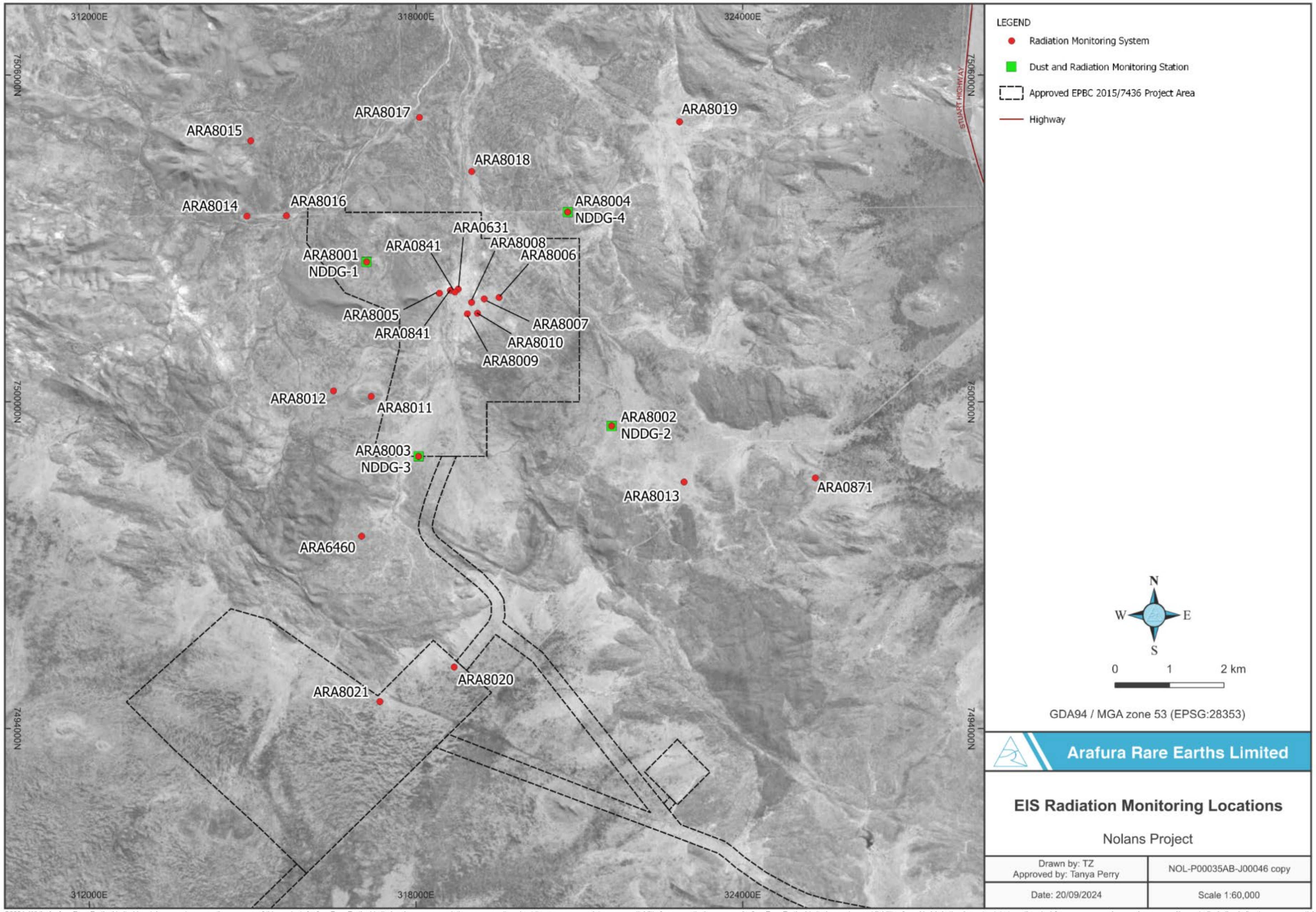


Figure 7—1 EIS Radiation Monitoring Locations

7.2.1 Gamma Monitoring

A general area survey was conducted in a grid pattern across the mine site area and at sites remote (background) from the Project area. Background sites included two measurements in Kerosene Camp Creek and two measurements at the Aileron Roadhouse. The measurements were taken at locations on and off the ore deposit, and a summary of the results is provided in Table 7—1.

Table 7—1 Summary of Gamma Measurements at the monitoring locations

Location	Environmental Gamma Dose Rate (µSv/h)			Sample Number
	Average	Max.	Min.	
On deposit	0.38	0.63	0.18	12
Off deposit	0.19	0.35	0.13	37
Background	0.17	0.18	0.15	4

The gamma radiation levels in the region have been extensively studied through a number of surveys. A summary of the results is provided in Table 7—2.

Table 7—2 Summary of Gamma Monitoring Results

Sample Program and Method	Average Results (µSv/h)
Nolans Bore (on deposit)	0.8 (highs to > 10)
Nolans Bore (off deposit)	0.25

The EIS provides a summary of gamma radiation levels from other areas of Australia. The data shows that the baseline levels vary considerably around the country. The levels shown in the above tables for the Nolans Bore region are consistent with other areas where there is an outcropping of naturally occurring radioactive materials.

In 2008 Arafura conducted detailed low-level aerial radiometric surveys of the mine site and Process Plant area. The results are shown in Figure 7—2. Aerial radiometric surveys provide a picture of gamma radiation levels across wide areas and are more efficient than handheld gamma surveys. They are useful for obtaining a regional snapshot. It is usual to use aerial surveys to identify areas for more detailed ground surveys.

The Arafura aerial radiometric survey results clearly show the area of the Nolan Bore mineralisation, with average gamma radiation levels up to almost 1 µSv/h, compared to the regional values of between 0.02 and 0.20 µSv/h. These values are consistent with ground truthing gamma survey results shown in the above tables.

The Arafura aerial radiometric survey did not extend to the borefield area, as this area was known to be generally unmineralised. However, the Northern Territory Department of Mines (now Department of Mining and Energy) did conduct a low-resolution regional airborne survey in 1997. Results are available on the Government Geoscience website (Northern Territory Geological Survey (NTGS):

https://industry.nt.gov.au/projects-and-initiatives/geoscience-projects/geophysical-acquisition.

Figure 7—3 shows collated radiometric data across the area of the borefield. It can be seen that the gamma radiation levels of the borefield area are in the range of approximately 0.05 to 0.15 μSv/h, which is typical of large areas of Australia where there is no uranium or thorium mineralisation, i.e. there are no areas of elevated gamma radiation across the borefield footprint.

Noting that the data in Figure 7—3 is a different dataset to that collected by Arafura (Figure 7—2), the relative colours shown vary between the two figures. However, for comparison purposes, the reference scales on each figure are the same.

The inclusion of both sets of data provides a comparison, and assurances that work in the borefield and other areas away from the ore deposit will not result in radiation exposure above that of natural background levels.

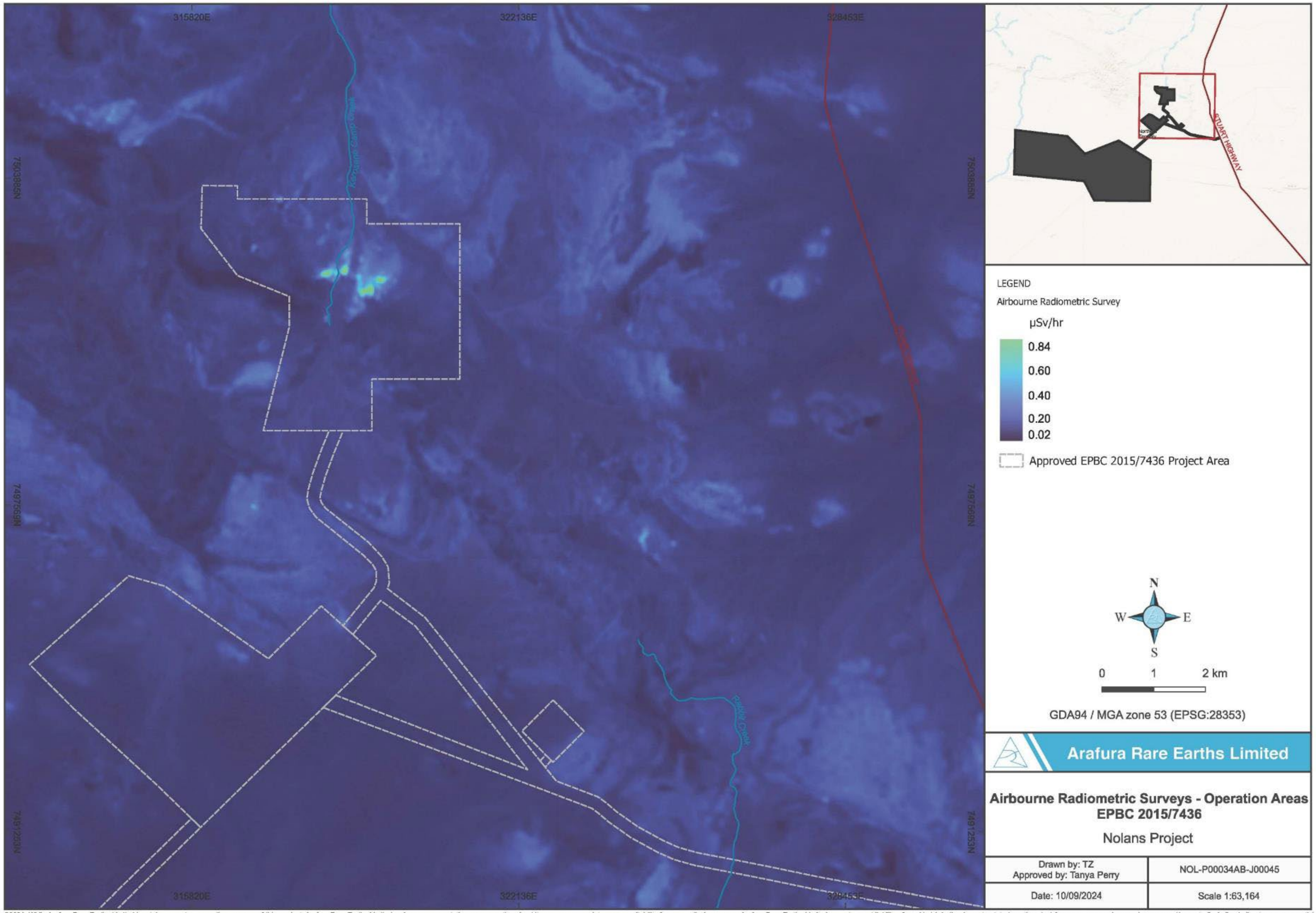


Figure 7—2 Aerial Gamma Surveys – Nolans Project Mine & Process Plant Areas (based on Arafura 2016)

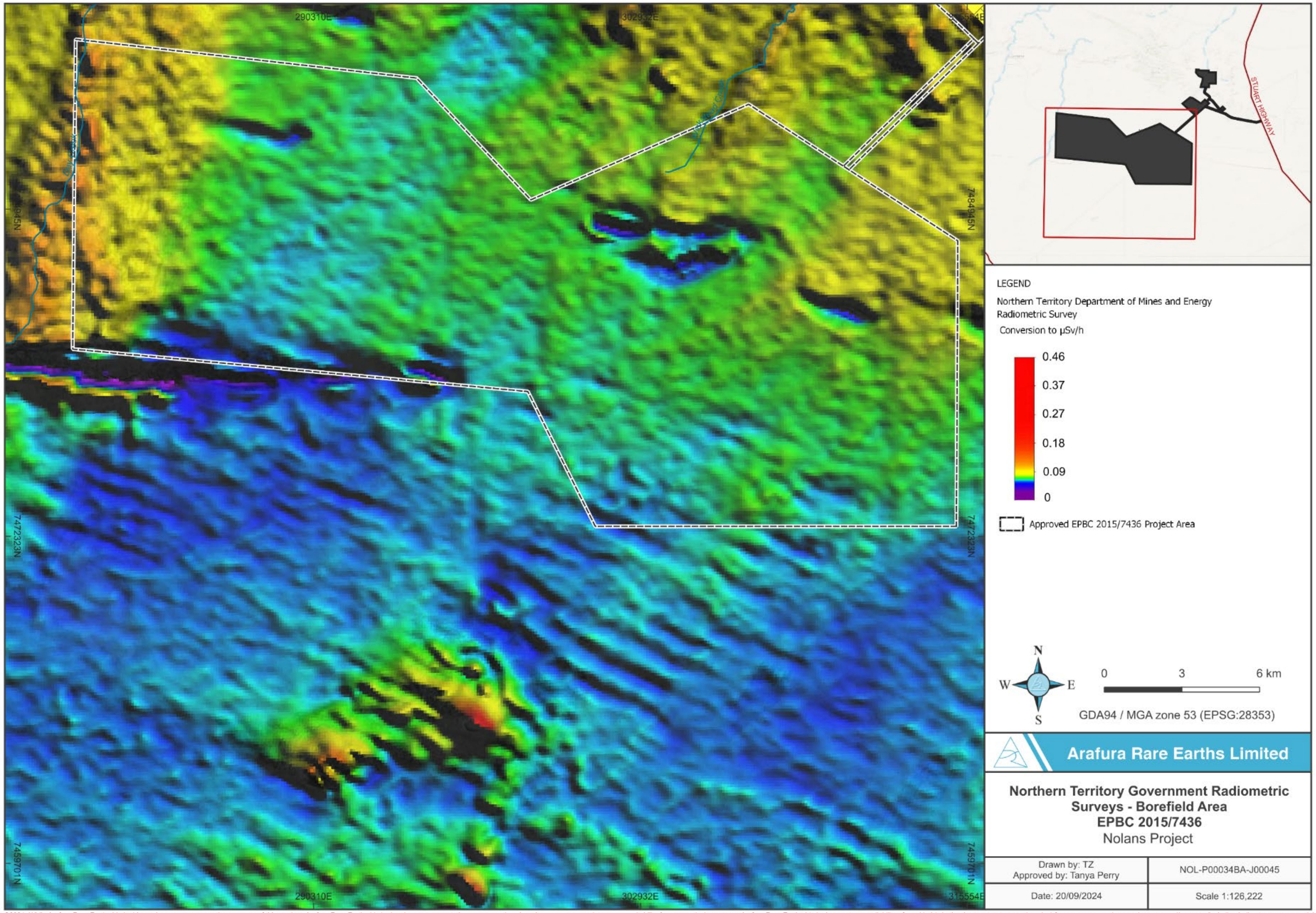


Figure 7—3 Radiometric Surveys of the Nolan Project Borefield Area

7.2.2 Soil and Sediment Analysis

Earlier surface soil sampling was undertaken at three locations: one upstream from the Nolans Bore deposit in the mine site, one downstream, and the third at a site distant (background) from the Project Area near the Aileron Roadhouse. Results are presented in Table 7—3.

Table 7—3 Soil Radionuclide Results

Location	Radionuclide Concentration (Bq/kg)									
	U238	U234	Th230	Ra226	Pb210	Po210	Th232	Ra228	Th228	K40
Mine site	27	20	25	23	15	20	56	77	75	805
Downstream of mine site	25	18	24	18	10	17	32	42	42	891
Background	77	30	72	53	45	47	118	118	121	925

The results show that the concentrations of uranium and thorium in the soil samples from the roadhouse are naturally elevated compared to the samples from the mine region and comparable to the Australian average.

An extensive program of soil and sediment sampling (>230 samples) has also been completed across the region, and these results are shown in Table 7—4.

Table 7—4 Summary of Soil and Sediment Sampling

Sample Type	Number of Assays	Uranium (av.& range in parts per million (ppm))	Thorium (average and range in ppm)
Crustal average	---	2.7	10.5
Soils (on deposit)	9	22 (3.28-83.3)	328 (44.1-950)
Soils (off deposit)	17	5.51 (2.47-24.3)	63.2 (23.2-416)
First drill meter (on deposit)	142	55.6 (1.4-655)	791 (10.4-8730)
First drill meter (off deposit)	18	5.85 (1.6-19)	50.5 (9.55-149)
Stream sediments	51	3.16 (1.36-13.7)	44.5 (14.6-180)
Stream sediments (fine-grained fractions)	51	8.21 (2.81-21.5)	119 (31.7-360)

Uranium and thorium concentrations for a range of samples have been determined and show that:

- Soils and stream sediments in the region have above crustal average uranium and thorium concentrations. This is typical of the region.
- Uranium and thorium compositions of the soils and stream sediments are broadly similar.

- Soils on top of the Nolans Bore ore deposit have higher average uranium and thorium compositions than those outside of the deposit, although there is considerable overlap. In many instances, the first drill meter includes a mixture of soil and the underlying rock, some of which are mineralised.
- It is difficult to distinguish the stream sediment signature of the Nolans Bore deposit because of the masking effect of elevated levels of radionuclides in the region.

7.2.3 Vegetation Analysis

Earlier sampling of vegetation was undertaken at the same three locations as the soil samples reported in Table 7—3. The results are shown in Table 7—5.

Table 7—5 Vegetation Radionuclide Results

Location	Radionuclide Concentration (Bq/kg)									
	U238	U234	Th230	Ra226	Pb210	Po210	Th232	Ra228	Th228	K40
Mine site	0.9	2.1	0.3	14.0	25.5	21.6	0.4	22.0	7.2	433
Downstream of mine site	1.3	2.3	1.0	8.5	29.0	19.5	2.4	20.0	7.5	609
Background	1.1	1.6	1.1	26.5	38.0	23.3	2.4	69.5	21.9	531

The enhanced concentrations of Po210 and Pb210 are generally observed and primarily due to the decay of atmospheric radon (UNSCEAR 2000).

Extensive vegetation sampling has also been completed across the region, and these results are shown in Table 7—6.

Table 7—6 Summary of vegetation sampling

Vegetation type	Number of Assays	Uranium (average and range in parts per million (ppm))	Thorium (average and range in ppm)
Grass (on deposit)	9	0.022 (<0.01-0.06)	0.22 (0.1-0.39)
Grass (off deposit)	17	0.015 (<0.01-0.12)	0.14 (0.02-1.37)
Tree leaves (on deposit)[1]	10	0.046 (<0.01-0.06)	0.15 (0.03-0.59)
Tree leaves (off deposit)[2]	17	0.01 (<0.01-0.08)	0.02 (<0.01-0.04)
Tree leaves (on deposit)[3]	75	0.077 (<0.01-0.48)	0.537 (0.01-5.31)
Tree leaves (off deposit)[4]	1127	0.016 (<0.01-0.71)	0.021 (<0.01-0.34)

[1] Environmental sample with coincident grass and soil samples.
[2] Environmental sample with coincident grass and soil samples.
[3] Exploration sample from 2006-2013.
[4] Exploration sample from 2006-2013.

7.2.4 Groundwater Sampling

Two groundwater samples were collected and analysed and the results are presented in Table 7—7. Table 7—8 presents the additional groundwater sampling within and upstream of the Nolans Bore ore deposit.

The results show that the groundwater radionuclide concentrations are elevated and highly variable across the region.

Table 7—7 Groundwater Radionuclide Results

Location	Radionuclide Concentration (Bq/L)									
	U238	U234	Th230	Ra226	Pb210	Po210	Th232	Ra228	Th228	K40
Nolans Bore (stock bore)[5]	2.5	8.6	<0.05	0.15	<0.01	0.004	0.015	3.1	0.32	1.1
Aileron Roadhouse Bore	6.4	20.8	0.12	0.26	0.33	0.314	0.034	0.78	0.16	0.7

Table 7—8 Summary of Groundwater Sampling

Location	Number of Assays	Uranium (average in ppm)	Thorium (average in ppm)
In deposit	5	0.354	<0.0001
Upstream and off deposit	9	0.361	<0.0001

7.2.5 Dust Deposition

Dust deposition gauges were placed in September 2010 at four locations approximately two to three kilometres distant from the proposed mine area in approximately northwest, southeast, northeast and southwest directions, being downwind, upwind, and orthogonal to the prevailing southeast wind direction. Locations are showed in Figure 7-1. A summary of the baseline background results is provided in Table 7—9.

[5] Now abandoned and no longer accessible.

Table 7—9 Dust Deposition

Dust Deposition Gauge	Total Dust Deposition (g/m2/day)	Thorium Deposition (µg/m2/day)	Uranium Deposition (µg/m2/day)
NDDG-1 (NW)	0.067	0.36	0.20
NDDG-2 (SE)	0.017	0.16	0.07
NDDG-3 (SW)	0.041	0.40	0.29
NDDG-4 (NE)	0.025	0.14	0.08

The uranium and thorium concentrations in the deposited dust are relatively consistent at approximately 3 ppm and 10 ppm, respectively. These figures are consistent with worldwide background levels of radionuclides in soils (UNSCEAR 2000) and the average composition of the continental crust.

7.2.6 Dust Concentrations in Air

Between September 2010 and March 2011, dust concentration sampling was conducted to measure PM_{10} dust. The results show daily average PM_{10} dust concentrations varying between 1 and 35 µg/m^3 over the sampling period, with an average dust concentration of 16 µg/m^3. Radionuclide analyses were not conducted on the dust; however, based on the soil concentrations and the dust deposition results, giving uranium and thorium concentrations of 3 ppm and 10 ppm, respectively, and assuming that the dust is resuspended soil, the radionuclide concentrations in the air can be calculated. The results are 0.4 mBq/m^3 for uranium and 1.2 mBq/m^3 for thorium.

7.2.7 Radon and Thoron Concentrations

During 2015, real-time radon and thoron monitoring was carried out at Nolans Bore (Arafura 2016). The results indicate a high level of variability in both radon and thoron concentrations, up to two orders of magnitude, consistent with variations observed elsewhere.

The natural airborne radon and thoron concentrations are variable, ranging well over an order of magnitude in a typical 24-hour cycle and possibly up to three orders of magnitude.

During the sampling period, the average radon concentrations were calculated to be approximately 80 Bq/m^3, with average thoron concentrations being approximately 800 Bq/m^3.

The thoron activity concentrations are significantly higher than the radon activity concentrations. However, this is as expected (Arafura 2016) due to both the higher thorium content of the outcropping deposit and the shorter half-life of thoron.

In addition to real-time monitoring, longer-term radon and thoron concentration averages were determined. Detectors were placed in the field for a period of four months. The average concentrations of these results are provided in Table 7—10.

Table 7—10 Passive Radon and Thoron Averages

Location	Average concentration	
	Radon (Bq/m^3)	Thoron (Bq/m^3)
Within mine footprint	44	470
Outside mine footprint (regional)	29	120

7.3 Post-EIS Radiation Monitoring

Since the publication of the EIS, Arafura has increased the monitoring network of Environmental Radiation Monitoring Locations (ERMLs), which has enabled additional data to be collected to build on the existing baseline data. The ERMLs will continue to operate through construction and operations and into closure. The data will be used to determine the potential impacts of the Project. It is also expected that these ERMLs will be used post-closure to determine the effectiveness of closure activities.

Figure 7—4 shows the ERMLs at the Project site. A summary of the recent monitoring at the ERMLs is provided in the following sections.

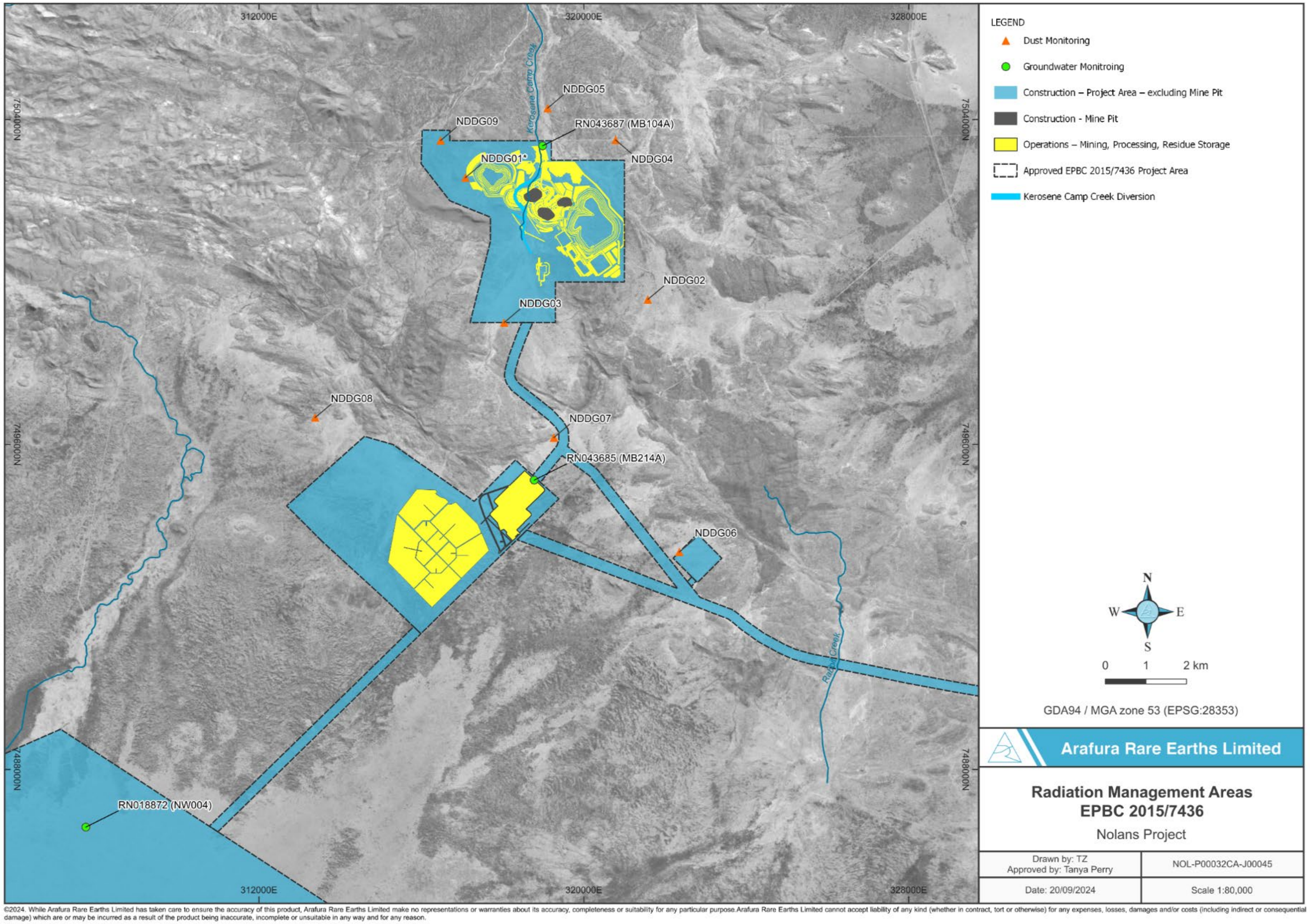


Figure 7—4 Current Nolans Project Environmental Radiation Monitoring Locations (ERMLs)

7.3.1 Radionuclide in Dust Monitoring

Two full years of dust deposition monitoring have occurred. Samples are collected on a quarterly basis from the eight sites shown on Figure 7—4, composited for a full year and then sent for gravimetric and radiometric analysis. A summary of results to date can be seen in Table 7—11 and Table 7—12 for rates of radionuclide deposition contained within the dust.

Table 7—11 Annual Average Monthly Dust Deposition

	Dust Deposition (g/m^2.month) (Average and range provided)	
	Year 1 (2022)	Year 2 (2023)
Average	1.12 (0.46 – 2.01)	0.78 (0.45 – 1.10)

Table 7—12 Annual Average Monthly Radionuclide Deposition

Analyte	Radionuclide Deposition (Bq/m^2 month) (Average and range provided)	
	Year 1 (2022)	Year 2 (2023)[6]
U238	0.03 (0.01 – 0.06)	0.04 (0.01 – 0.14)
U234	0.04 (0.01 – 0.10)	0.08 (0.01 – 0.41)[1]
Th230	0.03 (0.01 – 0.08)	0.05 (0.02 – 0.14)
Ra226	0.03 (0.01 – 0.07)	0.02 (0.01 – 0.05)
Pb210	3.89 (2.10 – 5.79)	4.08 (3.41 – 4.41)
Po210	3.88 (2.70 – 5.77)	3.37 (1.94 – 4.60)
Th232	0.02 (0.01 – 0.04)	0.02 (0.01 – 0.04)
Th228	0.03 (0.01 – 0.10)	N/A

The elevated Pb210 and Po210 results in Table 7—12 are due to environmental radon decaying. It is well documented that in the air, there are elevated concentrations of Pb210 and Po210 (UNSCEAR). Bonnyman in 1972 reported Pb210 deposition levels of 7.92 Bq/m^2. The elevated levels of Po210 are due to its ingrowth from Pb210.

[6] The Y2 result for U234 is influenced by one higher measurement. This is likely to be due to an analysis error, since the concentrations of U234 should be practically identical to the concentrations of U238 due to them being the same element. When this anomalous result is removed, the annual values for U234 are 0.04 (0.01 – 0.10), which is more consistent with the measured U238 values.

7.3.2 Radionuclides in Groundwater

In 2023 and 2024, sampling of groundwater was undertaken at four bores in the Project area and radiometrically analysed. Average results are shown in Table 7—13 and Table 7—14.

It is relevant to note that all these results are lower than the values reported in the EIS.

Table 7—13 Average Radionuclide Content (U238 Decay Chain)

Location	Radionuclide Concentration (Bq/l)						
	U238	U234	Th230	Ra226	Pb210	Po210	Rn222
Mine Area[7]	0.98	2.8	0.002	0.07	<0.013	0.002	2.0
Process Plant Area	0.60	1.7	<0.002	0.04	0.016	0.008	1.2
Borefield Area	--*	1.85	<0.002	0.03	0.028	0.006	--[8]

Table 7—14 Average Radionuclide Content (Th232 Decay Chain)

Location	Radionuclide Concentration (Bq/l)		
	Th232	Ra228	Th228
Mine Area	0.001	0.26	0.02
Process Plant Area	0.001	0.24	<0.02
Borefield Area	<0.001	0.11	<0.02

7.3.3 Ongoing and Future Environmental Radiation Monitoring

See Section 12.0 for an overview of the environmental radiation monitoring that will continue at the Project site.

[7] Mine area sample is down gradient and off deposit
[8] Excludes outlier data

8.0 RADIATION EXPOSURE AND MANAGEMENT

This section of the RPRWMP describes the management and controls for each of the Project phases. Arafura is committed to the health and safety of people and the protection of the environment. A risk-based approach will be applied to each phase of the Project to ensure that management and controls are commensurate with the radiological risk.

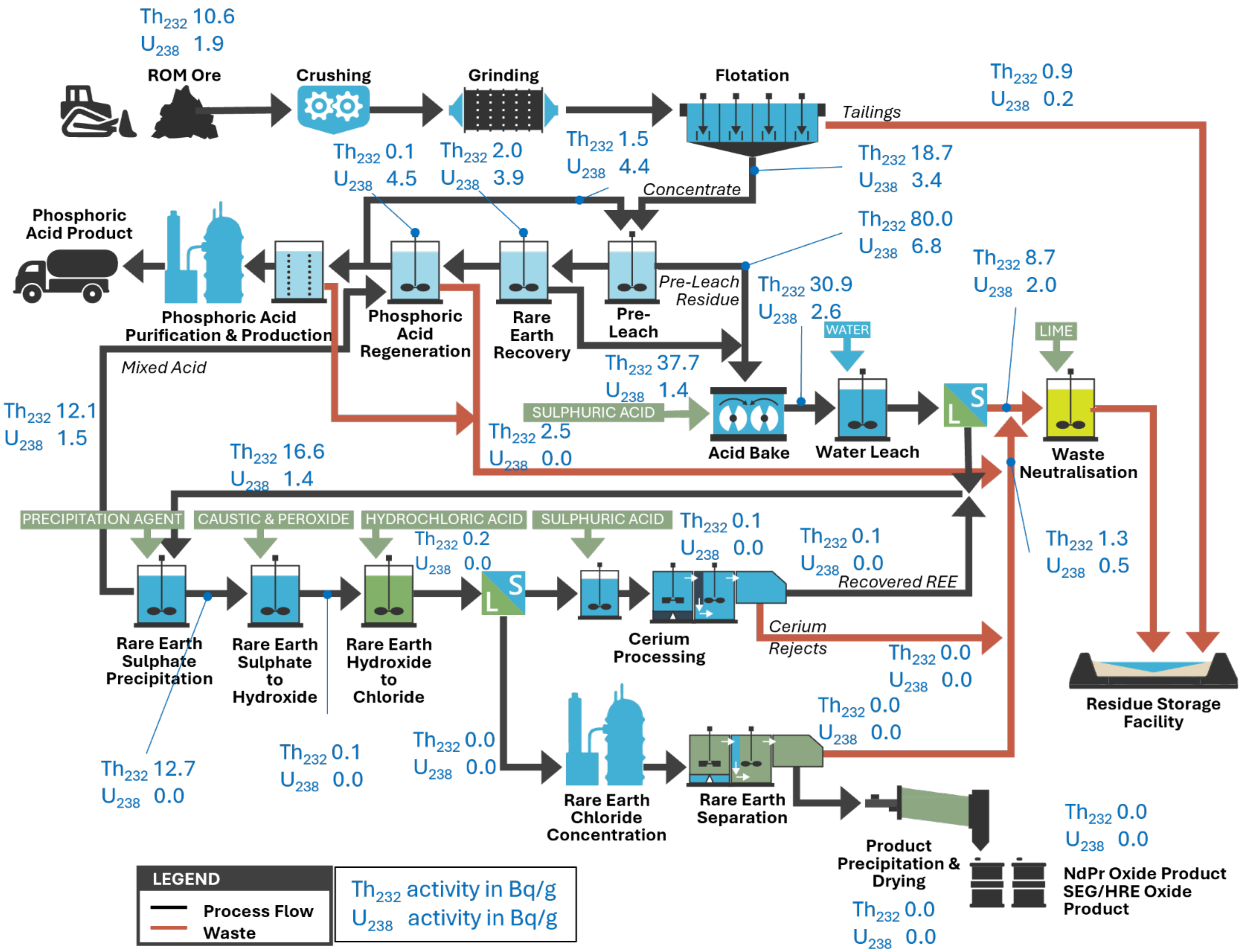
8.1 Radiological Characteristics of the Project

Arafura has a comprehensive understanding of the radiological characteristics of the Project. The mineralisation is well defined, with average mined ore concentrations of approximately 2,500 ppm for thorium (equivalent to 10.6 Bq/g) and 150 ppm for uranium (equivalent to 1.9 Bq/g).

For the processing of the ore, the deportment of radionuclides has been characterised through test work and is summarised in Figure 8—1.

Of note, radionuclides are removed through the process and reported to the RSF. Final products for sale that will be taken offsite are defined as non-radioactive.

The characterisation of the ore and the process streams provides the basis for determining the necessary controls to ensure that workers, the public and the environment are protected from any adverse levels of radiation.



Note: no Uranium or Thorium in the saleable products

Figure 8—1 Uranium and Thorium Deportment Through the Nolans Project Mining and Processing

8.2 Radiation Exposure Pathways

The management and controls apply to the radiation exposure pathways. For the Project, the primary radiation exposure pathways have been identified and are described as described in Sections 8.2.1 - 8.2.5 below.

8.2.1 External Gamma Irradiation

Gamma radiation is emitted from radioactive materials and depends upon the radionuclides in the materials and their concentration. Exposure to gamma radiation is usually controlled through:

- Limiting time of exposure.
- Separating the source of material from people or distancing people from the source.
- Shielding, where necessary.

Gamma radiation results in exposure inside the body from a source that is outside the body. Gamma radiation levels can be predicted based on empirical relationships between the different radionuclide concentrations and gamma radiation levels. Gamma radiation is also readily measurable using a handheld instrument or personal monitoring badges.

8.2.2 Inhalation of Long-lived Radionuclides in Dust

Dust can contain different radionuclides that can be inhaled. Depending upon the dust particle size and solubility of the radionuclides, the dose received from the inhalation can vary. The dose from dust inhalation is generally due to the longer-lived radionuclides in dust, which can continue to emit radiation until cleared from the body.

The chemical characteristics of the radionuclides mean they can be transported to different parts of the body through normal biokinetic processes. For predictive modelling, conservative default values are used when making dose assessments. During operations, dust inhalation will be measured through monitoring.

The radionuclide characteristics of the dust can also be measured, or knowledge of the process that generated the dust can be used to determine the characteristics.

8.2.3 Inhalation of Radon and Thoron Decay Products

Due to the presence of both uranium and thorium in the Project materials, there will be two gaseous isotopes of radon present. Radon-222 (known as radon) and Radon-220 (known as thoron). Each of these radon isotopes decay to produce decay products, which can be inhaled and deliver an immediate dose in the lungs.

The doses that arise from the inhalation of the isotopes of radon are treated differently from the doses received through the inhalation of radionuclides in dust. This is because the radon isotope decay products are short-lived, while the radionuclides in dust are long-lived (in this RPRWMP the term radon refers to the Radon-222 isotope, and the term thoron refers to the Radon-220 isotope).

8.2.4 Surface Contamination (As a Source of Potential Ingestion of Radionuclides)

Ingestion of radionuclides can occur when radioactive contamination is, for example, transferred from dirty hands to food. The ingestion pathway is generally a low exposure pathway and is not usually considered in worker dose assessment unless an incident occurs where there is exposure.

For the public, the ingestion pathway is considered. This could occur if radioactive emissions from the Project are deposited in the environment and are taken up into the food chain. The ingestion dose pathways can be predicted from air quality modelling before an operation commences and can be monitored during operations through environmental dust deposition monitoring.

8.2.5 Estimates of Total Dose

As part of the EIS (Arafura 2016), dose estimates were made for workers and the public. Dose estimates were revised following the publication of new dose factors by the ICRP in 2017.

The estimated doses continue to remain low and are defined as:

- Mineworkers – up to 5 mSv/y.
- Process Plant workers – up to 2.5 mSv/y.
- Accommodation village workers – up to 0.2 mSv/y.
- Residents of Aileron Roadhouse – up to 0.09 mSv/y.
- Residents of Alyuen Community and Alice Springs less than 0.05 mSv/y.

The occupational dose limit is 20 mSv/y, and the member of the public dose limit is 1 mSv/y.

To ensure that worker and public doses are optimised (and considered to be 'As Low As Reasonably Achievable – ALARA'), Arafura will implement internal management control levels. These are operational action levels that may be changed from time to time and set at levels lower than the dose limits that will trigger an investigation and subsequent additional controls.

The management control levels are:

- Occupational exposure – 10 mSv/y (with a pro-rate quarterly dose constraint of 2.5 mSv).
- Member of the public – 0.3 mSv/y.

8.3 Project Areas and Risk-Based Radiation Management Controls

Identification of potential radiation hazards and the controls that will be implemented are described in the following sections according to Project areas and phases, due to the varied radiation exposure profile across the site and the phases of the Project.

Table 8—1 describes the phases of the Project, and the Project areas are shown in Figure 8—2, Figure 8—3 and Figure 8—4.

Table 8—1 Summary of Project Phases and Radiation Exposure

Project Phase	Activities	Occupational, Public or Environmental Exposure Due to Activities	Controls
Construction – all of site preparation and construction *(Excluding work on mine pit footprint)*	▪ Earthworks. ▪ Borefield development. ▪ Majority of the Kerosene Camp Creek diversion for mine site development. ▪ Flood protection bunds and channels to prevent water flow into the mine area. ▪ Mine area water collection ponds and other surface water management structures. ▪ Process Plant Construction. ▪ RSF Construction.	No occupational or environmental exposure.	See Section 8.4. Note that any activities on the mine pit footprints will result in implementation of the mining 'operational controls' (see Section 8.5). However, this is not planned to occur during this phase of the Project. Figure 8-2 and Figure 8-3
Construction – Mine Pit Development and Operations – Mining	▪ Finalisation of the Kerosene Camp Creek diversion. ▪ Removal of mine overburden (waste or spoil). ▪ Mining of mineralised material and unmineralised NORM. ▪ Development and management of WRD.	Occupational and environmental exposure.	See Section 8.5. Figure 8-4
Commissioning and Operations – Processing	▪ Commissioning and operations of the Process Plant. ▪ Commissioning and operation of the RSF.	Occupational and environmental exposure.	See Section 8.6.
Closure	▪ Site decommissioning. ▪ Closure of the RSF.	To be defined.	See Section 13.0.

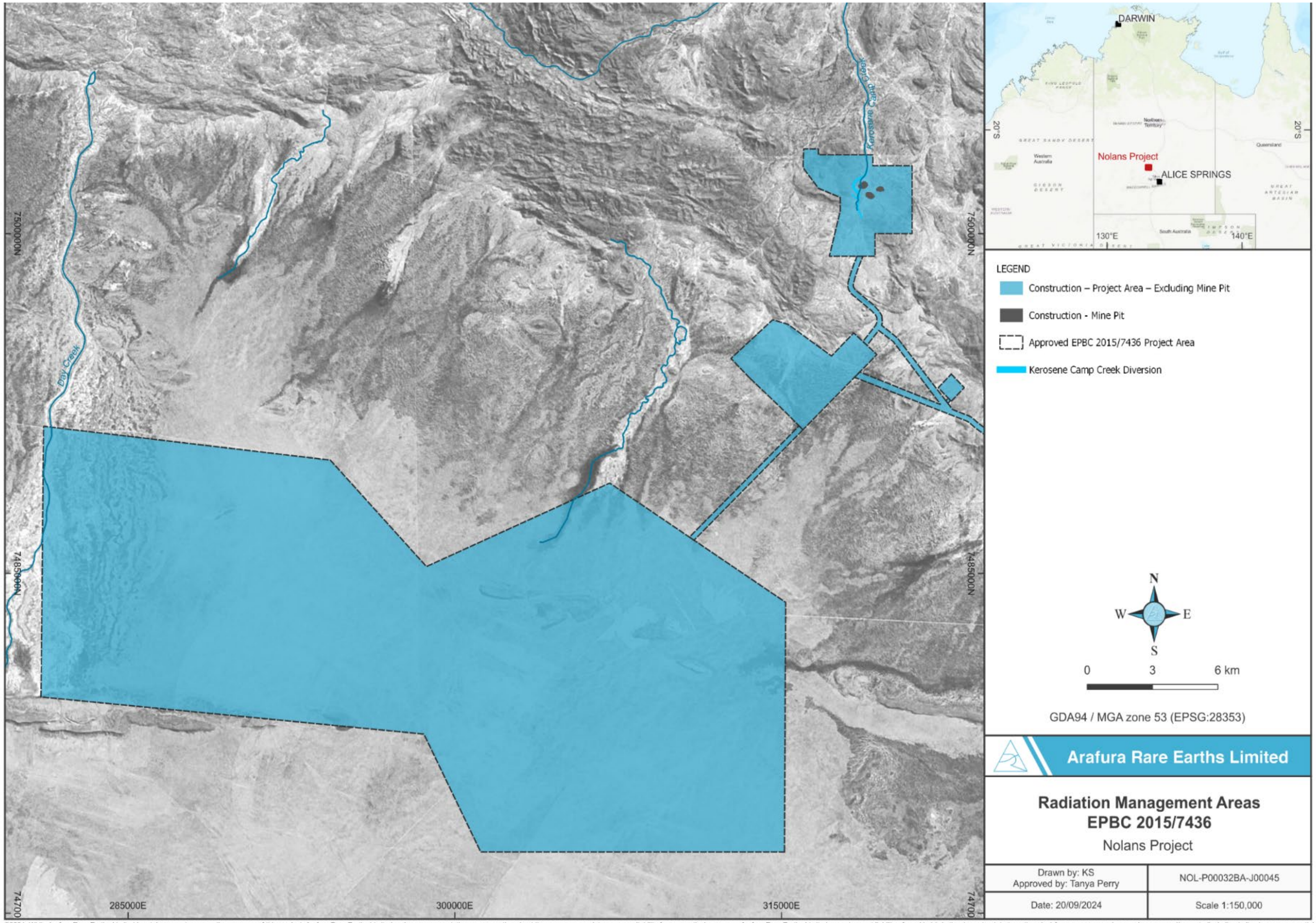


Figure 8—2 Project Areas – Construction

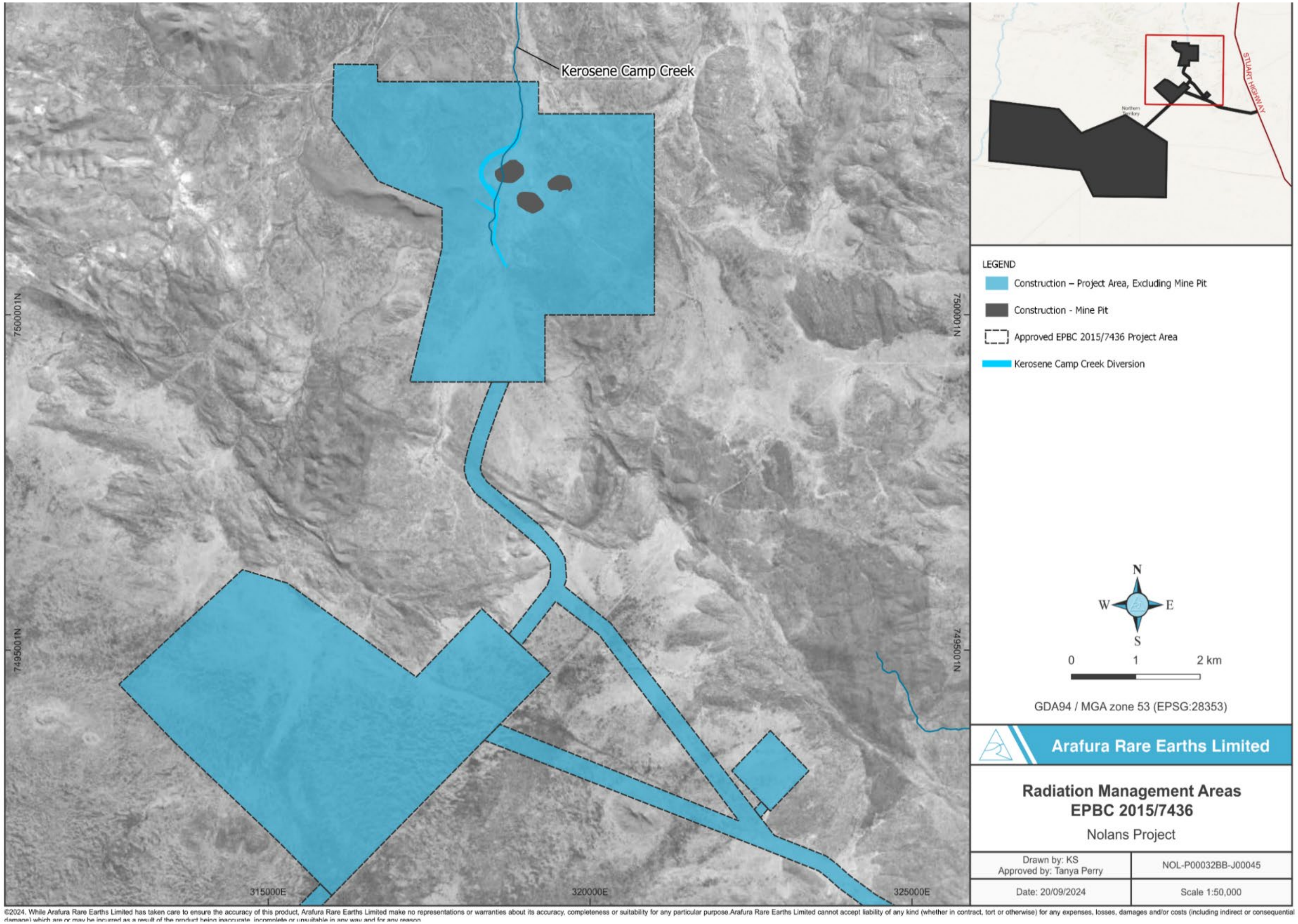


Figure 8—3 Project Areas – Construction, Closer View of Non-Borefield Areas

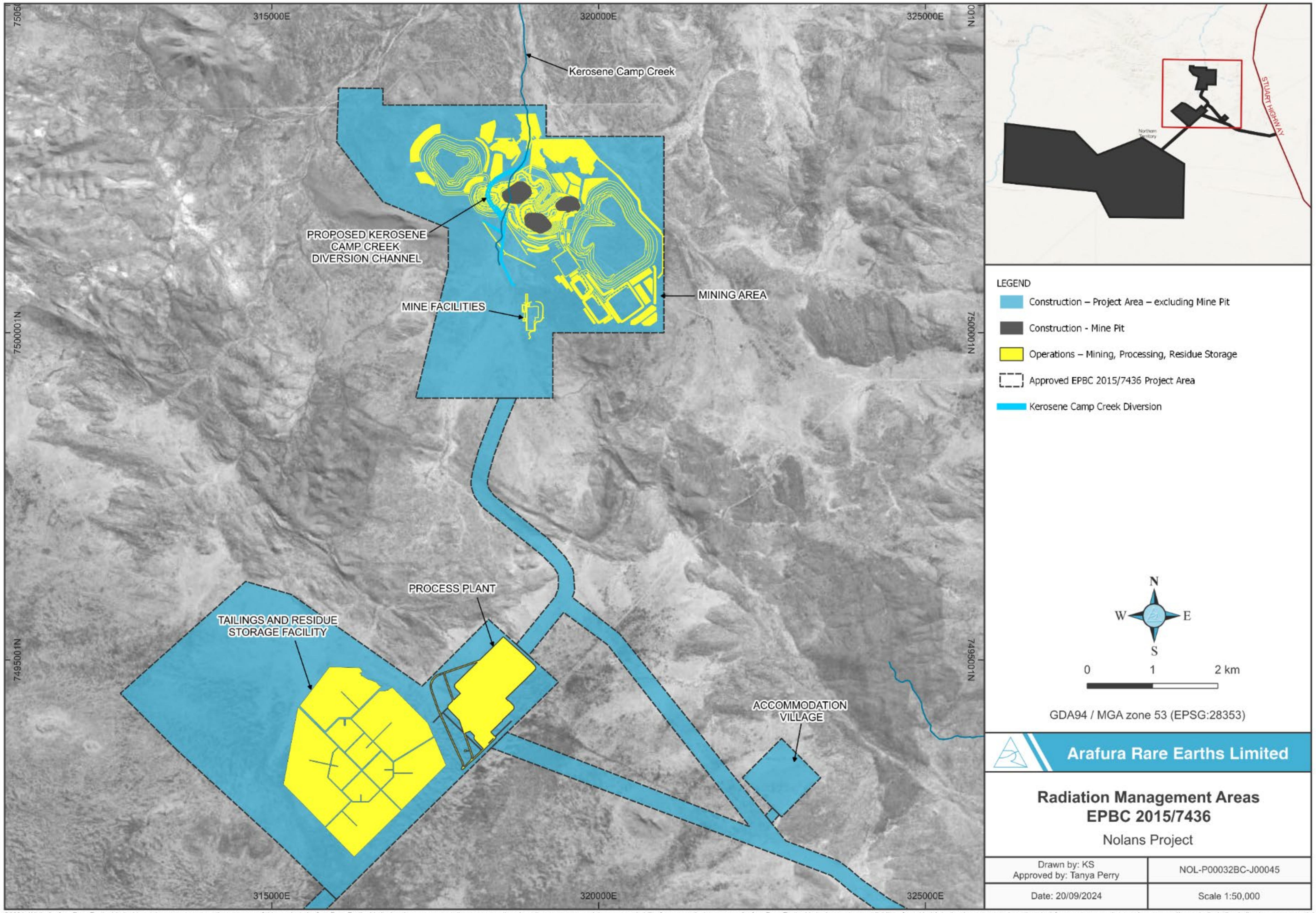


Figure 8—4 Project Areas – Construction and Operations – Mining, Processing and Residue Storage

8.4 Activity Description and Controls: Construction – Project Area, Excluding Mine Pit

The first construction works at the Project site will involve a site preparation works phase, including earthworks, roadworks, initial foundation concrete pouring, communications infrastructure, and installation of further water bores in the borefield. An overview of the works is provided below.

The general radiation management controls that will be applied from the recommencement of site preparation work and will continue to apply through all construction and operational phases of the Project are also described below.

Construction works will recommence soon after the Project Financial Investment Decision (FID) is made.

8.4.1 Activity Description

Mining Area, Excluding Mine Pits

No construction activities will occur on the mine pit footprint during this phase of the Project (see Figure 8—2 and Figure 8—3).

Construction activities adjacent to the mine pit area will include site preparation of surface water management infrastructure, consisting of:

- Majority of the Kerosene Camp Creek diversion to enable mine site development.
- Flood protection bunds and channels to prevent water flow into the mine pit area.
- Mine area water collection ponds and other surface water management structures.

Construction activities within the area surrounding the mine pits are scheduled to commence approximately 9-12 months after the recommencement of construction.

The actual development of the mine (pre-stripping and building internal mine infrastructure (including explosives compound and haul roads) will be conducted by the mining contractor and is considered an operational mining activity (see Section 8.5).

Process Plant

The Process Plant will be constructed using a traditional method. Following cut to fill earthworks, a modular approach is used with concrete bases, structural steel support structures, various mechanical equipment, tanks, electrical instrumentation control services and interconnecting piping.

A fundamental design feature of the Process Plant is containment for potential spills. Process tanks and vessels will be located within concrete bunds for secondary containment. Extraction or containment will be used as design controls where dust generation is expected.

The key areas of the Process Plant are described below.

Beneficiation Plant

The Beneficiation plant will include crushing, grinding and classification, flotation, tailings dewatering, a process water pond and beneficiation reagents preparation infrastructure. Where necessary, bunding will be installed for spill containment.

Hydrometallurgical Process Plant

The Hydrometallurgical Process Plant includes the majority of the shared infrastructure and services. The main Process Plant is a series of complex processing areas where mechanical equipment, including pumps, tanks and agitators, pressurised and non-pressurised vessels and filters are utilised for extraction and separation processes to treat the concentrate from the Beneficiation Plant. The products will be Neodymium and Praseodymium oxide (NdPr), and mixed middle-heavy rare earths (SEG/HRE) oxides.

The key controls in this area of the plant are secondary containment for any spillages and containment of dust-generating activities. Enclosed structures will be either naturally or mechanically ventilated.

Sulphuric Acid Plant

The Sulphuric Acid Plant consists of solid sulphur receipt and handling, sulphur melting and filtration, contact and absorption processes, and product acid cooling. Sulphur is burned in pure oxygen, not air, and therefore, the plant area also includes a cryogenic oxygen plant, which consists of air intake, compression, purification, heat exchange, distillation, and heat exchange equipment.

No radiological controls are required in this area.

Non-Process Infrastructure

Non-process Infrastructure (NPI) relates to the infrastructure to support construction and mining activities and includes the development of infrastructure within the following areas:

- mine area offices
- accommodation village
- power supply and distribution
- water supply and distribution
- wastewater collection and treatment
- waste management
- fuel storage and distribution
- access roads and tracks
- vehicle wash down
- communications.

Additional water monitoring and abstraction bores are also planned to be installed in the borefield area.

During this construction phase, the following controls will be implemented. As noted, these controls will continue through the main construction and operations phases.

8.4.2 General Controls

8.4.2.1 Worker HSE Induction, Including Radiation Safety Induction

All employees and contractors will receive an induction upon commencement (with an annual refresher), informing them of the hazards associated with the workplace. The induction will include an introduction to radiation and the implementation of controls to ensure radiation safety for personnel. Specific training will be provided to personnel handling process materials containing elevated levels of radionuclides, including mine pit workers.

Managers and supervisors will receive additional training in the recognition and management of situations that have the potential to increase a worker's exposure to radiation.

Information on radiation will be made available to new workers as required, and a key role of the Radiation Safety Officer (RSO) and staff will be communicating all aspects of radiation. At the completion of each reporting year, workers will receive a formal communication about their radiation exposures for the previous year.

The inductions and training will be developed and undertaken by qualified trainers under the instruction of the Project RSO.

8.4.2.2 Site Access

Access to the main operational site will be through a secure site entrance (which may be a manned gatehouse or a remote-controlled recorded access/egress arrangement). The system will link to a record-keeping system to ensure that all personnel accessing the site have been appropriately inducted and trained.

8.4.2.3 Administrative

The development of operational administrative controls in this phase will include:

- Establishment of a pre-employment medical check program.
- Development of safe work procedures, including radiation safety requirements.
- Identification of requirements for personal protective equipment (PPE) and quality assurance systems, such as fit testing of respirators and face masks.
- Development and implementation of procedures to segregate, isolate and clean contamination or contaminated equipment.
- Mandatory use of personal hygiene facilities (such as boot wash and handwash facilities) at entrances to lunchrooms and offices.
- Procedures and licencing of any laboratory or field-based equipment that uses radiation (such as x-ray fluoroscopy and portable handheld XRF instruments).

The final engineering and detailed design for the plant was not complete at the time of preparation of this RPRWMP. However, it is expected there will be a number of radiometric density gauges installed throughout the Process Plant. The procurement, licencing, transport and installation of these gauges will comply with the relevant legislation. Once in service, the gauges will be monitored by the RSO and operated in accordance with the legislation.

8.4.2.4 Pregnant Workers

Specific procedures for pregnant workers will be developed and applied to workers who declare their pregnancies. The process will involve raising awareness through training and refresher training and moving them into areas or tasks that ensure that doses to the unborn foetus will be less than 1 mSv/y. This is based on the presumption that the foetus will be afforded the same level of protection as applies to a Member of the Public.

8.4.2.5 Radiation Safety Officer

Arafura will employ a suitably qualified and experienced radiation safety professional during the initial phase as the Statutory RSO.

The statutory role will transition from the part-time role currently undertaken by Arafura's Principal Geologist.

The Australasian Radiation Protection Accreditation Board will accredit the Statutory RSO and will be provided with appropriate equipment, staffing, and facilities to ensure the adequate implementation of their duties.

The Statutory RSO will directly advise the site General Manager and will be responsible for:

- Fulfilling the responsibilities of the Statutory RSO, as required by the regulatory authority.
- Overseeing the implementation of the RPRWMP and its procedures in collaboration with the Arafura Environment Team.
- Ensuring that all regulatory requirements for radiation protection are met and that related reports are submitted on time.
- Advising senior management on radiation protection requirements.
- Ensuring that the various radiation-related procedures and programs outlined in this RPRWMP are developed in accordance with the relevant standards.

8.4.2.6 Health, Safety and Environmental Management System

Arafura has developed a Health, Safety and Environmental Management Systems (HSEMS) for the construction and operations activities. Radiation is a hazard that is considered and addressed in the HSEMS.

The HSEMS includes (but is not limited to):

- Work Instructions (WI) for routine tasks, based on job hazard analysis and the identification and assessment of potential radiation hazards, will be considered in their development.

- Permit to Work (PTW) process to ensure that appropriate steps are taken to identify and mitigate hazards and risks to people, environment and equipment.
- Job Hazard Analysis (JHA) process for situations when a WI is not available. The JHA serves the same function as a WI, which is to document how to complete a task in a step-by-step process, with hazards and controls identified and documented for each step. Authorisation of JHA shall be gained before commencing the task.
- Radiation Clearance Procedure for machinery and equipment leaving site.
- Clearance check process for tools and equipment leaving the Project Area.

8.5 Activity Description and Controls: Construction and Operations – Mine Pit and Mining

8.5.1 Radiation Area Control Status

The three main exposure pathways for the mine are:

- *Gamma exposure:* from working close to exposed mineralisation. Workers on foot (drill and blast crews, grade control and some technical staff) will have real-time gamma monitors to control gamma doses. Mining equipment operators have shielding from their equipment.
- *Dust Exposure:* from dust generated from mineralised material. Dust suppression through use of water sprays and air-conditioned cabins on vehicles enclosed will control exposures.
- *Inhalation of the decay products of radon:* these are not expected to be significant due to natural ventilation. Air-conditioned cabins will provide control for equipment operators. Monitoring will be undertaken, and respiratory protection will be used if necessary.

The following area classifications will be applied to the mine area and controls implemented accordingly:

Radiation Supervised Area – will be implemented for the full operational mining area, including mine pits, stockpiles and surrounds, ore haulage route, maintenance areas and truck parking area (go-line), due to the potential for radiation doses to exceed 1 mSv/y.

Radiation Controlled Area – will be implemented for mine development, drilling and other in-pit operations associated with ore mining, due to the potential for radiation doses to exceed 5 mSv/y.

Controlled areas will also be implemented for specific locations associated with mineralised material, as identified by the Statutory RSO, in consultation with the Chief Geologist and Mine Manager.

Note that the controls outlined in Section 8.4 will continue to apply.

8.5.2 Activity Description

Mine development, followed by mining of ore, is expected to commence approximately 2 years after FID. The work will be conducted by a dedicated mining services contractor.

Once the mine development work commences, the mine will be considered operational and the controls in this section will apply.

Early mine development activities include clearing and grubbing, finalisation of the initial Camp Creek diversion, pre-stripping, and construction of haul roads and stockpiles. Additional grade control and resource in-fill drilling together with assay sample preparation could also be undertaken.

Mining will use conventional open pit mining methods including drill and blast, waste and ore mining with hydraulic excavators, rear dump trucks and Run of Mine (ROM) haulage activities to transport ore to the Process Plant, approximately 8.5 km to the south.

The mine is expected to have a life of 28 years, with processing of ROM stockpiles to continue until fully depleted for a further 10 years.

8.5.3 Classification of Mined Materials

Mined material will be trucked from the mining operations to one of four locations based on the classification of the material type:

- Ore will be placed on the ROM stockpile with designated zones for each ore type. The different material types will then be blended to produce an average product for processing.
- Material defined as low-grade mineralisation will be stockpiled separately for future processing.
- Material defined as NORM waste will be placed in the centre of the Waste Rock Dump (WRD), where it will be progressively covered by benign waste material.
- Material defined as benign waste will be used to form the outer cover of the WRD, with some separately stored for final closure cover material.

The estimated quantities of these four material types across the life of the mining operation are listed in Table 8—2.

Table 8—2 Classification of Mined Material

Material	Approx LOM Volumes (Mt)	Combined Activity Concentration (Bq/g)	Comment
Ore[9]	39.9	≈ 10Bq/g	Classified as *radioactive*
Low grade ore	1.0	> 1Bq/g and < ≈10Bq/g	Classified as *radioactive*
NORM Waste	90.8	> 1Bq/g and < ≈5Bq/g	Classified as *radioactive*
Benign waste	87.2	< 1Bq/g	Not classified as *radioactive*

Note that the definition of NORM waste (where NORM stands for Naturally Occurring Radioactive Material) is material with naturally occurring uranium and thorium concentrations that exceed 80 ppm and 240 ppm, respectively.

8.5.4 Controls

8.5.4.1 Handling of Mined Materials

A key control for operations (and later closure) is to ensure that mined material is properly sorted and that material with low uranium and thorium levels is segregated and stored. Segregation of mined materials is necessary to support the building of the waste rock stockpiles, which will encapsulate the NORM waste.

Scanning devices, such as gate portals, have been shown to be inefficient due to the low levels of radioactivity in the mined materials. Arafura will utilise in-mine management methods used at nearly all other mines (including those mining radioactive materials).

[9] Some areas of higher grade material will be mined and stored separately and blended for processing

A feature of the Nolans Bore deposit is that the geology and layout of mineralisation lends itself to bulk analysis of materials. This allows for sorting decisions to be made in the mine itself, with materials being visually identifiable.

The following controls will be implemented:

- The primary control will be geological modelling, resource estimation and detailed mine planning, which will identify areas where radioactive mineralised material, low-grade altered rock and potential host rock NORM exist. Confirmatory in-pit geological mapping, radiometric surveys, grade control, drilling, and analysis will complement the mine planning.
- Quality assurance measures, such as regular monitoring, will be used to confirm the sorting of the mined materials.
- Grade Control Technicians will follow a safe work procedure to monitor gamma levels at the dig face or on rock piles.

Arafura will utilise material and production management software to provide data support and track the placement of mined materials.

8.5.4.2 Change Rooms

The Project will have a change room arrangement to enable workers to change into work clothes at the commencement of their shift and then shower and change into casual clothes at the end of their shift, as per the routine site requirements. The changerooms will also enable workers in the mine to shower and change before entering clean workplaces (such as offices). This requirement will apply to workers in designated *Radiation Supervised* and *Radiation Controlled* Areas.

Dirty clothes will be laundered on site, and wastewater will be sent to the on-site water treatment plant.

8.5.4.3 Inductions, Training and Information

In addition to the standard site induction, (as noted in Section 8.4.2.1), the mining contractor personnel will have an additional mine-specific radiation induction to include the specific radiation hazards associated with the mining activities. This will cover:

- Requirements for radiation monitoring.
- Hygiene controls and the minimisation of the spread of contamination.
- Importance of dust controls.
- Worker responsibilities with regard to instructions issued by the Statutory RSO.

Mine supervisors will receive additional training in the recognition and management of situations that have the potential to increase a worker's exposure to radiation.

8.5.4.4 Mobile Equipment Specifications

All heavy mobile equipment will be air-conditioned. Operating practices will stipulate windows to be closed and air conditioning always on. The aim is to minimise the potential impacts of dust.

8.5.4.5 Dust Suppression

Dust will be minimised using standard dust suppression techniques around processing buildings and product and tailing stockpiles areas as appropriate, i.e. wetting of materials before handling, wetting of roadways and dust collection systems on drills. Wearing of respiratory protection will depend on the exposure risk.

8.5.4.6 Wash-Down Facilities

A separate wash-down pad will be established for vehicles intending to leave site. All vehicles or equipment leaving site that have been used in the mining area, mining operation or in the Process Plant will be required to be washed by the user. The vehicles and equipment will then be checked for radioactive contamination by suitably trained personnel.

If free from contamination, a certificate will be issued, and the vehicle/item will be allowed to be removed from site. Washing, cleaning, and obtaining a radioactive contamination clearance are the responsibility of the equipment users, whether they are company staff or contractors.

Plant, equipment or items that have come into contact with radioactive materials, will not be allowed to leave site without a certificate of clearance or documentation, as required by the Transport Code (ARPANSA 2019).

8.5.4.7 Transport of Ore to Process Plant

Trucks will transport ore from the mine to the Process Plant. The ore has yet to be crushed at this stage and is expected to generate minimal dust during transport. In the event that dust is generated, water sprays will be used as a control, with trucks required to drive through a water spray arrangement.

8.5.4.8 Radiation Clearance Certificates

Certificates will be issued for items that are permanently leaving site, such as hire equipment items being returned to owners, earthmoving equipment and departing drill rigs. Copies of the certificates will be kept on file for future reference.

An item will be defined as not contaminated when there is less than 0.4 Bq/cm^2 for beta and gamma emitters, and low toxicity alpha emitters and less than 0.04 Bq/cm^2 for all other alpha emitters, as defined in the ARPANSA Transport Code (ARPANSA 2019). Equipment that cannot be cleaned below this level will be subject to controls, as defined by the Statutory RSO.

Other controls are personal protective equipment, procedural changes, housekeeping and job rotation.

8.5.4.9 Occupational Radiation Monitoring

The full suite of radiation monitoring to be implemented for Operations – Mining, Processing and Residue Storage is covered in Section 11.0.

8.6 Activity Description and Controls: Operations - Processing

8.6.1 Radiation Area Control Status

The three main exposure pathways for the Process Plant are:

- *Gamma exposure:* identified locations in the plant (pipes and tanks) contain sufficient quantities of gamma-emitting materials to represent an exposure hazard. The engineering controls for these areas include shielding and implementation of access controls.
- *Dust Exposure:* identified locations in the plant (driers, dry storage vessels and dust collectors) have the potential for generation of dust-containing radionuclides. The controls for these include containment, access control and specifically designed ventilation systems (with baghouses, as necessary).
- *Spillage of process materials:* these can become dust hazards if allowed to dry, or sources of gamma radiation. Controls for spillage are focussed on ensuring any spillage is contained and able to quickly and efficiently be cleaned using wet methods (such as hosing down to a sump) before it dries out.

Figure 8—5 shows the entire Process Plant and areas where radiation will be present. It can be seen that the green icon identifies the areas where spillage controls are necessary. The yellow and red icons identify areas where gamma and dust controls are required.

Radiation Supervised Area – the entire Process Plant and RSF will be designated as a Radiation Supervised Area, from the commencement of commissioning onwards.

Radiation Controlled Area – the areas denoted by the red and yellow icons in Figure 8—5 will be designated as Radiation Controlled Areas. The Statutory RSO and Process Plant Manager will review these over time.

Note that the previously identified controls will continue to apply for this phase.

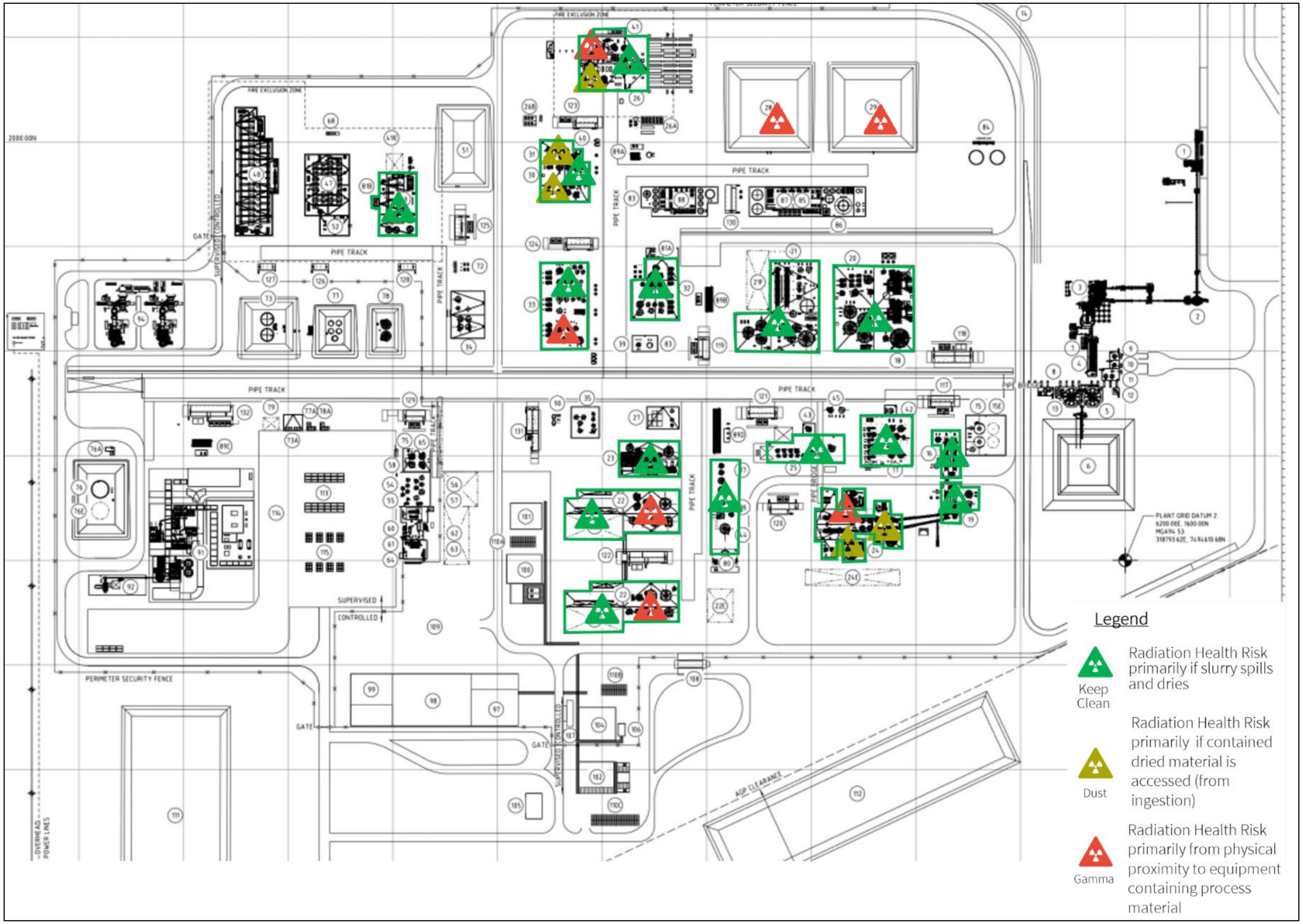


Figure 8—5 Radiation Control Areas of the Process Plant

8.6.2 Activity Description: Commissioning

Non-process infrastructure, namely buildings, wastewater treatment plant and other equipment, will be commissioned using industry-standard processes. Commissioning of the Process Plant will commence with mechanical completion testing, followed by energisation and testing with air and water. All equipment and control systems will be tested during this period.

The final stage of commissioning will involve the introduction of ore and chemical reagents. At this point, the Process Plant will effectively be live, and the risks associated with operations are assumed to be present. The risks of radiation exposure associated with the processing and refining of the ore will be managed and controlled from this point onwards.

8.6.3 Activity Description: Processing

At a high level, the process consists of the following production steps:

- Beneficiation.
- Phosphate extraction which consists of:
  - Pre-leaching the flotation concentrate in phosphoric acid.
  - Heating of the weak phosphoric acid to precipitate minor dissolved rare earths.
  - Separation of the pre-leach residue and precipitated rare earths for further processing in rare earth extraction.
  - Regeneration of the weak phosphoric acid with sulphuric acid, which is recycled from the rare earth extraction, to produce gypsum waste and strong phosphoric acid.
  - Purification of the excess phosphoric acid to produce a merchant-grade phosphoric acid for sale.
- Rare earth extraction, which further processes the rare earth-rich residue from phosphate extraction:
  - Acid baking in conventional paddle mixers with sulphuric acid at 250°C, followed by water leaching of the discharge.
  - Precipitation of clean rare earth sulphate from the water leach liquor to produce a mixed acid, which is recycled to phosphoric acid regeneration.
- Rare earth processing, where the rare earth sulphate is dissolved in water before precipitation of the rare earths as a hydroxide using caustic soda. Followed by selective leaching of non-cerium rare earths with hydrochloric acid to produce a cerium-free rare earth chloride solution and a low-grade cerium stream.
- Cerium processing, where the low-grade cerium is dissolved in sulphuric acid before processing in a solvent extraction circuit to produce a high-grade cerium liquor and a raffinate stream containing the remaining rare earths. The cerium liquor is neutralised and sent to the RSF, and the raffinate is recycled to recover the rare earths.

- Separation, which consists of two sequential rare earth solvent extraction circuits, for the production of a SEG/HRE rare earth product and an NdPr product. Both of which are precipitated using oxalic acid, prior to calcining to produce oxides.

All by-products from processing are retained in the processing circuit until either reutilised in the process, distributed for sale, or transferred to the RSF via a closed-circuit system. The individual processing areas are interconnected through various mechanical, piping and conveyor systems to ensure effective handling of the materials.

8.6.4 Controls

The general controls for the entire Process Plant are listed below. They are focused on ensuring that any spillages are controlled, contained and easily removed.

- Crushers and conveyor systems fitted with dust control measures, such as dust extraction.
- Enclosed equipment for targeted areas, incorporated during design to minimise dust emissions.
- Use of scrubbers or bag houses, where appropriate.
- Bunding to collect and contain spillages from tanks containing radioactive process slurries, with bunding sized to contain at least 110% of the volume of the largest tank in the event of a catastrophic failure.
- Tailings and the tailings pipeline corridor to be bunded to contain any spillage.
- Sufficient access and egress for mobile equipment to allow cleanup where large spills are possible.
- Wash-down water points and hoses supplied for spill cleanup.
- Procedures to control exposures during the maintenance of ventilation systems.

For the Radiation Controlled Areas (identified by the yellow and red icons on Figure 8—5), design reviews have been conducted and specific controls included:

- increased pipe and tank wall thicknesses, shielding or separation from walkways to reduce gamma radiation levels.
- restricted access - in some cases, key card access will be required.
- installation of dedicated extraction/ventilation systems.
- online monitoring.

The radiation monitoring program will assess worker and public doses. It will also be used to determine the effectiveness of the design and operational controls. See Section 11.0.

8.6.4.1 Radiation Clearance Certificates

Certificates will be issued for items that are permanently leaving site, such as hire equipment items being returned to owners, earthmoving equipment and departing drill rigs. Copies of the certificates will be kept on file for future reference. An item will be defined as not contaminated when there is less than 0.4 Bq/cm^2 for beta and gamma emitters and low toxicity alpha emitters and less than 0.04 Bq/cm^2 for all other alpha emitters, as defined in the ARPANSA Transport Code (ARPANSA 2019). Equipment that cannot be cleaned below this level will be subject to controls, as the Statutory RSO defines.

8.6.4.2 Occupational Radiation Monitoring

The full suite of radiation monitoring to be implemented for Operations – Mining, Processing and Residue Storage is covered in Section 11.0.

9.0 RADIOACTIVE WASTE MANAGEMENT

Arafura does not intend to transport radioactive waste from the Nolans Project Area. The mining, processing and waste management will all occur on site.

9.1 Storm and Wastewater Management

Water that has come in contact with mineralised material, such as stormwater runoff from the ore stockpile or Process Plant, may contain entrained radioactive materials. The aim of site design is to collect and contain all surface water. The method of control involves the construction of sedimentation dams, from which water can be reclaimed, and appropriate collection bunds and channels. Sedimentation and spillages of mineralised materials will be reclaimed when safe to do so.

Wastewater from wash-down areas and cleanup water will be captured for treatment, reuse, or evaporation.

9.2 Process Residue Management

The Process Plant will produce three individual residue streams:

- beneficiation residue (tailings).
- gypsum residue (gypsum).
- water leach residue (WLR).

All waste streams generated from the Process Plant will be pumped as a slurry to the RSF - a purpose-built, long-term, earth-fill, lined containment facility. The RSF footprint has been designed for the entire life of mine (LoM) and will be a permanent facility that will be closed and rehabilitated on site without the need for any further residue handling (see Site Closure Section 11.0 below).

The RSF will have a decant pond for liquor evaporation which may have a build-up of radioactive sediments over time. The pond will be excavated from time to time depending on the operational requirements.

The RSF will be constructed in a series of stages over the LoM. Each stage will comprise two individual cells, which are constructed and operating concurrently - one cell to store the beneficiation tailings stream and the second cell for the combined gypsum and WLR streams.

The beneficiation tailings cell will have a soil liner and full basin underdrainage system. The gypsum/water leach residue cell will be lined with a high-density polyethylene (HDPE) geomembrane located above a soil liner with underdrainage system, leakage control and recovery system. In total, 10 cells (five beneficiation tailings cells and five gypsum/water leach residue cells) will be constructed to store the LoM residue production of approximately 20.6 Mt.

Each cell will operate for approximately seven to nine years and will then be decommissioned and capped in preparation for rehabilitation, which will occur concurrently with ongoing operations for the first four cells (the final two immediately post-closure). See Section 13.0 for details regarding Site Closure.

Subsequent cells will be constructed immediately adjacent to the initial structure. In addition to the volume occupied by the residue, each cell can contain rainfall runoff due to the extremely short duration of storms experienced in Central Australia.

9.3 Contaminated Waste Management

In this document, radioactively contaminated waste is defined as material that is itself not radioactive but is contaminated by radioactive material, such as process materials. In many cases, this material can be decontaminated and recycled. In some cases, this is unable to occur, and disposal is required.

Radioactively contaminated waste materials generated by the Project are expected to include equipment and wastes from operational areas, including equipment, steel, discarded conveyor belts, rubber lining material, pipes, filter media and used protective equipment that is contaminated with radioactive ores or process materials.

The criteria for a waste to be defined as radioactively contaminated waste is when the material exceeds the operational surface contamination clearance standard (see APPENDIX G of this document) or has a total radionuclide concentration of more than 1 Bq/g.

Where practical, radioactively contaminated waste will be decontaminated and disposed of via normal waste disposal methods or sent for recycling. Where this is not possible, and depending on the nature of the radioactively contaminated waste, several disposal options would be available as follows:

- Incorporation into the waste rock dump.
- Disposal in a dedicated contaminated waste on-site landfill facility (note that this may be a separate area of the site landfill).
- Disposal into the mine at the end of operations.

The Project will capture and retain records of the disposal, including type of material, quantities and locations of radioactively contaminated waste.

Arafura will document and implement a contaminated waste management procedure (refer to APPENDIX K), which aims to minimise the quantities of waste to be disposed of.

Arafura recognises that additional waste disposal licences are required under the *Northern Territory Radiation Protection and Control Act 2004* and Regulations 2007. These will be obtained prior to commencement of the Construction – Mine Pit phase.

9.4 Additional Controls

The current proposal for the Nolans Project does not include the transport of radioactive products or waste offsite. Radioactive samples may require transport off site, in which case Arafura will engage a qualified service provider to transport the materials. Arafura's Radiation Transport Requirements are specified in APPENDIX B and an associated Radiation Material Transport Procedure in APPENDIX C, in accordance with the ARPANSA Transport Code (ARPANSA 2019). These documents will be implemented as part of Arafura's Health and Safety Management System.

The Radiation Transport Requirements will be provided to any service provider engaged by Arafura to transport radioactive materials offsite. The document details the management requirements that the service provider must meet and have appropriately reflected in their Transport Management Plan.

To support the RPRWMP, the following procedures have been developed and included as appendices of this Plan:

- Radioactive Materials Transport Management Requirements (APPENDIX B)
- Radiation Transport Management Procedure (APPENDIX C)
- Gamma Radiation Monitoring Procedure (APPENDIX D)
- Long Lived Radionuclides in Dust Sampling Procedure (APPENDIX E)
- Radon Decay Product Sampling Procedure (APPENDIX F)
- Thoron Decay Product Sampling Procedure (APPENDIX G)
- Radiation Surface Contamination Monitoring Procedure (APPENDIX H)
- Radiation Gauges and Sealed Sources of Radiation Management Procedure (APPENDIX I)
- Dose Assessment Procedure (APPENDIX J)
- Radiation Equipment Clearance Procedure (APPENDIX K)
- Radioactively Contaminated Waste Procedure (APPENDIX L)
- Environmental Radiation Monitoring Procedure (APPENDIX M)

The procedures are integrated within and support the Project's HSEMS.

10.0 DEMONSTRATION OF COMPLIANCE

Compliance requirements for radiation impacts relate to dose limits for workers and members of the public and screening levels for non-human biota as outlined in Section 6.1 (Approach to Radiation) and 12.2 (Impacts to Non-Human Biota). Ongoing monitoring aims to ensure that impacts do not exceed compliance levels and that action levels are established to provide timely alerts when doses may be approaching compliance levels. In Section 16, the company commits to providing a statement of compliance as part of the annual report submitted to DCCEEW. See APPENDIX M.

11.0 OCCUPATIONAL RADIATION MONITORING

The purpose of the occupational radiation monitoring program is to achieve three key aims:

- To provide raw data for the assessment of worker and public doses. The calculated doses are then compared to the recognised dose limits and the internal Arafura dose constraints. As noted in Table 11—3, doses for workers will be assessed on a three-month basis and compared to pro-rata three-month limits and constraints.
- To identify unexpected changes in the radiation levels, which will act as initiators of further investigations. Table 11—3 provides the formal defined action levels.
- To ensure that controls are effective as designed and continue to operate as required.

Upon commencement of commissioning of the Process Plant, a two-stage monitoring program will be implemented for all personnel working in the process and waste storage facilities, as described below.

The first stage will focus on start-up and commissioning, with the twin aims of confirming the preliminary dose estimates and ensuring that the installed radiation controls are effective. The second stage will be focused on routine operations.

11.1 Commissioning

The Commissioning Radiation Monitoring Program is outlined in Table 11—1 and is expected to run for approximately three to six months or when the process is deemed to be stable. Once this point has been reached, a review of all monitoring will be undertaken, and a decision will be made on implementing the Operations Radiation Monitoring Program, as outlined in Table 11—2.

A key part of the commissioning monitoring program is assuring that the design controls (such as tank wall thicknesses and access controls) are effective. As areas of the Process Plant are commissioned, specifically the controlled areas identified in Figure 8—5, routine monitoring will occur, with results documented. A review will be undertaken where controls are not achieving the desired outcomes.

Table 11—1 Commissioning Radiation Monitoring Program

Radiation Exposure Pathway and Monitoring Method	Mine	Process Plant	Administration and Workshop Areas
Gamma radiation Survey with handheld monitor.	Weekly surveys in mining operations areas, including: ▪ Mine pit. ▪ Truck unloading areas. ▪ Go-line. ▪ Maintenance and office areas. ▪ Sample layout and preparation areas. Monitoring to commence once the ore body is contacted or when drilling commences.	▪ Weekly walkthrough survey of all plant areas.	Monthly area surveys
Gamma radiation Personal OSLD badges.	▪ Real-time monitoring of workers in mine pit. ▪ Monthly OSLD badges on all production miners (those involved with ore). ▪ Monthly OSLD badges on selected development miners (those not involved with ore). ▪ Monthly OSLD badges on selected support staff (such as maintenance personnel).	▪ Monthly OSLD badges on all Process Plant workers. ▪ Monthly OSLD badges on selected support staff (such as all maintenance personnel).	*Not applicable*
Airborne dust Sampling pumps with determination filter paper, dust mass and gross alpha.	Five times per week sampling of personal dust monitors Note 1 for: ▪ Equipment operators ▪ Maintenance personnel	▪ Ten times per week sampling of personal dust monitors Note 1. ▪ Ten fixed location samples each week in selected work areas.	Monthly area samples
Radon and Thoron Decay Products Sampling using the appropriate method.	Selective, real-time continuous monitoring in mining area. Daily radon and thoron decay product sample in each mining area.	▪ Weekly grab samples in Process Plant.	*Not applicable*

Radiation Exposure Pathway and Monitoring Method	Mine	Process Plant	Administration and Workshop Areas
Surface Contamination Surface alpha and beta monitoring.	Weekly survey of: ▪ Workshop ▪ Offices ▪ Lunchroom ▪ Change room	Monthly survey of: ▪ Process Plant ▪ Workshop ▪ Offices ▪ Lunchroom ▪ Change room	Monthly area survey

Note 1: Personal dust monitors are portable devices attached to individuals to assess an individual's exposure levels to dust. A random subset of personnel will be selected each week (5 from mining area, 10 from processing area) to wear the devices.

11.2 Operations

Table 11—2 Operations Radiation Monitoring Program

Radiation Exposure Pathway and Monitoring Method	Mine	Process Plant	Administration and Workshop Areas
Gamma radiation Survey with handheld monitor.	Monthly areas surveys in mining operations areas, including: ▪ Mine pit. ▪ Truck unloading areas. ▪ Go-line. ▪ Maintenance areas. ▪ Geological sample layout and preparation areas – when in use	Monthly walkthrough survey of all Process Plant areas, including conveyors.	Quarterly area surveys
Gamma radiation Personal OSLD badges	▪ Real-time monitoring of workers in pit. ▪ Quarterly OSLD badges on production miners (those involved with ore). ▪ Quarterly OSLD badges on selected development miners (those not involved with ore). ▪ Quarterly OSLD badges on selected	▪ Quarterly OSLD badges on all Process Plant workers. ▪ Quarterly OSLD badges on selected support staff (such as maintenance personnel).	*Not applicable*

Radiation Exposure Pathway and Monitoring Method	Mine	Process Plant	Administration and Workshop Areas
	support staff (such as maintenance personnel).		
Airborne dust Sampling pumps with radiometric and gravimetric analysis of filters.	Five times per week sampling of personal dust monitors Note 1 for: ▪ Equipment operators ▪ Maintenance personnel ▪ Geological sample layout and preparation areas – when in use	▪ Ten times per week sampling of personal dust monitors Note 1. Ten fixed location samples each week in selected work areas.	Monthly area samples
Radon and Thoron Decay Products Sample using the appropriate method.	Selective real-time continuous monitoring in mining area. Daily radon and thoron decay product grab sample in each mining area.	Monthly grab samples in concentrator area and hydrometallurgical area.	*Not applicable*
Surface Contamination Surface alpha and beta monitoring.	Monthly survey of: ▪ Workshop ▪ Lunchroom ▪ Offices ▪ Change rooms	Monthly survey of: ▪ Plant ▪ Workshop ▪ Lunchroom ▪ Offices ▪ Change rooms ▪ Laundry	Quarterly area survey

Note 1: Personal dust monitors are portable devices that are attached to individuals in order to assess an individual's exposure levels to dust. A random subset of personnel will be selected each week (5 from mining area, 10 from processing area) to wear the devices.

An overview of the monitoring methods is provided below, and monitoring methods and training will be developed to ensure that staff undertake monitoring in the correct manner.

Gamma radiation:

- Survey with handheld gamma monitor.
- Personal gamma radiation badges.
- For identified tasks, real-time electronic gamma dosimeters will be used to provide immediate and detailed information for task management.

Radionuclides in airborne dust:

- Low-volume air sampling pumps with inhalable sampling heads will be used to collect an air sample onto a filter paper - which would then be gross alpha counted to determine the alpha activity concentration in air. The collected mass would also be measured to determine the mass concentration in the air.

Radon and thoron decay product concentrations:

- Grab a sample using the Borak method (note that there are a range of methods available (DMP 2010)).

Ingestion of radionuclides:

- Walkthrough surveys of workplaces, change rooms and offices will be conducted using a surface contamination probe.

11.3 Action Levels

The company has established action levels (also known as investigation or trigger levels) to identify radiation levels requiring investigation and additional controls. The action levels do not represent an immediate danger to life and health; rather, they are a leading indicator for management. The action levels are based on published recommendations and amended to take into account the particular exposure pathways for the operation. With the aim of identifying when exposures, if left unattended, may lead to doses that exceed the annual dose limits (Department of Mines and Petroleum 2010). Managing Naturally Occurring Radioactive Material (NORM) in mining and mineral processing guideline. NORM Reporting requirements: Resources Safety, Department of Mines and Petroleum, Western Australia).

If radiation measurements are at or above Arafura's Action Levels, then the responses detailed in Table 11—3 shall occur immediately. Note that the intention of the Action Level is to initiate an investigation, with the aim of identifying root causes. The method of investigation to be applied must align with the requirements of the HSEMS.

Table 11—3 Site Wide Radiation Action Levels

Radiation Measurement Type	Action Level	Response
Gamma radiation (handheld)	5 µSv/h	▪ Investigate and identify source. ▪ Consider additional shielding. ▪ Provide real-time electronic monitoring.
Gamma radiation (real-time monitors) - external gamma radiation	100 µSv/day	▪ Investigate. ▪ Consider worker rotation, where exposure management is required.
Gamma radiation (OSLD) (monthly result)	1 mSv/month	▪ Investigate and identify source. ▪ Consider worker rotation, where exposure management is required.
Radon/thoron decay product concentrations	2 $\mu J/m^3$	▪ Increase monitoring – if levels do not reduce, consider PPE or ventilation.
Surface Contamination	Visual contamination and/or 0.4 Bq/m^2 ($\alpha+\beta$)	▪ Immediate clean up in "clean" areas. ▪ Notification to work area supervisor
Airborne Dust	0.2Bq/m^3	▪ Identify source and review controls. ▪ Investigate additional controls.
Total Dose	2.5 mSv per quarter	▪ Investigate exposure pathways and review controls.

11.3.1.1 Monitoring Equipment and Support

Arafura will source monitoring equipment that is approved for use by the NT Regulator.

Table 11—4 provides a typical list of monitoring equipment.

In addition, the monitoring programs will ensure the following:

- Recognised sampling methodologies are documented and regularly reviewed, including pre-operational checks.
- Procedures for routine instrument calibration, including regular traceable calibration checks and more frequent on-site calibration checks.
- Spare instruments are used for redundancy and when equipment is undergoing off-site calibration.
- The results of all calibrations of radiation monitoring equipment are recorded and registered by the Statutory RSO.
- The calibration records will contain the instrument type, model and serial number of the instrument, the date of the calibration and the particular radiation source used.

- An instrument maintenance and repair program are developed.

Arafura will establish quality assurance in the context of the broader health, safety and environmental management plan, and in accordance with Australian Standards. Radiation protection requirements will be part of this system.

Table 11—4 List of Typical Equipment Required for Occupational Radiation Monitoring

Radiation Measurement Type	Sampling Methods and Equipment
Gamma radiation	▪ Handheld gamma radiation monitor. ▪ Electronic dosimeters.
Personal gamma monitor	▪ OSLD badges (provided and analysed by a service provider).
Airborne Dust	▪ 2 L/min personal dust pumps fitted with approved inhalable filter holders. ▪ Microbalance for weighing filters. ▪ Alpha slide drawer assembly and rate-meter.
Radon and Thoron Decay Products	▪ Real-time radon and thoron detectors. ▪ 2 L/min personal dust pumps fitted with approved inhalable filter holders. ▪ Portable alpha slide drawer assembly and rate-meter.
Surface contamination	▪ Surface contamination probe and rate-meter.

11.3.1.2 Dose Assessment Method

The method for calculating worker and public doses will be in accordance with the recognised international methods outlined by the ICRP (ICRP 2007), the IAEA (IAEA 2014) and in Australia by ARPANSA (ARPANSA 2005). A summary is provided below.

The total dose is calculated as the sum of the committed effective doses from each of the exposure pathways, which are:

- Irradiation by gamma radiation.
- Inhalation of the decay products of radon and thoron.
- Inhalation of radionuclides in dust.

11.3.1.3 Gamma Radiation

OSLD badges will be provided to individuals in workgroups and the average will be applied across the entire workgroup. When the results for an entire workgroup are not available (for example, through a mass loss of badges), then estimates will be made based on the previous set of results. The estimates will be made by the Statutory RSO, who will take into account the work conditions during the period when monitors were not available. All assumptions will be recorded.

Individual results that are anomalous may be excluded from the overall workgroup average, if there is good reason and this reason is formally justified and noted. For example, an outlier may be due to identified variances in work, tasks, hours or incidents, which do not reflect the overall workgroup. Therefore, after investigation, the Statutory RSO may exclude this result and record the justification for its exclusion.

11.3.1.4 Radionuclides in Dust

The assessment of dose from the inhalation of radionuclides in dust can be complex. The recognised process considers factors such as the radionuclide composition of the dust and its characteristics (including particle size, solubility, and biokinetics). Summary dose conversion factors (which are factors that convert an intake into a dose) are provided in Table 11—5 and are based on the most conservative solubility values provided by ICRP (ICRP 2017) and the relative radionuclide activity concentrations.

Note that dose conversion factors are provided for two particle sizes. The dose assessment is anticipated to use the more conservative 1 µm factors. However, there may be circumstances where the factors for 5 µm may be used. These will be determined and justified by the Statutory RSO.

Table 11—5 Dust Dose Conversion Factors

Dust Type	Dust Dose Conversion Factor (µSv/αdps*)	
	AMAD** = 1 µm	AMAD = 5 µm
Ore dust	6.0	3.5
Beneficiation tailings	6.2	3.6
Beneficiation concentrate	5.9	3.4
Processing residue	5.4	3.1

* The unit αdps refers to '*alpha disintegrations per second*' and is measured during gross alpha counting of dust filters.

**AMAD = Activity Median Aerodynamic Diameter

When calculating a dust dose, the following steps will be undertaken:

- Determine an average long-lived radionuclide concentration in air (in units of αdps/m^3) by averaging the activity concentrations for a number of dust samples for a particular workgroup.
- Multiply the average concentration by the exposure period in hours to determine exposure (in αdps h/m^3) for the exposure period.
- Multiply by the standard breathing rate of 1.2 m^3/h to give an intake (αdps) for the exposure period.
- Multiply by the dust dose conversion factor to give a dose (µSv) for the exposure period.

11.3.1.5 Radon and Thoron Decay Products

The general method for calculating doses from exposure to radon and thoron decay products is based on determining exposure and then applying a dose conversion factor. The ICRP has recently adopted a new dose conversion factor for radon and thoron decay products, and these are listed in Table 11—

6. Note that a calculated average is included in this table, as the ICRP dose conversion factors do not cover all workplace types.

Table 11—6 Radon and Thoron Decay Product Dose Conversion Factors

Project Area	Dose Conversion Factor (mSv per $mJ.h.m^{-3}$)	
	Radon (Rn222) Decay Products	Thoron (RN220) Decay Products
Mining environment	3.1	1.4
Indoor Workplaces	5.7	1.6
Average	4.4	1.5

When calculating radon and thoron decay product dose, the following steps will be taken:

- Determine average radon and thoron decay product concentration in air (in units of $\mu J/m^3$) by averaging the activity concentrations for a number of filter samples for a particular workgroup. The sampling methods are detailed above.
- Multiply the average concentration by the exposure period in hours to determine exposure (in $\mu J.h/m^3$) for the exposure period.
- Multiply by the standard breathing rate of 1.2 m^3/h, to give an intake (µJ) for the exposure period.
- Convert µJ to mJ and apply dose conversion factor to give dose (mSv) for the exposure period.

12.0 ENVIRONMENTAL MONITORING – CONSTRUCTION AND OPERATIONS

12.1 Monitoring Program

Arafura has undertaken environmental baseline monitoring since the commencement of exploration and has a detailed database of results (as summarised in Section 7.0).

A fixed network of eight (8) Environmental Radiation Monitoring Locations (ERMLs) was installed by Arafura in 2020 for the purposes of further baseline radiological assessment. The baseline program is intended to transition to an operational monitoring network.

The purpose of the ERML network is to provide a standard and regular method to monitor potential increases in environmental radioactivity due to the operation of the Project. The monitoring results will be compared to the pre-operational results and reported annually. On a rotational basis, a high-volume sampler may be used, where power is available.

The ERMLs will continue to function through the operation phase and then continue post-closure. This will provide a continuous record of any impact the Project has on the environment.

The pre-operational baseline data will also provide the naturally occurring radiation levels that will be subtracted from the member of public dose estimates to ensure that only the Project increment is being reported.

Figure 7—4 shows the locations of existing environmental dust monitoring sites, which are the locations of the ERMLs. Table 12—1 outlines the monitoring that will be undertaken at each ERML, together with the timing for implementation. This monitoring will build from the earlier baseline data collected.

Table 12—1 Environmental Radiation Monitoring Location Program

Medium	Analysis Parameter	Monitoring at each ERML	Use	Timing for implementation
Air	Ambient gamma radiation levels.	At each ERML - handheld gamma meter	Identification of Changes	Area survey prior to the recommencement of construction. Once every 3 years at the ERMLs.
	Radon and Thoron concentrations in air.	Quarterly passive detectors for radon and thoron.	Identification of Changes to Public Dose Assessment.	Implement for commencement of Construction – Mine Pit.
	Dust concentrations in air and radionuclide analysis of collected dust for the long-lived	High Vol Sampler (power required) established at the camp.	Public Dose Assessment.	For recommencement of construction.

Medium	Analysis Parameter	Monitoring at each ERML	Use	Timing for implementation
	radionuclides of U and Th decay chains.	(Location to be considered following initial data collection).		
Dust - naturally depositing from air	Dust deposition from air and analysis for long-lived radionuclides in the U and Th decay chains.	Quarterly passive deposition gauge and analysis of annual composite for mass and radionuclides.	Identification of Changes Non-human biota assessment.	Dust collection and analysis to continue, as described in Section 7.3 (baseline). Non-human biota assessment to follow commencement of Operations – Mine and Process Plant.
Soil	Radionuclides in soils and analysis for long-lived radionuclides in the U and Th decay chains.	Surface and 15cm soil samples and at the location of ERML and prior to closure.	Identification of changes. Identification of any post-contamination (for closure).	Prior to commencement of Operations – Mining. Prior to commencement of site closure.
Groundwater (GW)	Gross α + Gross β.	Consistent with existing monitoring program (see Section 7.3.2).	Identification of Changes.	Continue current annual sampling.
	Elemental U and Th.			
	Radionuclides - long-lived U and Th decay chains.	One-off selected bores.		Prior to commencement of Operations – Mining.

Note: For dust deposition, elemental analysis of the dust can also assist in providing an indication of the source of the deposited dusts.

12.2 Impacts on Non-Human Biota

The recognised method for determining the impacts on non-human biota (NHB) is the ERICA assessment method (where ERICA is short for Environmental Risk from Ionising Contaminants: Assessment and Management). ARPANSA notes that the ERICA Software Tool is applicable for use in Australia for assessing radiological impacts to NHB (ARPANSA 2010). The software uses changes in media radionuclide concentrations and species-specific whole-body concentration ratios to provide a standardised measure of radiological impact to reference species.

The latest version of the ERICA software was released in June 2023 (version 2.0) (ERICA 2023).

Arafura undertook predictive ERICA modelling for the EIS, which indicated that radiological impacts to non-human species would be low. To confirm the modelling and provide ongoing monitoring, Arafura will undertake ERICA assessments for standard species, including Australian-specific species that have published concentration ratios.

ARPANSA notes that a screening level for non-human biota of 10 μGy/h is appropriate and that exceedances of this level should initiate a more detailed investigation (Reference: Guide for Radiation Protection of the Environment, Guide G-1 ARPANSA 2015).

Assessments will be undertaken at locations defined by the location of the ERMLs. This is because the *media concentration* data, which is the foundation of an ERICA assessment, would be derived from annual composites of dust deposition monitoring results at the established ERMLs.

Established natural background radionuclide concentrations will be subtracted from the sample results to ensure that only project-originated materials are considered in the impact assessment.

ERICA assessments will commence once the operations phase commences and be conducted annually initially, with the intention to reduce the frequency of assessment if the collected data supports a lower-risk monitoring program.

13.0 SITE CLOSURE

As described in Section 9.2, Project closure planning will be progressive over the life of the Project to meet the required actions, following baseline and operational monitoring. This is a standard industry practice, allowing the Project to adapt to changes in the Project Plan and a continuously growing database fed by operational monitoring activities.

As described in Section 17.0 below, an annual review of this RPRWMP will be conducted to identify improvement opportunities. In addition, a 5-year external audit of the implementation of this RPRWMP will be conducted. The audit will be used to consolidate collected information and, where appropriate, provide additional inputs for the closure planning.

13.1 Overview

The closure and final rehabilitation of the Project are governed by the Mine Closure Plan (MCP). However, it is acknowledged that radiation-related criteria form one part of the overall closure management for the site. The RPRWMP is intended to be a stand-alone document that informs the radiation management requirements of the MCP. The plans are necessarily linked, and any changes to final closure options in the MCP must be made in consideration of the requirements detailed in the RPRWMP, and the RPRWMP revised accordingly, where required. Note that all closure options relevant to radiation management are included for completeness in this RPRWMP. All future development of mine closure planning will lead from the content and requirements described within this RPRWMP (and associated references provided).

From a radiological perspective, the closure and rehabilitation aim is to ensure that the radiation levels in the Project Area and surrounding areas are consistent with the pre-development levels post-closure.

Arafura conducted a post-closure radiological risk assessment, focussed on potential failures of controls for the RSF. In addition, the gaps in existing knowledge have been identified and will continue to be reviewed and addressed throughout the operational phase of the Project.

Waste management decommissioning/closure activities are to comply with commitments in the approved EIS, relevant Northern Territory and Commonwealth legislative requirements, including the guidance provided in ARPANSA, Radiation Protection Series 9 - Code of Practice and Safety Guide for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing, 2005.

At closure, contaminated plant and equipment will be cleaned and decontaminated (where possible) and moved off site for recycling. Procedures will leverage those developed for the construction and operational phases as described in Section 9.3. Where this is not possible, it would be safely and securely encapsulated and disposed of in the RSF or waste rock facility.

The major rehabilitation feature from a radiological perspective is the RSF. The major earth-moving activities will involve benign material that is not classified as radioactive and therefore won't be subject to any radiological controls upon closure.

An evaluation of alternative closure and rehabilitation strategies for the mine pit and RSF was undertaken for the Nolans Project as part of the drafting of the EIS Supplementary Report submitted to the NT government in 2017 (Section 4.1.1, page 281). Options for closure included encapsulation of NORM (not backfilling the pit) and backfilling of the open pit, and these were evaluated based on minimising short and long-term financial risk. The EIS Supplementary Report (2017) provides the detailed evaluation completed by Arafura; however, a summary of the key conclusions is provided in Table 13—1 below.

Table 13—1 Evaluation of alternative rehabilitation and closure strategy of backfilling pits (EIS Supplementary Report 2017)

Aspect of closure and rehabilitation strategy	Detail
Potential Benefits – Backfilling Pits	
Reduced visual impact	▪ Size of final WRDs will be significantly reduced if waste material is backfilled
Reduced post-closure footprint	▪ Size of final WRDs will be significantly reduced if waste material is backfilled, footprint required for final landform will, therefore, be significantly reduced.
Reduced exposure of WRDs to weather elements over 1,000 years	▪ EIS Supplementary Report considered post-closure exposure scenarios, which included the failure scenario of erosion of TSF/RSF/WRD walls ▪ Risk assessment considered potential radiological impacts to be minor compared to other impacts of failure (refer to Table 4-11, Section 4.9, page 323 of the EIS Supplementary Report, 2017).
Potential Negatives – Backfilling Pits	
Not able to access ore beneath final pit void for future mining	▪ Full extent of additional mineral resource beyond the deposit at depth is currently unknown. ▪ Similar resources and grades have been identified below the current pit limits ▪ Backfilling reduces potential to extend the life of mine of the Project beyond the current 38 years.
Increased environmental risk	▪ Increased risk of impacts to environmental aspects such as surface water and groundwater and increased dust if WRDs are not progressively rehabilitated. ▪ Increased management requirements during operations to ensure environmental impacts are minimised, avoided and/or mitigated.
Waste rock stored (i.e. not rehabilitated) until closure	▪ WRD left as open dumps at natural angle of repose until closure. ▪ WRD left unshaped and un-contoured are more susceptible to wind and water erosion. ▪ Leaving TSFs and RSFs uncovered until end of mine life poses significant risks.

Aspect of closure and rehabilitation strategy	Detail
Significant cost of 'double-handling' waste rock	▪ Cost of removal of all facilities, returning them to a single pit is estimated at $900M. ▪ Cost of this magnitude would likely make the Project unviable, or, at the least, have a significant impact on the life of the Project because the lower grade material would be far less economic. ▪ Progressive backfill can be undertaken if multiple pits are in operation, however the Nolans Project is a single pit operation.
Limiting potential opportunity to reprocess tailings, a potential future resource	▪ Although not included in the scope of this Project, the beneficiation tailings represents a potential resource which may be exploited in the future. ▪ Backfilling this material would limit this opportunity.
Limited progressive closure throughout operations	▪ Arafura's objective is to progressively rehabilitate disturbed areas as soon as they are available, making it likely that most WRDs will be closed, rehabilitated and stable well before mine closure. ▪ Backfilling the pit would require disturbing areas that have been demonstrated as already safe and stable. ▪ Also proposed to progressively cover TSFs and RSFs, to re-disturb these facilities would increase the potential risk of release and substantially increase the post-closure monitoring period of the Project.
Tailings and residues moved to Ti Tree Basin Catchment	▪ In response to stakeholder concerns about the processing facility in the Ti Tree basin catchment, Arafura has proposed a two-site option with residues located approximately 8 km south of the open pit. ▪ The risks associated with disturbing the residue material to transfer it back to the pit would increase significantly as it the material would have to be re-slurried to pump back to the open pit. ▪ Deposited material would then require a period of settlement and dewatering before rehabilitation could safely occur.
WRDs will still exist post-closure	▪ The total volume of materials extracted from the open pit will not fit back in the mined-out pit void. ▪ The beneficiation process and subsequent rare earths processing will increase the mined quantity of ore due to the addition of reagents, water, etc. ▪ Waste rock is estimated to have a swell factor of 30%. ▪ Approximately 150 Mt will exist above the pit or remain as a remnant WRD.

Based on the above considerations, leaving the WRDs/TSF/RSF in situ and capping at closure was the preferred option based on acceptable residual risks and being economically viable.

Note that standard industry practice has adopted encapsulation of NORM as a low-risk option, where relevant to the aspect of closure. This approach is aligned with the WA NORM Guidelines (DMP 2010).

13.2 Closure Design

This section details the closure design and considerations associated with closure domains that require measures to manage radiation. Details with respect to generic mine closure for these domains (e.g. seeding, ripping, slope design, etc.) are outlined in the MCP and are not covered in this document.

The closure domains considered in this RPRWMP are the:

- Waste rock dumps – WRD
- Residue storage facility – RSF
- Process plant
- ROM pad
- Mine pit.

13.2.1 Waste Rock Dumps

The two WRDs at Nolans have been designed and scheduled to ensure encapsulation in a staged development and rehabilitation approach across the LoM schedule (refer to Appendix N).

Overburden and waste rock will be deposited in two purpose-constructed WRDs over the LoM, with a final waste rock quantity of 178 Mt (71 Mbcm), consisting of 49% benign and 51% NORM by volume. The two WRDs will hold waste volumes built to a relative level (RL) of 720 m, with a height of 60 m above natural surface, which is consistent with the local topography. Each of the two waste dump locations is divided into a number of discrete dumps to allow staged encapsulation and progressive rehabilitation (see Figure 13—1 and Figure 13—2).

NORM waste will be encapsulated within the WRD by separating the NORM waste and placing centrally within the dump. Benign waste will be placed on the outer embankments and/or stockpiled to cover NORM waste cells as mining progresses.

The waste landforms designed have sufficient capacity to store all the waste mined from the pits.

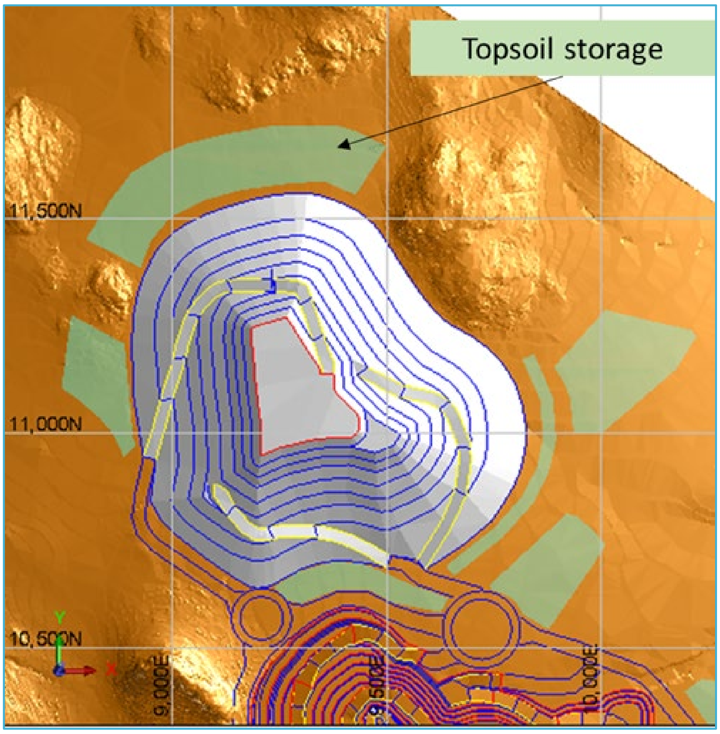


Figure 13—1 Northern Waste Dump (Final Surfaces) and Topsoil Stockpiles

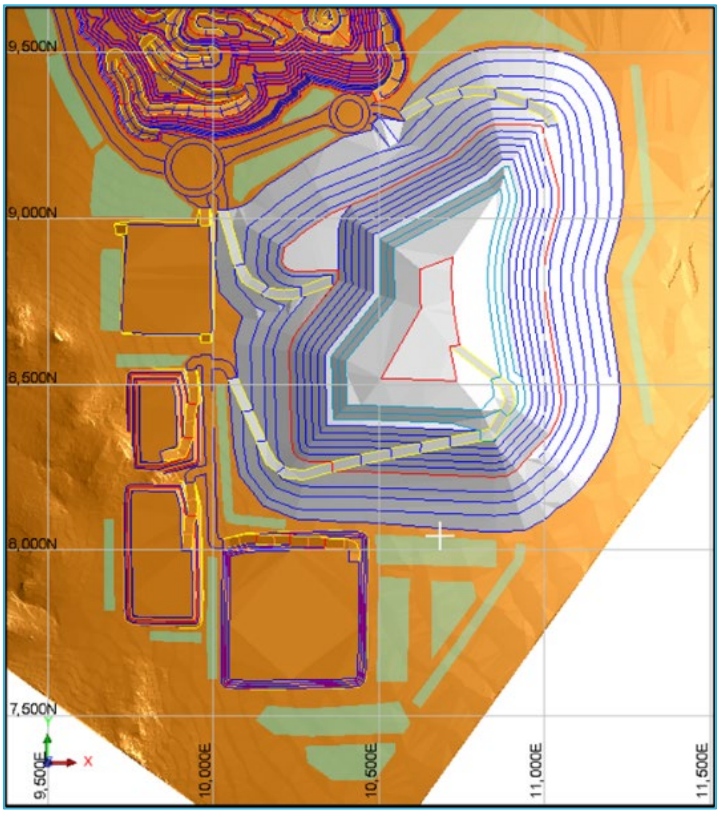


Figure 13—2 Southern Waste Dump (Final Surfaces), and Topsoil and Long-Term Stockpiles

The southern WRD is the largest WRD (approximately 1 km by 1.25 km) split up into five stages with a total capacity of 69.2M cubic meters. The final stage contains the majority of the volume capacity (63%), consisting of entirely benign waste to encapsulate the previous four stages.

The northern WRD is smaller (approx. 1 km by 750 m) and split up into three stages to ensure encapsulation requirements, with a total capacity of 22.2M cubic meters.

Progressive reprofiling of the completed WRD stage annulus' will be achieved with dozer push. This will be followed by other rehabilitation requirements, as described in the Mine Closure Plan, including topsoil placement, contouring and seeding.

Waste separation and management is covered in Section 9.0 above.

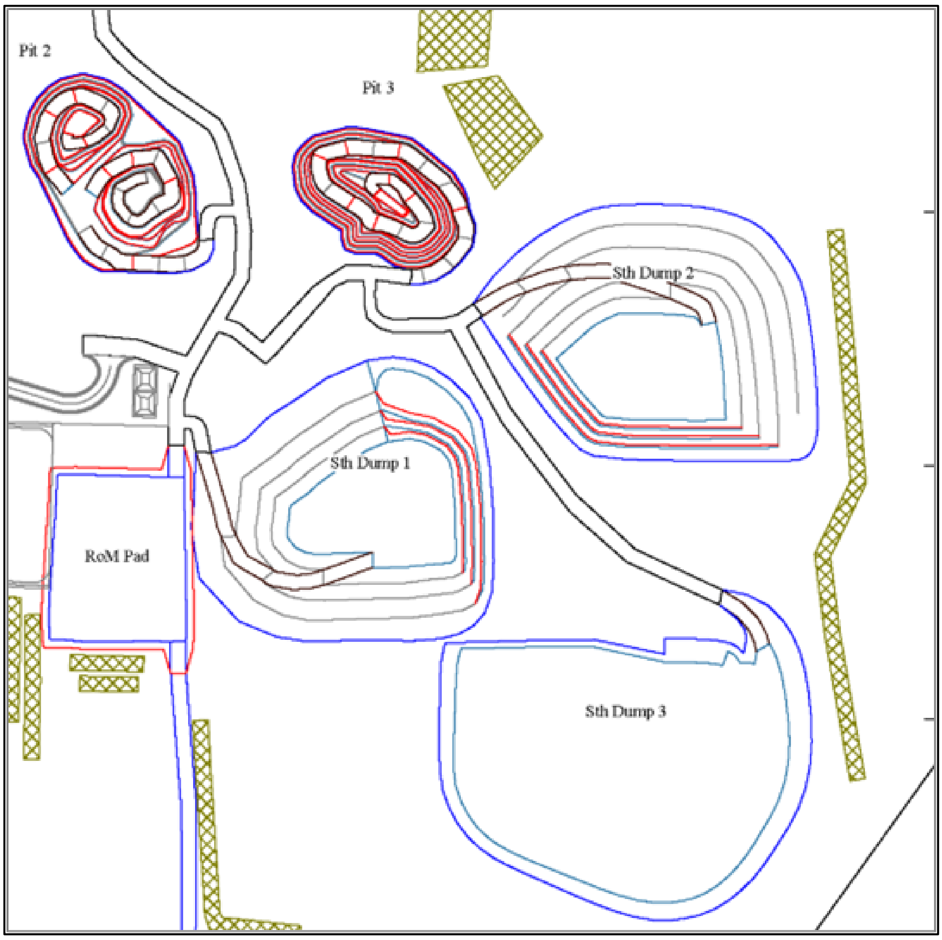


Figure 13—3 Example of the Southern WRD Staged Development and Rehabilitation Plan (Year 7)

The following rehabilitation measures are proposed with respect to the WRDs:

- A minimum encapsulation thickness of 3.5 m has been recommended from a geotechnical stability standpoint covering the outside annulus, to ensure a minimum of 2 m thickness be maintained from any face sloughing.

- The minimum 2 m benign thickness ensures benign volumes can be effectively used to achieve all encapsulation requirements, given the similar volumes of both NORM and benign waste over the LoM plan.
- Detailed staged encapsulation and progressive rehabilitation plans will be prepared during future Operational Mine Planning work.

As per approval conditions under the Mine Management Plan (approved by the Northern Territory regulator), the WRD stage development and rehabilitation plans will be reviewed by an independent engineer, before operations commence and as rehabilitation progresses.

13.2.2 RSF

Deposition during the final stages of operation will be adjusted to develop the final residue surface profile, with a gentle slope towards the closure spillway. This will minimise the re-shaping of the residue surface required to ensure it drains freely prior to capping.

This section focuses on the management of NORM material in the RSF.

Underdrainage system

Underdrainage from the RSF is unlikely to have elevated levels of radionuclides, due to their insolubility. To confirm, radionuclide levels will be monitored during the operations phase.

Elevated NORM levels are most likely to be associated with high sediment levels, if unplanned build up occurs in the underdrainage system. Prevention of sedimentation in the system will be considered through the RSF design phases. It is a closure risk that will be further defined during the operations phase.

The underdrainage system will continue to operate for some time after completion of capping and re-vegetation, to drain excess water from the residue deposit. The quantity of water recovered from the underdrainage system is expected to reduce with time. Experience with similar facilities suggests that water recovery may continue for a period of several years following decommissioning. During this time, water from the underdrainage will be pumped back to the Process Plant for recycling or treatment. After the flow ceases, the underdrainage pumps will be removed and the underdrainage tower/riser pipe backfilled and sealed as part of the rehabilitation process.

Beneficiation RSF

The final cover for the residue surface, subsequent to decommissioning, will be confirmed during the operations phase based on ongoing operational residue geochemistry test results. The following cover design for the residue beach is currently envisaged:

- general fill layer (500 mm)
- low permeable soil liner (300 mm)
- general fill as store and release layer (1,000 mm)
- topsoil/growth medium layer (100 mm)

- re-vegetation of area
- erosion protection material to be placed in dedicated flow path as required, to reduce erosion before vegetation is re-established.

Gypsum and water leach residue RSF

The final cover for the residue surface, subsequent to decommissioning, will be confirmed during the operations phase based on ongoing operational residue geochemistry test results. The following cover design for the residue beach is currently envisaged:

- general fill layer (500 mm)
- low permeable soil liner (300 mm)
- 1.5 mm geosynthetic HDPE liner
- liner protection soil layer (500 mm)
- general fill layer (1,000 mm)
- topsoil/growth medium layer (100 mm)

Closure spillway

The RSF closure spillway will be excavated during the rehabilitation works of the RSF, subsequent to decommissioning of the individual cells. The closure spillway will be excavated from the final supernatant pond location through the perimeter embankment and a discharge channel constructed.

Individual spillways will be constructed for each cell to reduce the risk of concentrated flow causing excessive erosion. The spillway will be sized to safely manage a probable maximum precipitation rainfall event.

Due to the staging of the individual cells, experience with the performance of the closure spillway constructed for the first cells can be used to improve the design for the following cells. At final closure of the facility (Process Plant expected to run for approximately 38 years and the final RSF stage to be completed after approximately 41 years), it is expected that the adopted design will have demonstrated that it is stable over the long-term.

The currently proposed cover design is as follows:

- A capillary break layer of coarse gravel/rockfill material to block migration of any salts from the residue into the upper layer of the cover. This layer will also provide a working base for the additional cover construction works, as well as a shielding layer to any radiation emitted from the tailings.
- A 300 mm low permeable fill layer to minimise infiltration into the residue mass and therefore limit the possibility of seepage from the facility.
- In addition to the low permeable soil layer, a 1.5 mm HDPE cover layer will be installed over the Gypsum and Water Leach Residue Cells, as well as a 500 mm protection layer above the geosynthetic layer to minimise the risk of punctures.

- A store and release layer of between 500 mm and 1000 mm thickness comprising suitable borrow material that is both erosion resistant and provides suitable storage characteristics.
- A growth medium surface layer. The upper 150 mm to be lightly ripped topsoil and non-reactive material reclaimed from stockpiles to form a rock mulch and promote vegetation growth.

It is expected that the quantities of material required for the cover system will be readily available from topsoil, non-mineralised surficial alluvial material, and from local borrow areas.

13.2.3 Process Plant

The Process Plant will require decontamination prior to decommissioning and removal from site for resale, reuse or disposal. The decontamination process will be directly related to the removal of material within and around the Process Plant.

At closure, a decommissioning plan will be developed that outlines the specific cleaning measures, location of residue collection, contamination management and quality assurance processes for disposal offsite.

Closure management measures associated with elevated radioactivity during the decommissioning process are:

- Sediment contained within the sumps within the Process Plant footprint shall be disposed to the RSF. HDPE liners shall be removed and disposed to the RSF cells for encapsulation.
- All equipment shall be cleaned prior to removal from site.
- Decontamination residues shall be disposed to the RSF for encapsulation.
- Material that cannot be cleaned sufficiently or disposed of offsite shall be disposed either to the mine pit, WRD or RSF.
- Monitoring shall occur around the Process Plant to identify areas for decontamination. Where elevated levels occur, materials will be removed and disposed to either the WRD or RSF for encapsulation.

13.2.4 ROM Pad

The ROM Pad has the potential to have elevated levels of radioactive materials, due to residual ore and dust occurring over the area. As such, the area will be rehabilitated to remove radioactive materials. The low-grade ore stockpile footprints may have similar contamination to the ROM pad. The low-grade stockpiles are intended to be encapsulated at the end of mine life with benign waste due to their proximity to the southern waste rock dump. Alternatively, they will be rehabilitated in the same way as the ROM pad.

The following closure measures are proposed:

- Removal of top 500 mm of material from the operating footprint of the ROM pad and disposal within either the WRD NORM cells or RSF.
- Monitoring to confirm effectiveness of the cleanup.

13.2.5 Mine Pit

The following closure strategy to manage radiation risk for the open pit domain includes:

- Pit walls will be retained at the final batter angles, provided these are geo-technically stable.
- Installation of pit abandonment bunds. This involves positioning the abandonment bund beyond the zone of potential geotechnical instability to ensure that any subsidence of the pit walls does not affect the integrity or effectiveness of the bund. The bund will also be constructed of competent rock that can withstand the long-term effects of erosion and weathering.
- The safety bund will also restrict inflow to the pit lake, resulting in the lake being below the surrounding groundwater level.
- The road access into the pit will be blocked by placing rock windrows at the top of the original ramps.
- Groundwater inflow from the pit walls will be allowed to collect within the pit and evaporate. It is anticipated that a small pit lake will develop, but the depth, quality and rate of filling is yet to be scientifically modelled. Water quality is expected to deteriorate over time due to the evapo-concentration of salts and other elements.
- Signage will be installed to warn people of the risks associated with the open pit void. The need for signage will be discussed with stakeholders prior to closure.

13.3 Radiological Closure Criteria

The specific radiation closure objectives and completion criteria for the Project are as follows:

- Radiation exposures to members of the public are less than 1 mSv/y (above natural background levels).
- Post exposures to flora and fauna will not exceed the recognised screening dose rate of 10 uGy/h as a result of operational and closure activities.
- Radiation levels are consistent with the levels that existed prior to operations.
- All containment systems are safe, stable and non-eroding.

To achieve the criteria, the aim is to ensure that the post-closure radiation levels (including ambient gamma radiation, radon and thoron concentrations in air, dust deposition, radionuclides in airborne dust and radionuclides in ground and surface water), are consistent with the pre-operational levels as shown in the EIS (Arafura 2016) and updated in this RPRWMP.

The post remediation radiation monitoring program will continue for a period of at least 10 years and will include the Project Area and adjacent areas to the Project, in line with the current network of installed ERMLs (Figure 7—4) to confirm that the closure criteria are achieved and maintained.

Table 13—2 Environmental Radiation Monitoring Program at each ERML

#	Aspect	Risk Pathway	Closure Outcome	Completion Criteria	Measurement Tool
1	Rehabilitation and Mine Closure	Infrastructure left at closure does not align with Post-Mining Land Use.	No general waste shall remain upon completion of mining and closure activities.	All waste is removed and disposed of appropriately.	Closure audit completed that includes a summary of infrastructure retained.
			No infrastructure is left on site unless Regulators and post-mining land managers/owners agree to it.	The landholder has accepted the responsibility for the ongoing management, maintenance and final disposal of infrastructure that will be left in place post-closure.	Agreement with Landholder prior to closure outlining what infrastructure shall remain. Details of the agreement will be presented as part of the approved MMP.
			Disturbed surfaces rehabilitated to facilitate future specified land use.	Liabilities of any infrastructure to be retained are defined and approved by relevant key stakeholders prior to any asset transfer taking place.	Signed asset transfer agreement in place prior to transfer of legal responsibility.
2	Rehabilitation and Mine Closure	Inappropriate design and/or poor construction & rehabilitation practices. Legacy tailings disposed of inappropriately. Residual contamination from historical tailings material remains at Project completion.	No NORM contamination shall remain upon completion of mining and closure activities.	Soils with elevated NORM levels are cleaned up and remediated at the completion of mining.	Prior to closure, a contamination survey of infrastructure areas, where ore and elevated NORM material were handled, shall be completed.
			No contaminated infrastructure or soils remain on site.	All potentially contaminating material is disposed to the RSF or WRD and encapsulated.	Closure audit that delineates where all material is disposed at closure. Any known or potentially contaminated sites are recorded, reported & remediated.
				All infrastructure is appropriately cleaned prior to disposal offsite.	All infrastructure appropriately cleaned and certified as clean prior to disposal offsite.

#	Aspect	Risk Pathway	Closure Outcome	Completion Criteria	Measurement Tool
			Constructed Landforms (WRD, TSF, ROM pad) will be non-polluting/ non-contaminating, and toxic or other deleterious materials will be permanently encapsulated to prevent environmental impacts.	NORM material is suitably encapsulated to ensure that there is no measurable impact on the surrounding environment measured 10 years after closure.	Soil and groundwater chemical concentrations do not exceed ARPANSA 'environmental investigation levels' or pre-mining average background concentrations, whichever is the greater.
				At the cessation of mining, all elevated NORM material is encapsulated fully within the WRD or RSF.	Closure audit to ensure elevated NORM material is fully encapsulated within the WRD or RSF.

13.4 Radiological Control in Closure Decision Making

The final closure options are outlined in the MCP and will be verified through the additional work to be undertaken during the operations phase, as described in the MCP. When environmental, policy or engineering data is obtained that alters the current knowledge regarding rehabilitation options, it will be considered and risk assessed to ensure that the optimal remediation and closure options are implemented. This will also be the case for radiation-related aspects. If the options for closure alter, a radiation risk assessment would be conducted.

A key part of the closure planning and review involves the incorporation of the outcomes of the 5-yearly audit of the implementation of this RPRWMP.

13.5 Post-closure Radiological Risk Assessment

The major rehabilitation feature from a radiological perspective is the RSF.

Table 13—3 Exposure Scenarios from Features Events Processes (FEP)-Style Assessment

Exposure Scenario	Dose Pathway and Potential Dose
Long-term degradation of the RSF	▪ Residue/tailings contaminate traditional or future food sources, leading to an increase in human doses. ▪ Considered to be unlikely in the near term due to rehabilitation performance targets. ▪ Potential doses likely to be less than 1 mSv/y due to: – Low radionuclide content of residue/tailings (consistent with naturally occurring concentrations found in some regions of the world) Relatively low abundance of natural food sources in the region.
Inadvertent intrusion into RSF	▪ Information on the final location of the RSF is lost. For example, in future drilling exploration programs or earth moving programs. ▪ Potential doses are likely to be low due to identifying residue/tailings or waste material once uncovered. This assumes that if there is sufficient technology for drilling or earthmoving, then there would be technology to identify hazards. ▪ An additional scenario is that residue/tailings are mined as resources – in this case, it is appropriate to assume that protection mechanisms would be in implemented.
Seepage from residue/tailings to groundwater which expressed in potable water supplies	▪ Modelling shows that radionuclides are unlikely to be mobilised with any seepage. ▪ The concentration of radionuclides in any seepage would be further diluted by pre-existing groundwater. ▪ Level of potential contamination is likely to be undiscernible from naturally occurring variations in groundwater radionuclide concentrations.

13.6 Radiation Specific, Closure Knowledge Base Considerations

Radiation protection is a key consideration in closure, and Arafura will continue to collect data and undertake radiation-related test work during the operations phase to inform final closure and remediation decision-making. The data and information will also be used to verify the conclusions of the radiological risk assessment. All closure options relevant to radiation management are included for completeness in this RPRWMP. All future development of mine closure planning will lead from the content and requirements described within this RPRWMP (and associated references provided).

Key work to be undertaken to address knowledge gaps relating to radiation, identified from the closure risk assessment and detailed in the Project MCP, will include:

- Monitor for any operational impacts through monitoring undertaken at the ERML locations (see Section 12.0). This information will be compared to the baseline results to determine whether any changes occur and if they result in impacts. The results will be used in radiological impact assessments of flora and fauna and for impacts on members of the public.
- Conduct ongoing test work to optimise the selection and segregation of benign waste for final rehabilitation. As well as characterising the cover material, the testing will also provide information on the optimal depth of cover materials for the tailings and NORM materials. As noted previously, the post-closure targets for radiation levels are based on the premise of ensuring that the post-closure levels are consistent with the pre-operational level.
- Monitoring the extent of soil contamination from radiation. This is likely to only be apparent close to closure. Contaminated soil investigations will be undertaken where potentially contaminative activities have taken place. Where contamination is identified, appropriate remedial actions will be implemented.
- Ongoing review of operational monitoring data to identify any trends that may impact on the post-closure radiation environment.
- Ongoing refinement of cover design for encapsulation cells, including the design of capillary breaks and assessment of cover volumes, to ensure suitable risk management whilst providing an effective soil depth to maximise vegetation cover growth.

The full suite of knowledge gaps identified during the closure risk assessment completed as part of drafting the MCP for the Project have been provided as Appendix O for reference only.

14.0 QUALITY ASSURANCE

Arafura has established a site-wide health, safety, environmental and operational quality management system. The quality assurance aspects for radiation protection are integrated into the site HSEMS.

The key considerations for a radiation protection quality assurance program are outlined in ARPANSA (2005) and include compliance with relevant Australian Standards and traceability of radiation measurements, calibration documentation and auditing systems.

The RPRWMP, monitoring program, operating procedures, monitoring results and administrative practices will be formally reviewed annually (as outlined in Section 17.0) and an independent external review will be conducted every five years in accordance with timeframes at similar operations in Australia.

The practical considerations of the quality assurance program include:

- Ensuring that all radiation monitoring equipment and instrumentation is fit for purpose and considered to be industry standard.
- Ensuring that technical staff are trained in the correct use of monitoring equipment and that audited procedures are established for undertaking monitoring tasks (see appendices).
- A prescribed program of instrument maintenance by a suitably qualified instrumentation technician.
- A program of instrument calibration involving off site calibration of key instruments against primary standards and routine checks against on site secondary standards.
- During the annual reviews (as noted above), conducting a check on key instruments to ensure traceability of performance to national standards (for example, checking against appropriate Australian Standards).
- Maintaining documentation, covering records of instruments, their calibrations and maintenance log and any changes due to equipment upgrades.

15.0 RECORD KEEPING

An online data management system will be used to store and manage all information relating to radiation management, monitoring and worker doses.

Periodic reports will be prepared from information stored in the electronic database. Regular dose reports will be provided to workers and upon request.

All new workers will be asked about previous experience in radiation workplaces, and a record of any previous exposures will be obtained where appropriate.

All records will be maintained for the life of the operation.

16.0 ACCIDENT, INCIDENT AND EMERGENCY RESPONSE

The Project will establish and maintain a site-wide Emergency Response Plan, which will be further developed as the Project progresses. This plan will contain provisions for responding to accidents and incidents involving radioactive materials, including density probes and density gauges.

It should be noted that it is highly unlikely that there would be an incident resulting in harm due to radioactivity due to the relatively low concentration of radioactivity in the ore and products.

Potential incidents have been identified as follows:

- Radiation monitoring, either routine or investigative, identifying elevated radiation levels, which would be considered an incident within the Arafura incident management process and, therefore, be investigated, with remedial actions implemented.
- Loss of containment of radioactive tailings or residues resulting in environmental contamination. The potential radiological risk from such an event is very low and was assessed by Arafura during the EIS process.
- Density probe stuck in the drill hole, resulting in a temporary or permanent loss of control of a strong radioactive source by the geophysical contractor.

Where an incident occurs that results in an exposure to a worker, an incident dose assessment will be made by the Statutory RSO. This will involve the RSO investigating the incident and determining a conservative dose estimate. If the incident involved a worker, then the incident dose estimate will be filed with the workers' dose records.

17.0 SYSTEM REVIEW

A review of the RPRWMP will be undertaken annually or whenever there is a significant change in the operation or the waste management system, following the recommencement of construction activities, and include the following:

- Assessment of the monitoring results and review of the monitoring program.
- Consideration of any changes that have occurred over the previous 12 months and potential radiological impacts.
- Review of the effectiveness of the radiation protection controls.
- Confirmation of work area classifications.
- Identification of any improvement opportunities.

The annual review will be an internal review with a summary provided to the relevant regulatory authority. Any changes to the RPRWMP identified through the review would be subject to regulatory authorisation.

Arafura will undertake an external audit of the RPRWMP every five years. A recognised radiation protection practitioner would conduct the external audit.

Any revisions of the RPRWMP that involve aspects of mine closure will be correspondingly addressed in a revision of the MCP, with the revised MCP provided to DCCEEW for information purposes following its approval under the *Environment Protection Act 2019*.

18.0 REPORTING

The following will be reported through existing reporting obligations to the relevant regulators:

- summary of monitoring results
- discussion on trends in the data
- investigation reports into anomalous monitoring
- details of any incidents or accidents
- details of any changes in monitoring or monitoring methods
- outcomes of any reviews.

If required, worker dose information will be made available to the ARPANSA National Dose Registry on an annual basis.

As part of the annual report to DCCEEW, the company will provide a statement of compliance. This will describe and outline the average and maximum doses received by the workers, as well as the public and non-human biota, as a result of operational activities.

In the event of a non-compliance (i.e., radiation levels exceed statutory limits), the company will provide electronic notification to the Department of Climate Change, Energy, the Environment and Water (DCCCEEW) within 2 business days of becoming aware of the non-compliance, as per Condition 42 of EPBC2015/7436. Further details of the event, including corrective measures and results of any investigations conducted, will be provided in writing to DCCEEW within 12 business days of identification of the non-compliance (Condition 43 EPBC2015/7436).

19.0 REFERENCES

DMP, 2010. *Managing Naturally Occurring Radioactive Material (NORM) in mining and mineral processing guideline.*

DoIR, 1997. *Safety Bund Walls around Abandoned Open Pit Mines*

GHD, 2016. *Nolans Project, Environmental Impact Statement (EIS), Arafura Resource Ltd, February 2016.*

GHD, 2017. *Nolans Project, Environmental Impact Statement (EIS) – Supplementary Report, October 2017.*

GHD, 2019. *Arafura Resources Ltd, Nolans Project Section 14A Notification, June 2019.*

IAEA, 2004. *ISAM 2004 Safety Assessment Methodologies for Near Surface Disposal Facilities, Volume 1, 2004, IAEA.*

UNSCEAR, 2000. *Report Vol. I Sources and Effects of Ionising Radiation.*

APPENDIX A RESUME FOR MR JIM HONDROS OF JRHC ENTERPRISES

Jim Hondros
Director – JRHC Enterprises Pty Ltd
CV - 2025

Email : jim@jrhc.com.au
Phone: 0439 348 922

PO Box 372,
Stirling, SA 5152

Qualifications:

- Bachelor of Applies Science (1984)
- Graduate Diploma in Occupational Hazard Management (1987)
- Master of Applied Science (1991)

Professional Affiliations:

- Certified Radiation Safety Advisor – Australasian Radiation Protection Accreditation Board (ARPAB)
- Member - Australian Radiation Protection Society (ARPS)
- Member – Australian Institute of Occupational Hygienists (AIOH)
- Member – Environmental Institute of Australia and New Zealand (EIANZ)

Experience Summary

- 1984 – 1995 Operational experience in operational and senior management roles covering radiation monitoring, government liaison (State and Federal), resource and project management, in the areas of Radiation, OH&S, Environment and Emergency Response
- 1995 – 1996 Corporate Policy Adviser – Environment
- 1997 – 1998 Senior Manager Community Relations and Environment
- 1999 – 2002 Group Manager – Occupational Health and Safety
- 2002 – now Self Employed at JRHC Enterprises Pty Ltd. Work includes:
    - Policy advice and direction in relation to radiation for various companies whose materials and products contain Naturally Occurring Radioactive Materials (NORM).
    - Occupational and environmental radiological impact assessment for numerous projects (both uranium and non-uranium) as part of State and Commonwealth approvals.
    - Specific radiation, OH&S and environmental project work, both nationally and internationally, (including advice on design, development of practical management measures and competency development).
    - Provision of ongoing radiological advice and support to numerous companies (including mentoring and training of technical staff, technical advice, development of management systems, establishing design criteria, working with design teams, monitoring, waste management, transport of radioactive materials, and nuclear fuel cycle implications).
    - Establishment and management of baseline environmental radiation monitoring programs and designing and implementing occupational radiation monitoring and training.
    - Facilitation of workshops for industry, regulators and community on radiation protection and OH&S.
    - Review and interpretation of specialised technical reports.
    - OH&S audits, Research & development road-mapping.
    - Liaising with First Nation Australians, companies, regulators and communities (including public forums) on radiation protection.
    - Working with operations staff and First Nation Australians community groups on the development of engagement strategies, developing partnerships, and mentoring.

Governance

2024 – now	Immediate Past President of the Australasian Radiation Protection Society
2023 – now	Vice President of the Asia Oceanic Radon Association
2022 – 2023	President of the Australian Radiation Protection Society
2020 –now	Member of ARPANSA Radiation Health Advisory Council
2019 – now	Co-chair of International Radiation protection Association working group on NORM
2014 – now	Member of the Australian Radiation Protection Society Executive Committee
2006 – 2009	Member - Radiation Health Committee and Nuclear Safety Committee, ARPANSA
2006 – 2008	Chair – Trust for Nature (Victoria)
2004 – 2006	Trustee – Trust for Nature (Victoria)
2004 – 2012	Director – Parakeelya Foundation
2002 – 2006	Honorary Lay Person - Deakin University Research Ethics Committee
1999 – 2002	Chairman – Lawn Hill and Riversleigh Pastoral Holding Company
1998 – 2002	Director – Aboriginal Development Benefits Trust
2000 – 2002	Director – World Alliance for Community Health
1997 – now	Member – Minerals Council of Australia – OHS Taskforce

Development

- Involvement in expert missions and conducting training for the International Atomic Energy Agency in Pakistan, Mongolia, Bulgaria, Jordan, Indonesia, Thailand, Brazil, Australia.
- Regular invited speaker on radiation protection at conferences conducted by the International Atomic Energy Agency (IAEA), the International Commission on Radiation Protection (ICRP), Asia Oceanic Congress on Radiation Protection (AOCRP), The International Radiological Protection Association (IRPA) and the Australasian Radiation Protection Society (ARPS).
- Developer of a series of OHS and radiation safety lectures for IAEA "The Uranium Production Cycle" series for and E-Learning program
- Guest lecturer for the University of Adelaide Centre for Radiation Research Education and Innovation Graduate Certificate in Radiation Management
- Author on several IAEA publications, including radon in workplaces, controls for radioactively contaminated lands and NORM residue management.
- Industry representative on the development of documentation on the implementation of the ICRP60 recommendations.
- Detailed site familiarity visits to numerous national and international mineral sand, rare earth, base metals, and uranium mines and processing facilities and nuclear facilities.
- Co-Chair of the IRPA NORM Task Group
- Team Member of Research on Improving the Relevance of International Radiological Risk Assessment Tools to Australian Arid Environments (through Flinders University)
- Numerous radiation safety publications

APPENDIX B RADIOACTIVE MATERIALS TRANSPORT MANAGEMENT REQUIREMENTS

RADIOACTIVE MATERIALS TRANSPORT MANAGEMENT REQUIREMENTS

PREFACE

Arafura Rare Earths Limited (Arafura) is intending to develop the Nolans Project in the Northern Territory of Australia.

It is intended that all final products that leave the operation will not be defined as radioactive. The radiological characteristics of the Nolans Project and the products are defined in the body of the Radiation Protection and Radioactive Waste Management Plan (referencing data presented in the Environmental Impact Statement for the Project). To take into account the transport of samples for analysis, this Radioactive Materials Transport Management Plan requirements document has been prepared as part of the Radiation Protection and Radioactive Waste Management Plan.

Transport of radioactive materials throughout Australia is subject to local radiation protection Acts and Regulations. This means that different licences may be required in different States and Territories, depending upon transport routes and destinations. However, all transport of radioactive materials in Australia is underpinned by the Australian Radiation Protection and Nuclear Safety Agency - ARPANSA Code for the Safe Transport of Radioactive Material – also known as the Transport Code (ARPANSA 2019).

When transporting radioactive materials that are defined as radioactive, Arafura will use the services of a licenced dangerous good transport service provider (TSP).

Arafura expects certain standards to be established and maintained during the transport of any radioactive materials and this document outlines the Arafura requirements for transport of the material.

This document does not, in any way, remove the responsibility of the transport service provider to transport the material in accordance with all legislative requirements and obtain all necessary licences for any jurisdiction through which the material is transported.

This document is the Arafura Radioactive Materials Transport Requirements and is abbreviated to RMTR for the rest of this document.

INTRODUCTION

Purpose

The purpose of this Radiation Management Transport Requirements (RMTR) is to outline the minimum Arafura requirements for the Transport Service Provider (TSP) in relation to their operational Transport Management Plan to ensure the safe and efficient transport of radioactive materials.

In this RMTR, radioactive materials mean:

- Ore, process material, products or samples that contain more than 1 Bq/g of any of the naturally occurring radionuclides from the uranium and thorium decays chains [IAEA 2014].

It is the responsibility of the TSP to develop their Transport Management Plan, with the following objectives:

- To ensure the protection of workers, the public and the environment from any harmful effects of radioactivity during the transport of radioactive materials.
- To ensure compliance with the requirements of the various jurisdictional Radiation Act and Regulations.
- To ensure that the transport of radioactive materials complies with the requirements of the ARPANSA Code for the Safe Transport of Radioactive Material, RPS C-2 (Rev. 1) (commonly referred to as the Transport Code).

Note that when transporting radioactive materials, the other potentially hazardous properties of the materials (such as acidity) must be taken into account during transport. The material may be subject to other dangerous goods classification.

Scope

This requirements document refers to the road, rail and sea transport of radioactive materials from the Nolans Project.

This document covers:

- Characteristics of radiation containing materials.
- Roles and responsibilities.
- Specific packaging requirements for radioactive material to be transported, including labelling, certification and documentation.

Roles and Responsibilities

The key responsibilities relating to the RMTR are outlined in Table 1—1.

Table 1-1 Roles and Responsibilities for the RMTR

Role	Responsibility
Transport Service Provider (TSP)	Defined as the "contract carrier" who is transporting radioactive material on behalf of the "consignor" or "shipper". The TSP will be responsible for developing their own Transport Management Plan (TMP).
The consignor or shipper	Arafura as the consignor or shipper. Responsible for ensuring that the TSP has an adequate and approved TMP, that meets the requirements defined in this RMTR.
Statutory Radiation Safety Officer	As employed by Arafura. Ensure that all packages of radioactive materials comply with the requirements of the ARPANSA Transport Code.

REGULATORY REQUIREMENTS

State Requirements for Transport of Radioactive Materials

Arafura may require transport of radioactive material within Australia to a number of States or Territories. It is the responsibility of the TSP to identify the specific legal requirements for the transport of the radioactive materials through the various States and Territories. Arafura requires that the TSP will have reviewed all appropriate legislation and obtained all necessary licences and approvals.

Table 2-1 provides a summary of the potential legislation that is applicable.

Table 2-2: Transport Requirements

Jurisdiction	Act/Regulation	Is the ARPANSA Transport Code Applicable (Y/N)
South Australia	▪ *Radiation Protection and Control Act 2021* ▪ *Radiation Protection and Control Regulations 2022*	Y
Western Australia	▪ *Radiation Safety Act* ▪ *Radiation Safety (Transport of Radioactive Substances) Regulations 2022*	Y
New South Wales	▪ *Protection from Harmful Radiation Act 1990* ▪ *Protection from Harmful Radiation Regulation 2013*	Y
Northern Territory	▪ *The Radioactive Ores And Concentrates (Packaging And Transport) Act 1980* ▪ *The Radioactive Ores And Concentrates (Packaging And Transport) Regulations 1980*	Y (2008 edition)
Queensland	▪ *Radiation Safety Act 1999* ▪ *Radiation Safety Regulation 2021*	Y
Victoria	▪ *Radiation Act 2005* ▪ *Radiation Regulations 2017*	Y

Standards for Transport of Radioactive Materials

The basis of regulation of transport of radioactive materials in Australia is the ARPANSA Transport Code, which is based on the International Atomic Energy Agency (IAEA) regulations for the Safe Transport of Radioactive Materials. The latest version of the ARPANSA Transport Code is from 2019 and is based on the 2018 version of the IAEA document.

A relevant aspect of the Transport Code is under clause 107(f). It states that the requirements of the Transport Code do not apply for materials (which may have been processed) containing naturally occurring radionuclides up to ten times the criteria.

TECHNICAL INFORMATION FOR TRANSPORT

Transport Activities

Radioactive products or samples that are subject to the requirements of the Transport Code will be packaged on site in IP-1 packaging (see Appendix B.1).

Material to be Transported

All materials from the project are defined as "Low specific activity material" (LSA), which is radioactive material that by its nature has a limited specific activity (see clause 226 of the Transport Code). Clause 409 of the Transport Code notes that uranium and thorium ores and concentrates of such ores, and other ores containing naturally occurring radionuclides are defined as LSA-1.

The radionuclide content of any radioactive samples will need to be determined by Arafura prior to transport in order to ensure that the correct transport requirements are met.

In the event that the radionuclide content and concentration of materials is not known, the Arafura Statutory Radiation Safety Officer shall make an assessment which will be based on alpha, beta and gamma measurements, together with information from process metallurgists and chemists.

Where a material is reasonably considered to be in secular equilibrium, the elemental uranium and thorium concentrations can be used to estimate the radiological characteristics of the material for transport. Where the material has been subject to chemical or thermal processing, the individual radionuclide concentrations shall be determined and a "basic radionuclide value (BRV)" shall be calculated in accordance with the equations provided in the Transport Code (ARPANSA 2019).

Clause 107(f) of the Transport Code notes that the requirements of the Code do not apply for a material containing naturally occurring radioactive materials, if the total activity concentration is less than ten times the calculated BRV.

Packaging

Radioactive materials for transport must be securely packaged in accordance with the Transport Code requirements (see Attachment 1).

In addition, a gamma measurement will be taken on the outside surface of the container to confirm that levels are less that 5uSv/h.

For a radioactive material subject to the Transport Code, the package will be required to have on each of the four vertical sides a 'Class 7' placard. Although an alternative is to place the UN number on the container (UN2912). Each individual package is required to also have a placard.

Note that the container may be required to have additional non radiation related dangerous goods placarding as required under the Australian Dangerous Goods Code, depending upon the hazard assessment of the product.

Transport Requirements

The general classification requirements for radioactive materials are shown in Table 3-1 below.

Table 3-3: Transport Classification

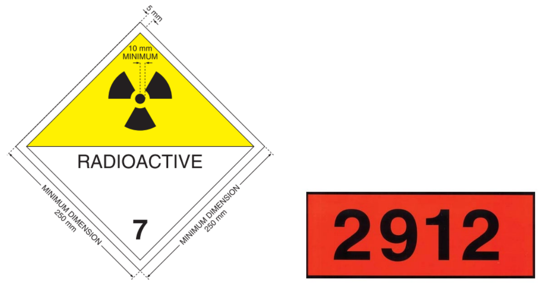
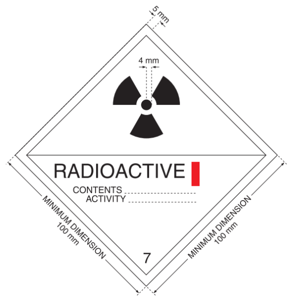
Transport Code Reference(s)	Criteria	General Requirements for Transport of Materials with NORM
Clause 401 Table 1	UN Number and Proper Shipping Name	UN2912 – Radioactive Material, Low Specific Activity (LSA-1)
Clause 409 (iv)	Classification of Material	LSA-1
Clause 521 Table 5	Industrial Packaging Requirements	IP-1 (see Attachment 1)
Clause 529	Category	I-White based on a measurement of gamma doserate of 0.4μSv/h from the package

Each radioactive package will require a label as shown in Table 3-2 below, with the following:

- *Content: LSA-1 – [Insert name of material]*
- *Activity: [To be calculated based on activity concentration and mass of material in package]*

Transport of any radioactive package will also require appropriate transport documentation and a surface contamination check.

Table 3-4: Placarding and Labelling Requirements

Package type	Placard/Label
Shipping container	
Radioactive package	

TRANSPORT MANAGEMENT PLAN

This section provides Arafura's requirements for the Transport Management Plan (TMP) that will be developed by the TSP.

Induction, Training and Information

The TSP must ensure that all staff involved in the transport of radioactive materials are suitably trained in the transport of radioactive materials.

It is expected that the TSP training covers:

- Information on the legal requirements.
- Responsibilities and duties under the legislation.
- Information on radiation.

Truck drivers should be Dangerous Goods certified and trained on what to do in the event of an incident during transport of the radioactive materials. All vehicles should also be registered for the transport of dangerous goods.

Duties of Workers

All TSP workers shall be aware of the requirements of the TMP for the transport of radioactive materials. Specific requirements should include:

- Compliance with relevant transport regulations (see Table 2-1 of this document).
- Ensuring that all notices and signs related to radiation are complied with.
- Ensuring that work is conducted in a manner that prevents a radiation incident from occurring.
- Understand the information available in the Safety Data Sheet (SDS).
- Immediately reporting any fault or defect that may result in a radiation incident to their supervisor.
- Following procedures and instructions to control and assess exposure to radiation in the workplace, including:
  - Complying with the instructions on radiation protection.
  - Participating in inductions, training and implementing learnings.
  - Wearing required personal protective equipment (PPE).
  - Taking care of any monitoring equipment provided.

Radiation Monitoring

As part of the operational RPRWMP, an appropriate worker radiation monitoring programme may be considered.

Safety Equipment in Good Order

For routine transport operations, it is unlikely that there would be a requirement for additional PPE. Standard safety equipment will be required for all transport work related activities in accordance with the TSP's operational safety management plan.

In the event of an incident resulting in spillage of materials, dust masks, goggles, gloves and white coveralls and a P2 disposable dust mask will be required to be worn when minimising the spread of material.

Record Keeping

The TSP will maintain records of transport and worker information including:

- Records of qualifications, training and competencies of all persons involved with the transport of radioactive materials.
- Details of all incidents and accidents and the remedial action to prevent recurrences. Reports should be provided to Arafura.
- Results of all monitoring and exposure records for each worker.
- Records of crew and drivers when radioactive material is being transported.
- Manifests, transport documentation and safety data sheets.

Operational Changes

From time to time, operational changes will be necessary. This could include last minute changes to routes, change of drivers and unplanned temporary storage. For any event or change outside of the routine transport conditions, the TSP driver will contact the TSP Logistics Manager, who will record the change and make an informed decision on whether the Arafura representative will be notified.

Review of the TMP

The TSP will regularly review their TMP, with any changes reported to Arafura.

Overview of Quality Assurance

In the TMP, the TSP is to provide an overview of their logistics management and their consignment tracking and chain of custody process.

Roles and Responsibilities for the TMP

The roles and responsibilities for both the TSP and the consignor should be outlined in the TMP and consider the following, as outlined in Table 4-1 below.

Table 4-5: Consideration for TMP roles and responsibilities

Role	Responsibility
Producer of Radioactive Material and Consignor (Arafura)	▪ Defining the characteristics of the material to be transported, identifying the receiving facility and making prior arrangements with the facility. ▪ Developing a safety data sheet (SDS) for the material. ▪ Packaging, labelling, and documenting the details of the material to be transported. ▪ Verifying the implementation of the provided TMP. ▪ Verifying packaging, labelling and documentation provided by the TSP. ▪ Notifying any changes in product specifications prior to transporting. ▪ Ensuring a safe load of the material within the Nolans Project.
Transport Service Provider (TSP)	▪ Preparing the TMP, achieving necessary approvals and implementing the TMP. ▪ Safely transporting the material to the described facility. ▪ In the event of an accident or emergency, implementing Arafura's Emergency Response Plan. ▪ Maintaining all road equipment (i.e. prime movers and trailers) to the manufacturers' specifications . ▪ Securing and maintaining valid permits and approvals from Australian, state and territory regulators. ▪ Ensuring required training is completed and licenses secured, with regular refresher/updates for transport personnel. ▪ Conducting surface contamination checks on containers prior to leaving the Nolans Project site.

RADIATION INCIDENTS CONTINGENCY PLAN

Overview

The loss of containment and the presence of radioactive material should not prevent qualified people such as emergency services personnel from undertaking rescue operations, including attending to the injured or fighting fires.

The Arafura radioactive materials will be classified as a low specific activity material and detailed incident response information is provided in the safety data sheet.

The incident and emergency response would be similar to that required when responding to transport incidents involving other types of metal concentrates.

Any incident involving a loss of containment or damage to a container of material should be reported to Arafura who have qualified personnel to provide assistance to on-site personnel regarding radiation and decontamination procedures.

Appropriate information shall be immediately available (as provided in the manifest) at all times for use in response to accidents and incidents involving dangerous goods in transport. The information shall be available away from the packages containing the dangerous goods and immediately accessible in the event of an incident (for example, the drivers' cabin).

Overall Approach

Overall, the radiation risks are very low and concerns regarding radiation should not get in the way of attending to immediate people safety and environmental protection. The basic measures to be adopted at the incident site include:

- Do not panic and stay calm.
- Assess the incident and gather facts – radiation is not an immediate problem, due to the low specific activity of the material.
- Determine if there are any other dangerous properties of the material that you need to be aware of (check the SDS).
- The main priorities are: rescue, life-saving, first aid, fire control and managing other hazards that may be present (for example, oncoming traffic).
- Do not try to clean up any spill.
- Isolate the spill or leak area with barricades to exclude members of the public.
- Escalate as necessary, dialling 000 if necessary, and follow any instructions provided.
- Keep unauthorised people away until emergency services arrive.
- Remain upwind 25m away and be aware of dust – be alert but not alarmed.

Incident reporting

If an incident occurs the following information will be documented:

- Nature and time of incident.
- Precise location.
- Quantity and condition of material involved.
- Details of any other particular hazards that may be present.
- Details of container number.
- Extent of damage or security breach.
- Sequence of events leading to the incident.
- Action taken.
- Notifications to consignee, regulatory authority, competent authorities, shipping line.

In the event of an incident, details shall be reported to the appropriate authority in accordance with licence conditions.

The TSP will conduct a review or investigation into each incident, in agreement with Arafura as Consignor, depending on the severity of the incident or near miss.

REFERENCES

International Codes and Standards

Title	Document Number
Code for the Safe Transport of Radioactive Material Radiation Protection Series C-2 (Rev. 1) March 2019	ARPANSA 2019
Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards	IAEA 2014
Regulations for the Safe Transport of Radioactive Materials (also known as the Transport Regulations)	IAEA 2018

ABBREVIATIONS AND DEFINITIONS

Abbreviation	Meaning
Arafura / ARU	Arafura Resources Limited
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
ERICA	Environmental Risk from Ionising Contaminants
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
NORM	Naturally Occurring Radioactive Material
RMTR	Radioactive Materials Transport Requirements
RP Act	Radiation Protection Act
Statutory RSO	Statutory Radiation Safety Officer
TMP	Transport Management Plan
TSP	Transport Service Provider
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
Bq/cm^2	Becquerel per square centimetre
m^3/h	Cubic meters per hour
mSv/y	Millisievert per year

APPENDIX B.1 INDUSTRIAL PACKAGING-1 (IP-1) REQUIREMENTS

The following table outlines the requirements for IP-1 packaging from the Transport Code:

Transport Code	Clause
534(a)	An IP-1, IP-2 or IP-3 design shall be legibly and durably marked on the outside of the packaging with "TYPE IP-1", "TYPE IP-2" or "TYPE IP-3", as appropriate.
636	The smallest overall external dimension of the package shall not be less than 10 cm.
623	A Type IP-1 package shall be designed to meet the requirements specified in paras 607–618 & 636
607	The package shall be so designed in relation to its mass, volume and shape that it can be easily and safely transported. In addition, the package shall be so designed that it can be properly secured in or on the conveyance during transport.
608	The design shall be such that any lifting attachments on the package will not fail when used in the intended manner and that if failure of the attachments should occur, the ability of the package to meet other requirements of these Regulations would not be impaired. The design shall take account of appropriate safety factors to cover snatch lifting.
609	Attachments and any other features on the outer surface of the package that could be used to lift it shall be designed to either support its mass in accordance with the requirements of para. 608 or shall be removable or otherwise rendered incapable of being used during transport.
610	As far as practicable, the packaging shall be so designed that the external surfaces are free from protruding features and can be easily decontaminated.
611	As far as practicable, the outer layer of the package shall be so designed as to prevent the collection and the retention of water.
612	Any features added to the package at the time of transport that are not part of the package shall not reduce its safety.
613	The package shall be capable of withstanding the effects of any acceleration, vibration or vibration resonance that may arise under routine conditions of transport without any deterioration in the effectiveness of the closing devices on the various receptacles or in the integrity of the package as a whole. In particular, nuts, bolts and other securing devices shall be so designed as to prevent them from becoming loose or being released unintentionally, even after repeated use.
613(A)	The design of the package shall take into account ageing mechanisms.
614	The materials of the packaging and any components or structures shall be physically and chemically compatible with each other and with the radioactive contents. Account shall be taken of their behaviour under irradiation.
615	All valves through which the radioactive contents could escape shall be protected against unauthorized operation.
616	The design of the package shall take into account ambient temperatures and pressures that are likely to be encountered in routine conditions of transport.
617	A package shall be so designed that it provides sufficient shielding to ensure that, under routine conditions of transport & with the maximum radioactive contents that the package is designed to contain, the dose rate at any point on the external surface of the package would not exceed the values specified in paras 516, 527 & 528, as applicable, with account taken of paras 566(b) & 573.
618	For radioactive material having other dangerous properties, the package design shall take into account those properties (see paras 110 and 507).

APPENDIX C RADIATION MATERIAL TRANSPORT PROCEDURE

RADIOACTIVE MATERIAL TRANSPORT PROCEDURE

Introduction

Ores and process materials at the Arafura Nolan Bore Project contain elevated concentrations of thorium and uranium. The concentrations of uranium and thorium exceed the levels at which a material is defined as radioactive.

While Arafura does not intend to initially transport final products that are defined as radioactive, there will be occasions when radioactive materials are transported, most likely for the purposes of sample analysis.

This procedure outlines the requirements for radioactive material transport.

Overall Performance Requirement

In accordance with the Radiation Protection and Radioactive Waste Management Plan (RPRWMP), any radioactive materials that require transport from the site (for example, samples for analysis) will be transported in accordance with the ARPANSA Transport Code [ARPANSA 2019] (referred to as the Transport Code).

Transport of radioactive materials will only be undertaken by the appropriately qualified officer of the company.

Implementation

The transport of radioactive material consists of two main processes:

- Radiation contamination clearance,

Radioactive material transport in accordance with the Transport Code.

Radiation contamination clearance is addressed in the Radiation Surface Contamination Monitoring Procedure (APPENDIX H).

Transportation of radioactive materials must meet authorisation, documentation, packaging, placarding and storage requirements in accordance with the Transport Code and Northern Territory requirements (*Northern Territory Radioactive Ores and Concentrates (Packaging And Transport) Act 1980* and *Northern Territory Radioactive Ores and Concentrates (Packaging And Transport) Regulations 1980*).

The key requirements are:

The company (consignor) is to ensure that the receiver (consignee) is able to accept the consignment under state and federal regulations.

- The material must be accompanied by a completed Dangerous Goods consignment declaration form, Safety Data Sheet (SDS) for the material, and emergency arrangements.

Materials must be packaged in accordance with the Transport Code Section 6 and the 'package' labelled and placarded in accordance with Radiation Protection Series C-2 (RPSC-2) Section 5 clause 534 – 548.

The above conditions do not apply to materials that are deemed to be exempt under RPSC-2 Section 4 clauses 401 – 406. Exempted and Excepted packages do not require a consignment declaration form.

Authorised transport service providers will be used for the transportation of the material. Service providers must demonstrate that their Radiation Transport Management Plan meets the requirements of Arafura's Radiation Transport Requirements (APPENDIX A).

- Radioactive samples and test material originating from the operation will be returned to site and disposed of in the TSF or held as geological/metallurgical records in a secure location.

References

ARPANSA Code for the Safe Transport of Radioactive Material, RPS C-2 (Rev. 1) (commonly referred to as the Transport Code)

Northern Territory Radioactive Ores and Concentrates (Packaging And Transport) Act 1980 (in force as of 1 July 2011)

Northern Territory Radioactive Ores and Concentrates (Packaging And Transport) Regulations 1980 (in force as of 1 January 2010)

APPENDIX D GAMMA RADIATION MONITORING PROCEDURE

GAMMA RADIATION MONITORING PROCEDURE

Introduction

Ores and process materials at the Arafura Nolan Bore Project contain elevated concentrations of thorium and uranium. This may lead to elevated gamma radiation levels in workplaces, resulting in worker exposure.

For occupational exposure, workers are allocated to workgroups and personal dosimeters are issued as required.

The purpose of this procedure is to conduct workplace area monitoring to confirm already identified areas of elevated gamma radiation, to ensure that controls remain effective and that levels remain controlled, and to identify any changes in gamma radiation levels that may occur due to changes in processes or process materials.

The general guidance for gamma radiation is that radiation levels should not change with time, and the monitoring technician should make notes during the survey.

The recognised action level for gamma radiation in any occupied workplace is 5 µSv/h. This value may be exceeded in some areas, and this should be noted. This may not be a concern if the area is not an occupied workplace.

If a gamma measurement exceeds 25 µSv/h, the Statutory Radiation Safety Officer (RSO) must be alerted immediately.

Overall Performance Requirement

The approved Radiation Protection and Radioactive Waste Management Plan outlines the gamma monitoring schedule. A suitably trained technician will take measurements according to the schedule.

Measurements will be undertaken in accordance with this procedure and regularly audited.

Implementation

Note that the exact method of measurement depends on the instrument used, and the general method is outlined below.

Instrument Preparation:

- Gamma surveys must be conducted at locations and times as specified in the Radiation Management Plan.
- Collect gamma monitor.

Ensure the survey meter has a good battery life and observe the background reading over a period of one minute and record.

Performing gamma surveys:

Go to the monitoring location and commence the survey.

- Hold the gamma meter at waist height and take measurements at the predefined locations.

- Record all results (maximums and averages), including any areas of high gamma radiation.
- All data shall be entered into the site radiation database at the end of monitoring.

APPENDIX E LONG LIVED RADIONUCLIDES IN DUST SAMPLING PROCEDURE

LONG LIVED RADIONUCLIDES IN DUST SAMPLING PROCEDURE

Introduction

Airborne dust monitoring includes both personal sampling and locational sampling. It is conducted to determine the exposure to workers and to also check on the effectiveness of control measures.

The primary purpose of this sampling procedure is to collect information on long-lived radionuclides in dusts that workers may inhale.

Radioactive dust sampling consists of two main components:

- Taking a representative air sample, which involves drawing air through a pre-weighed 25mm filter paper for a defined period at a defined flow rate, using a calibrated dust pump.
- Analysing the content of the sample for long-lived radionuclides, which involved placing the filter into an alpha counting slide drawer assembly and "alpha counting" for a prescribed time.

The first part of the method is conducted in accordance with Australian Standard AS3640-2004 (see reference). The radiometric analysis is defined in detail in this procedure,

Radiation inhalation dose mainly comes from the long-lived alpha-emitting radionuclide in airborne dust. For the dusts generated in the Nolan Bore Project, the ratio of long-lived alpha radiation will vary depending upon the particular area.

This must be taken into account when assessing doses from the inhalation of dusts (see Dose Assessment Procedure, APPENDIX I).

Overall Performance Requirement

The approved Radiation Protection and Radioactive Waste Management Plan outlines the schedule for occupational dust monitoring. A suitably trained technician will take measurements according to the schedule.

Measurements will be undertaken in accordance with this procedure and regularly audited.

Implementation

1. Filter pre-weighing:
   - Collect filters to be weighed and a corresponding number of clean petri dishes. Label each of the dishes with a unique sample identifier.
   - Weigh each filter using a calibrated microbalance and write the weight of the filter onto the petri dish. Cover and then place the filter into the dish. Complete the pre-weighing for the required number of filters for the monitoring event.
   - The filters will be 25mm 0.8 micron (pore size) Millipore filters.
   - Record the initial filter masses on the Airborne Dust Monitoring Sheet.

2. Sample head preparation:

   - Dismantle the inhalable sampling filter holder (also known as the sampling head) and using contact cleaner and lint free tissues; remove any dirt from the head body, supporting mesh and O-rings.
   - Assemble the sampling head by placing a clean O-ring followed by a dry supporting mesh inside the body of the head. Position a pre-weighed filter with a Teflon O-ring laid on top, onto the mesh. Firmly screw on the top section of the head and secure by using electrical tape to join the two sections of the head.
   - On the Airborne Dust Monitoring Sheet record the number of the sampling head, the pre-weighed filter mass and the filter sample number.
   - Attach the sampling head to a SKC AirChek Sampler that has been on charge for at least 24 hours. Record the AirChek Sampler number on the Airborne Dust Monitoring Sheet.

3. Pre-setting the Airchek Sampler used for area monitoring

   - Remove the clear plastic cover from the AirChek sampler controls by undoing the screw at the centre bottom of the plastic cover.
   - Turn the 'ON/OFF' switch from on to off to on again.
   - When the pump is running, press the 'START/HOLD' button.
   - Press the 'SET-UP' button for the display to indicate a delayed start. The first digit of the display will start to flash. Calculate the time in minutes until the sampler is required to start. Set that number of minutes on the display using the 'DIGIT SET' button to change the value of each digit. The 'DIGIT SELECT' button is used to change digits on the display. The 'DIGIT SET' button will change the flashing digit.
   - When the correct delay start time is displayed, press the 'MODE' button once. The sampling period can now be set. The display should indicate 'SAMPLING PERIOD', and the first digit should be flashing.
   - A sampler period of seven hundred (700) minutes should be set. This sampling period is twelve (12) hours, corresponding with a shift's duration. Use the 'DIGIT SELECT' and 'DIGIT SET' buttons to set the sampling period.
   - Once the sampling time is set, press the 'START/HOLD' button once. 'DELAYED START' should be flashing in the bottom left-hand corner and the delay start time should be visible. Once the sampler counts down the set delay time, the sampler will automatically run for the set sampling period.
   - Replace the plastic cover.

4. Pump flow rate calibration

   - Prior to pre-setting the sampling time and placing the sampler, operate the AirChek sampler with a sample head attached for two (2) minutes. After the sampler has warmed up, check the flow rate using the DC-Lite primary flow meter. If the flow rate is not 2.0 +/- 0.1 lpm, adjust the flow rate of the AirChek sampler using the 'FLOW ADJUST' screw on the front panel of the sampler. Adjust this screw until the flow rate is 2.0 +/- 0.1 lpm. Turn the screw clockwise to increase the flow rate and counterclockwise to decrease the flow rate.

- The control filters should be placed in sample heads on a pump. The pumps with control filters should then undergo a flow rate check. This is so that the control filters are subject to the same non-sampling procedures as the sample filters.

5. Distribution of sampling equipment

- In accordance with the dust monitoring program specified in the RPRWMP, distribute sampling pumps to the personnel or areas to be monitored at the commencement of shift. Start personal pumps, and any area pumps that do not have a delayed start set. Record the sampling head number, start time and details of the monitored personnel or areas in the Airborne Dust Monitoring Sheet.
- Arrange a collection point for personal pumps with individual wearers.
- After returning to the radiation laboratory, record the information in the Airborne Dust Monitoring Sheet.

6. Collection of sampling equipment

- Collect the pumps the following morning or towards the end of shift. Ensure that the wearers of personal pumps have a good understanding of how to turn the pump off. Arrange a point where the wearer can leave their personal pump to be collected. Collect and return the pumps to the radiation laboratory.
- Record the pump run-time in the appropriate column of the Airborne Dust Monitoring Sheet in the corresponding row for each pump.
- For personal samples, record comments from the operator regarding their activities during the day.
- For area samples, record any observations about the workplace that may have affected the sample result (for example, "windy day with excessive environmental sand in the area").

7. Dust filter weight analysis

- Separate the sampling head from each pump.
- Disassemble the sampling head and place the filter in the correct petri dish.
- Weigh the filter and record the mass on the petri dish and in the Airborne Dust Monitoring Sheet.

8. Dust filter radiometric analysis

- Do not alpha count the filter until at least 48 hours after the end of the sampling time. This gives time for any radon decay products to decay away. Counting the filter immediately will also result in short-lived alpha emissions being counted.
- Count the filter in a Ludlum alpha particle counter for a time interval of one hundred minutes. (Note delayed time for counting may apply).
- At the completion of counting, record the number of counts and the counter number in the appropriate column of the Airborne Dust Monitoring Sheet.
- Repeat the above steps for all pumps that are collected.

9. Enter results

- Once the sample has been counted, enter all data into the Radiation Monitoring database

- The database will provide notification of any further actions that may be required (for example, if the dust activity or dust concentration is above the reporting level).

10. Alpha counter considerations

    - Perform a background count (BC) for 100 minutes once each day. Record results in the daily monitoring form.
    - Perform a calibration check using an alpha calibration source each week and record in the monitoring database.
    - Make sure that the filters are counted for 100 minutes. To determine "nett" counts, subtract the latest background count from the gross count and record it in the Radiation Monitoring Database.
    - Clean the alpha counter sample tray with alcohol (swab) in between each count.

References

AS 3640-2004 – Workplace atmospheres – Method for sampling and gravimetric determination of inhalable dust

APPENDIX F RADON DECAY PRODUCT SAMPLING PROCEDURE

RADON DECAY PRODUCT SAMPLING PROCEDURE

Introduction

This procedure refers to the sampling procedure for radon decay products.

Ores and process materials at the Arafura Nolan Bore Project contain elevated concentrations of thorium and uranium. Both of these radionuclides decay through to the element radon. For uranium, the isotope of radon is Rn222 (commonly known as "radon"), and for thorium, the isotope is Rn220 (commonly known as "thoron").

Both of these decay isotopes are radioactive and decay to their respective decay products. The decay products are relatively short-lived (compared to the long-lived radionuclides), and therefore, it is important to assess their inhalation hazard.

Monitoring provides the basis for compliance testing and dose assessment.

Radon and thoron decay product sampling consists of two main components:

- Taking a representative air sample, which involves drawing air through a pre-weighed 25mm filter paper for a defined period at a defined flow rate, using a calibrated dust pump.
- Analysing the content of the sample for short-lived radionuclides, which involved placing the filter into a portable alpha counting slide drawer assembly and "alpha counting" for a prescribed time. Because of the different half-lives of radon and thoron and their decay products, the "timing" of various aspects of this sampling method is different.

A primary exposure pathway for workers is the inhalation of the short-lived decay products of the isotopes of radon (Rn222) and thoron (Rn220). Air sampling is conducted, and a strict counting time arrangement is applied in order to measure the dominant short alpha emitters in the respective decay chains. The methods are based on published papers and general guidance.

The assessment of doses from the measured concentration of the decay products in air is outlined in the Dose Assessment Procedure (APPENDIX I).

Many different methods exist for measuring radon and thoron decay products (see DMP 2010). Arafura uses the Borak method for radon decay products.

Overall Performance Requirement

The approved Radiation Protection and Radioactive Waste Management Plan outlines the schedule for occupational radon decay product monitoring. A suitably trained technician will take measurements according to the schedule.

Measurements will be undertaken as per this procedure and will be regularly audited.

Implementation

For radon decay products, the preferred method is the Borak method (also known as the "3-3-3" method), and the timing is as follows:

- Air sampling – 3 minutes
- Wait time before counting – 3 minutes
- Count time – 3 minutes

The method for analysis is detailed below:

- Place a Type A/E Glass Fiber Filter using tweezers into the sampling head.

Set the pump to run for 3 minutes at 2 litres per minute (refer to SKC 224-XR AirChek 52 Sample Pump manual for the operation of the pump).

- Note the start time and the sampling location.

The filter paper with the filtered decay products is then placed into the alpha counter, and a delay period of 3 minutes occurs before "counting" of the filter.

After the delay period, the filter paper is gross alpha counted for a period of 3 minutes.

A background count is usually conducted prior to the filter count.

The count data is then used to calculate the radon decay product concentration using the following equation:

- RDP (μJ/m^3) = (Counts x 0.2237) ÷ (Counter Efficiency)

The counter efficiency is located on the side of the Ludlum 2241.

References

DMP 2010 - Managing Naturally Occurring Radioactive Material (NORM) in mining and mineral processing guideline NORM 3.4 Monitoring NORM airborne radioactivity sampling
https://www.dmp.wa.gov.au/Documents/Safety/MSH_G_NORM-3.4.pdf

APPENDIX G THORON DECAY PRODUCT SAMPLING PROCEDURE

THORON DECAY PRODUCT SAMPLING PROCEDURE

Introduction

This procedure refers to the sampling procedure for thoron decay products.

Ores and process materials at the Arafura Nolan Bore Project contain elevated concentrations of thorium and uranium. Both of these radionuclides decay through to the element radon. For uranium, the isotope of radon is Rn222 (commonly known as "radon"), and for thorium, the isotope is Rn220 (commonly known as "thoron").

Both of these decay isotopes are radioactive and decay to their respective decay products. The decay products are relatively short-lived (compared to the long-lived radionuclides), and therefore, it is important to assess their inhalation hazard.

Monitoring provides the basis for compliance testing and dose assessment.

Radon and thoron decay product sampling consists of two main components:

- Taking a representative air sample, which involves drawing air through a pre-weighed 25mm filter paper for a defined period at a defined flow rate, using a calibrated dust pump.
- Analysing the content of the sample for short-lived radionuclides, which involved placing the filter into a portable alpha counting slide drawer assembly and "alpha counting" for a prescribed time. Because of the different half-lives of radon and thoron and their decay products, the "timing" of various aspects of this sampling method is different.

A primary exposure pathway for workers is the inhalation of the short-lived decay products of the isotopes of radon (Rn222) and thoron (Rn220). Air sampling is conducted, and a strict counting time arrangement is applied in order to measure the dominant short alpha emitters in the respective decay chains. The methods are based on published papers and general guidance.

The assessment of doses from the measured concentration of the decay products in air is outlined in the Dose Assessment Procedure (APPENDIX I).

There are many different methods for measuring radon and thoron decay products (see DMP 2010). Arafura uses the Rock method for thoron decay products.

Overall Performance Requirement

The approved Radiation Protection and Radioactive Waste Management Plan outlines the schedule for occupational thoron decay product monitoring. A suitably trained technician will take measurements according to the schedule.

Measurements will be undertaken as per this procedure and will be regularly audited.

Implementation

The procedure for thoron decay monitoring is outlined below:

- Place a Type A/E Glass Fiber Filter using tweezers into the sampling head.

Set the pump to run for 20 minutes at 2 litres per minute (refer to SKC 224-XR AirChek 52 Sample Pump manual for the operation of the pump).

- Note the start time and the sampling location.

The filter paper with the filtered decay products is then enclosed in a plastic container for a delay period of 5 hours.

After the delay period, the filter paper is gross alpha counted for a period of 10 minutes.

A background count is usually conducted prior to the filter count.

The count data is then used to calculate the thoron decay product concentration using the following equation:

$$Thoron\ Decay\ product\ Concentration\ (\mu J/m^3) = \frac{[(C_S - C_B)\ \mathrm{x}\ 20.8]}{(\mathrm{E\ x\ f\ x\ V\ x\ T})}$$

Where:

- Cs = gross count in interval T
- CB = background count in interval T

E = efficiency of detection equipment expressed as a fraction (cps/dps)

- f = conversion factor, (13.2 for this sampling and counting arrangement)
- V = volume of air sampled
- T = counting time in minutes
- 20.8 - factor to convert from WL (working level) to μJ/m^3.

References

DMP 2010 - Managing Naturally Occurring Radioactive Material (NORM) in mining and mineral processing guideline NORM 3.4 Monitoring NORM airborne radioactivity sampling
https://www.dmp.wa.gov.au/Documents/Safety/MSH_G_NORM-3.4.pdf

APPENDIX H RADIATION SURFACE CONTAMINATION MONITORING PROCEDURE

RADIATION SURFACE CONTAMINATION MONITORING PROCEDURE

Introduction

Ores and process materials at the Arafura Nolan Bore Project contain elevated concentrations of thorium and uranium, and when plant and equipment come in contact with the ores or process materials, there is a chance that they may become contaminated with radioactive materials.

Similarly, dust may deposit from the air and process materials (such as muds) may be carried into "clean" areas through workers' clothing, boots or contaminated equipment. The Radiation Protection and Waste Management Plan requires that surface contamination monitoring be conducted to identify where contamination has occurred and ensure that "clean" workplaces are not contaminated.

It is important to ensure that plant, equipment or clothing does not become contaminated and, therefore, potentially radioactive. Good cleaning practices will enable the return of items to a non-contaminated state. In some cases, the costs of the cleaning may make it prohibitive, for example, in the case of ingrained rust, requiring that the item be disposed of as radioactively contaminated waste. In these cases, the radioactive contamination is referred to as "fixed contamination" and does not represent a health risk due to its immobile state.

The main aim of this procedure is to provide a method for surface contamination monitoring.

The general guidance for surface contamination is that if the item "looks dirty", then it is likely to be contaminated. Therefore, surface contamination monitoring is really a check for the cleanliness of items and workplaces.

The recognised standard for what is considered surface contamination are levels of:

Over 3,700 Bq/m^2 – For all monitored areas excluding workshops

Over 37,000 Bq/m^2 – For workshops

Where readings above this level are recorded, the corresponding item or area must be cleaned or disposed of as radioactively contaminated waste.

Overall Performance Requirement

The schedule for surface contamination monitoring is outlined in the approved Radiation Protection and Radioactive Waste Management Plan. Measurements will be taken by a suitably trained technician in accordance with the schedule.

Measurements will be undertaken in accordance with this procedure and regularly audited.

Implementation

Note that the exact method of measurement depends on the instrument used; however, a generalised method is outlined below:

- For this procedure, use of the Ludlum 2241-3 Survey Meter with alpha probe (Model 43-65) is assumed.

- Move the control switch on the survey meter to "Surface Alpha" position.

Confirm the LCD display is NOT showing the battery icon; otherwise, consult a qualified technician to replace the batteries before commencing.

- Ensure the following switches are set:
  - "AUD" switch to "ON" position
  - The response switch to "S" position

The mode switch on "RATE" mode.

- Proceed to the location to be surveyed, as outlined in the Radiation Protection and Radioactive Waste Management Plan.

Hold the probe (with the very sensitive mylar window) toward the sun or light source and perform a light leak check. If the meter responds abnormally or starts repeatedly beeping, there is an error, likely a hole in the MYLAR film. Return the meter to a qualified technician for repair.

If no error sounds, hold the probe within 0.5cm of the selected surface and observe the reading. The reading will fluctuate on display; use a by-eye assessment and get the average result.

- Record results in the Radiation Monitoring Data Sheet.
- Move to the next surface and locations and repeat until all the monitoring is complete.
- Switch off the instrument and return to the office at completion of monitoring.

APPENDIX I RADIATION GAUGES & SEALED SOURCES OF RADIATION MANAGEMENT PROCEDURE

RADIATION GAUGES AND SEALED SOURCES OF RADIATION MANAGEMENT PROCEDURE

Introduction

Note that the design of the Arafura Processing Plant has yet to be finalised and there is uncertainty whether radiation density gauges will be used for process control. In the event that density gauges are to be used, this procedure will apply to those gauges.

This procedure applies to the management of radiation gauges and sealed radiation sources. This includes:

- the purchasing or taking receipt of radiation gauges
- work on or around radiation gauges
- use of radioisotopes in laboratories, and
- emergency response involving radiation gauges.

Radiation Gauges contain a small, intense radioactive source enclosed within a radiation shield. When a gauge is mounted in its normal working position or when removed but with the shutter locked in the "Off" position, radiation levels are low and within recognised regulatory limits.

If there is any sign of damage to a radiation gauge or radioisotope, or it has been dropped or incorrectly installed, the SRSO must be informed immediately.

Overall Performance Requirement

The SRSO will maintain a record of all radiation density gauges and radioisotopes installed and utilised at the Project and is responsible for ensuring that all are appropriately licenced. A register of the location of all radiation gauges on site will be stored in the occupational hygiene office. Personnel must complete maintenance logs during every inspection, and a copy forwarded to the SRSO.

Annual audits of density gauges and radioisotopes will be conducted.

Implementation

1. Procuring, Receipt and Notification

No radiation gauge or sealed source is permitted to be brought to site without the formal approval of the Statutory Radiation Safety Officer (SRSO).

All radiation density gauges and radioisotope sources require a "licence to possess" in accordance with the Northern Territory Radiation Protection Regulations.

- Upon arrival of the radiation gauge at the operation, the SRSO must:
  - Ensure that the documentation matches the label on the gauge
  - Conduct a gamma survey
  - Check the gauge is working correctly

- Check for any damage
- Ensure that signage is correct

The shutter or source control mechanism is operating correctly.

If the gauge is not to be installed when first arriving on site, it will be relocated by suitably trained personnel to a secure locked area until it is required. Only appropriately trained radiation personnel are authorised to access this area.

2. Installation and Maintenance

- No work can occur on a radiation gauge or sealed source without the formal authorisation of the SRSO.

A detailed installation plan will be established for each density gauge and be approved by the SRSO. Once installed, the gauge will be inspected by the SRSO to ensure that it is safe and secure and that all precautions are in place.

A regular gauge maintenance program will be established that includes:

- Cleaning radiation gauges of any contamination.
- Inspection and immediate reporting of any visible damage to the radiation gauge to the SRSO.
- Replacement of any missing or damaged radiation signage.

Where work is to be conducted in the vicinity of a gauge, it must be isolated in accordance with the procedure below.

3. Radioactive Gauge Clearance

Prior to work on and around radiation gauges, a Permit to Work must be completed.

A Radiation Gauge Clearance must be completed when a person is required to carry out work on a radiation gauge or any work in the vicinity of a gauge.

The Radioactive Gauge Clearance is issued in conjunction with the Permit to Work.

The SRSO or Authorised Officer are the only personnel authorised to isolate gauges.

4. Isolation of Gauges

The SRSO must accompany the worker who holds the Permit to Work to isolate the gauge and complete a Radioactive Gauge Clearance. The SRSO will turn the radiation gauge's shielding to the "beam off" position and lock it out using a safety padlock and attaching an isolation tag.

The SRSO is the only person who can authorise the work and the only person authorised to return the radiation gauge back to the "beam on" position. The key to locking the beam out must be held by the SRSO.

- After the radiation gauge has been switched to the "beam off" position and locked out, the SRSO will perform a gamma survey around the gauge to confirm the beam is off and record the results on the Radiation Gauge Clearance Certificate.

5. Recording

- Whenever a radiation gauge is moved temporarily or permanently, it must be logged by the SRSO.

6. Emergency Procedure

- An Emergency is defined as: any loss of control of the gauge, or any incident involving direct exposure of a person to the radiation beam. This may include but is not limited to:
  - A radiation gauge falling from its proper working position
  - A radiation gauge being removed from its position without authority
  - Any situation which damages, or may have damaged a radiation gauge
  - A radiation gauge found to be missing.

The SRSO is responsible for making an immediate assessment of the nature and scope of the hazard following any incident involving radiation gauges. They may call upon Emergency Services personnel and, depending on the nature of the incident, may:

Secure the area and establish control measures over access to the area

- Complete radiation monitoring survey
- Apply a shield to the radioactive source
- Remove the radiation gauge to the Radiation Store.

Following an emergency the SRSO will conduct an investigation into the incident. Estimates will be made of any possible radiation exposures.

APPENDIX J DOSE ASSESSMENT PROCEDURE

DOSE ASSESSMENT PROCEDURE

Introduction

This procedure describes the method used to calculate total effective dose for workers based on doses from the three main radiation dose pathways.

- Irradiation by external gamma radiation;
- Inhalation of Long Live Radionuclides in Airborne Dust (LLRD);

Inhalation of Radon and Thoron Decay Product (RnDP and TnDP).

The doses calculated for these three main pathways are then added together to calculate the total effective dose, according to the formula:

Total Effective Dose = Gamma dose + LLRD dose + RnDP and TnDP dose, where:

Gamma dose = personal gamma dosimeter readings OR Work Group Average (WGA) (in μSv)

LLRD Dose = WGA activity concentration in Bq/m^3 x hrs onsite x 1.2 m^3/hr breathing rate x DCF (in μSv)

- RDP dose = personal dosimeter OR

Area WGA RDP concentration in □J/m^3 x hrs onsite x for each individual x DCF for RDP (in μSv)

Overall Performance Requirement

Doses for workers will be calculated:

- Quarterly and compared to the quarterly dose constraint and limit
- Annually and compared to the annual dose constraint and limit

Where a quarterly workgroup dose exceeds the pro-rata quarterly dose constraint or dose limit, an investigation must be conducted.

Where an annual workgroup dose exceeds the annual dose constraint or dose limit, an incident will be logged into the internal incident management system for formal investigation.

Results of annual dose assessments are to be summarised into a report for internal distribution and review.

The respective limits are shown in Table A below.

Table A: Dose Investigation Levels

Criteria	Level (mSv)	Action
Quarterly Dose Constraint	2.5	Investigate exposure pathways & review controls
Quarterly Dose Limit	5	Immediate review and implement improvements
Annual Dose Constraint	10	Investigate exposure pathways and implement appropriate controls

Criteria	Level (mSv)	Action
Annual Dose limit	20	Statutory exceedance

The dose assessments will be conducted by the Statutory Radiation Safety Officer.

Implementation

1. Gamma Dose
    - Personal gamma exposure will be determined from the individual gamma monitors each quarter.
    - Workers who are not issued with personal gamma monitors will have their gamma exposure calculated from a combination of Work Group Averages (WGA) and individual time on site.
    - Where a worker or a group of workers has been identified to have been exposed to an incident dose, the incident dose is to be added to their final dose calculation.
2. LLRD Dose
    - LLRD area and personal monitoring data will be used to calculate the WGA for each similar exposure group (SEG).
    - Individual LLRD doses are calculated with a combination of WGA, individual time on site, and the relevant LLRD dose conversion factor.
    - Where a worker or a group of workers has been identified to have been exposed to an incident dose, the incident dose is to be added to their final dose calculation.
3. RnDP and TnDP Dose
    - Area RnDP and TnDP monitoring results will be utilised to calculate WGA, which will then be applied to each worker in that SEG.
    - Area RDP dose will be calculated from a combination of RDP district average, individual time on site, and the RDP dose conversion factor.
    - Where a worker or a group of workers has been identified to have been exposed to an incident dose, the incident dose is to be added to their final dose calculation.

APPENDIX K RADIATION CLEARANCE OF MACHINERY AND EQUIPMENT PROCEDURE

RADIATION CLEARANCE OF MACHINERY AND EQUIPMENT PROCEDURE

Introduction

The main aim of this procedure is to ensure that machinery and equipment that has come into contact with radioactivity is decontaminated and cleaned, prior to removal from site. This procedure recognises the surface contamination clearance levels outlined in the ARPANSA Transport Code which form the formal basis of the performance requirements for this Procedure.

Radioactive material is generally defined as follows:

material that contains more than 80ppm of naturally occurring uranium

material that contains more than 240 ppm of naturally occurring thorium

material that contains more than 1Bq/g of any radionuclide.

It is important to note that a piece of equipment cannot "become radioactive". What occurs is that the piece of equipment is contaminated with radioactive material (such as uranium dust or ore), and the aim is then to remove this contamination.

Overall Performance Requirements

All plant and equipment that leaves the main mining and processing area where:

- it has been in contact with radioactive material (such as a pump for radioactive slurries)
- it may have been subject to dust deposition (such as storage containers next to an ore crushing facility)
- it could be contaminated (such as a vehicle from the mine pit).

Must be inspected for cleanliness and subject to a radiation clearance before leaving the particular site.

It is the responsibility of the person authorising the removal of that piece of equipment from the site to ensure that the piece of equipment is checked and decontaminated, where required, before the equipment leaves site.

The critical requirement is to ensure that a piece of equipment is clean so that it can be freely transported and used elsewhere. To achieve this, the ARPANSA Transport Code (see reference) is usually used for guidance. This document defines 'contaminated equipment' as follows:

"The Contamination shall mean the presence of a radioactive substance on a surface in quantities in excess of 0.4 Bq/cm2 for beta and gamma emitters and low toxicity alpha emitters, or 0.04 Bq/cm2 for all other alpha emitters." (Clause 214)

Implementation

Prior to a piece of equipment being presented for final clearance, it should have already been physically cleaned and allowed to dry.

Physical cleaning can completed using a range of techniques, including, but not limited to:

- washing with a high-pressure hose
- scrubbing with a brush to remove caked-on mud or materials
- use of cleaning agents (solvents or acids)
- sandblasting
- flushing of some equipment (such as a pump)
- dismantling of certain equipment (where the inside is inaccessible, and contamination exists inside).

All cleaning must be undertaken in a nominated decontamination area or appropriately bunded area with a wastewater capture system.

Once a piece of equipment is cleaned and dry, it can then be inspected. There are two methods of checking the cleanliness of equipment:

1. A visual inspection (note that if a piece of equipment looks dirty, and even if it does not trigger the performance limit, it is not good practice for it to be sent from site).
2. A surface alpha contamination check using an appropriate monitor can be conducted on the dried surfaces of the equipment.

For the alpha check, it is important to check the internals or "out of sight" areas of equipment. For example, when inspecting a vehicle, it is important to be able to identify if there is contamination under the vehicle. Similarly, for equipment like pumps, it may be necessary to strip down the pump and clean before sending off site.

Equipment that is cleared to leave the site must be documented and signed off by the person who conducted the decontamination check and is authorising the removal of the equipment offsite.

References

Code for the Safe Transport of Radioactive Material (2019) https://www.arpansa.gov.au/regulation-and-licensing/regulatory-publications/radiation-protection-series/codes-and-standards/rpsc-2

APPENDIX L RADIOACTIVELY CONTAMINATED WASTE PROCEDURE

RADIOACTIVELY CONTAMINATED WASTE PROCEDURE

Introduction

Ores and process materials at the Arafura Nolan Bore Project contain elevated concentrations of thorium and uranium.

For radioactively contaminated waste, Arafura will implement a program that initially aims to minimise waste to be disposed of. Where practical, radioactively contaminated waste will be decontaminated and then disposed of via appropriate waste channels or recycled. Where this is not possible, alternative disposal options include:

- Incorporation into the waste rock stockpile.
- Disposal in a dedicated contaminated waste on-site landfill facility (note that this may be a separate area of the site landfill).
- Stored in a secure storage area until end of mine life and incorporated into the Project decommissioning plan.

Overall Performance Requirement

The Statutory Radiation Safety Office (SRSO) will conduct regular audits of radioactively contaminated waste. Areas to be audited include:

- Clear assignment and communication of responsibilities
- Education and engagement of the aspects of this procedure

Effectiveness of reporting, feedback and corrective measures

Implementation

Arafura will aim to minimise the amount of radioactively contaminated waste in accordance with the waste hierarchy.

- Minimise the waste generated throughout the operation and maximise the reuse and recycling of waste materials produced.
- Safely and securely store, handle, transport, and dispose of waste.

Implement effective recording, monitoring and tracking systems.

1. Approach
   - All members of the operations team will strive to minimise waste.
   - Every effort will be made to recycle, recover or reuse waste where possible.
   - All personnel will be required to make reasonable efforts to ensure that waste is properly segregated at the source.
2. Administration Controls
   - Radioactively contaminated waste volumes are to be collated monthly and consolidated into a monthly report.
   - A system of regular auditing will be established.
3. Waste Classification and Segregation
   - All radioactively contaminated waste will be identified at the source and sorted into different skips or stockpiles.
   - Waste materials that are contaminated with process materials are to be washed down in dedicated bunded areas prior to being placed as waste. The aim is for the waste item to be clean of removable contamination.
4. Waste Collection
   - Radioactively contaminated waste will be delivered to the appropriate waste disposal area in a safe and secure manner.
   - Bins, including location and collection schedule, is to be established and communicated to all supervisors and contractors by the nominated waste management resource.
5. Removal of Waste from Site
   - In general, radioactively contaminated waste will be disposed of on site.
   - Where required, radioactive contaminated waste may be disposed of in an offsite facility. This will only occur under the direction of the SRSO.
   - All waste leaving the site will be transported appropriately (using suitably permitted waste transport contractor(s), where required) and only taken to a licenced waste disposal facilities.
   - All waste radioactive contaminated waste leaving the site will be documented and accounted for.

  - If waste material is to be removed from site once it has been decontaminated, the regular site contamination clearance will be undertaken.

6. Reporting
   - Waste types and volumes are to be recorded.
   - Generated waste types and volumes are to be collated monthly and consolidated into a monthly report for internal distribution to management.
7. Bunded Wash-down Areas for Cleaning
   - A bunded wash-down area will be required to clean waste that is contaminated.
   - A wash-down area will also be established for cleaning waste that is leaving site.
8. Radioactively Contaminated Materials
   - An item of material is defined as radioactively contaminated when:
     - The item, equipment or material exceeds the surface contamination clearance level.
     - The item, equipment or material is calculated to contain, on average, a radionuclide concentration that exceeds 1Bq/g, or 10 Bq/g for some individual radionuclides (as assessed by a SRSO).
9. Radioactively Contaminated Waste
   - Where plant, equipment or items cannot be sufficiently cleaned and are classified as radioactively contaminated waste for disposal, the following options shall be considered:
     - Incorporation into the waste rock stockpile
     - Disposal in a dedicated contaminated waste on-site landfill facility (note that this may be a separate area of the site landfill)
     - Stored in a secure storage area until end of mine life and incorporated into the Project decommissioning plan.
10. Radioactive Process Material
    - Process materials include slurries, dusts, accretions, process liquors and reclaimed sump liquids.
    - The defined disposal method for this material is either to recycle the material back into the process or transfer to the TSF dam. Disposal into the TSF will require authorisation by the TSF manager.

APPENDIX M ENVIRONMENTAL RADIATION MONITORING PROCEDURE

ENVIRONMENTAL RADIATION MONITORING PROCEDURE

Introduction

Ores and process materials at the Arafura Nolans Project contain elevated concentrations of thorium and uranium. The conduct of the operations may result in offsite radiological impacts. Monitoring is required to identify changes in natural background levels and determine the effectiveness of emission controls.

Arafura has previously conducted baseline monitoring to determine the region's naturally occurring background radiation levels. The baseline monitoring will continue until operations commence.

Once operations commence, the monitoring program will transition to an operational environmental monitoring program.

Overall Performance Requirement

The approved Radiation Protection and Radioactive Waste Management Plan outlines the environmental monitoring schedule. A suitably trained technician will take measurements according to the schedule.

Measurements will be undertaken in accordance with this procedure and regularly audited.

Implementation

The monitoring methods are outlined in Table B below.

Table B: Environmental Radiation Monitoring Methods

Radiation	Measurement Method	Location and Frequency
Gamma	Passive environmental gamma monitors	OSLD or TLD badges (provided and analysed by service provider) located approximately 1m above the ground. Can be taped to the support stand, with quarterly changeover, at each monitoring location.
	Gamma survey	Handheld gamma survey of monitoring location.
Radon concentration	Passive environmental radon monitors	Passive radon detector placed one meter above the ground in protective housing (pipe with one open end to the ground), with quarterly changeover, at each monitoring location.
Dispersion of dust containing long-lived radionuclides	Passive dust deposition gauges	Continuous sampling at each monitoring location - changeover quarterly or more frequent as determined by rainfall. Samples for each monitoring location composited for one year then radiometrically analysed. Summary method is: ▪ 5 L dust jars with funnel and bird deterrent mount approximately 2m above ground away

Radiation	Measurement Method	Location and Frequency
		from trees. ▪ Copper sulphate solution placed in jar to prevent organic growth. When jar is collected, distilled water is used to wash any dust on funnel into bottle. Used bottle is capped and new bottle is placed in holder.
Radionuclides in surface and groundwater	Environmental water sampling	Annual long lived radionuclide analyses of water samples taken as part of the routine environmental water monitoring program.
Soil sampling for radionuclides	Sample collected and analysed for long-lived radionuclides	One sample collected prior to commencement of operations at each monitoring location.

APPENDIX N LIFE OF MINE SCHEDULE

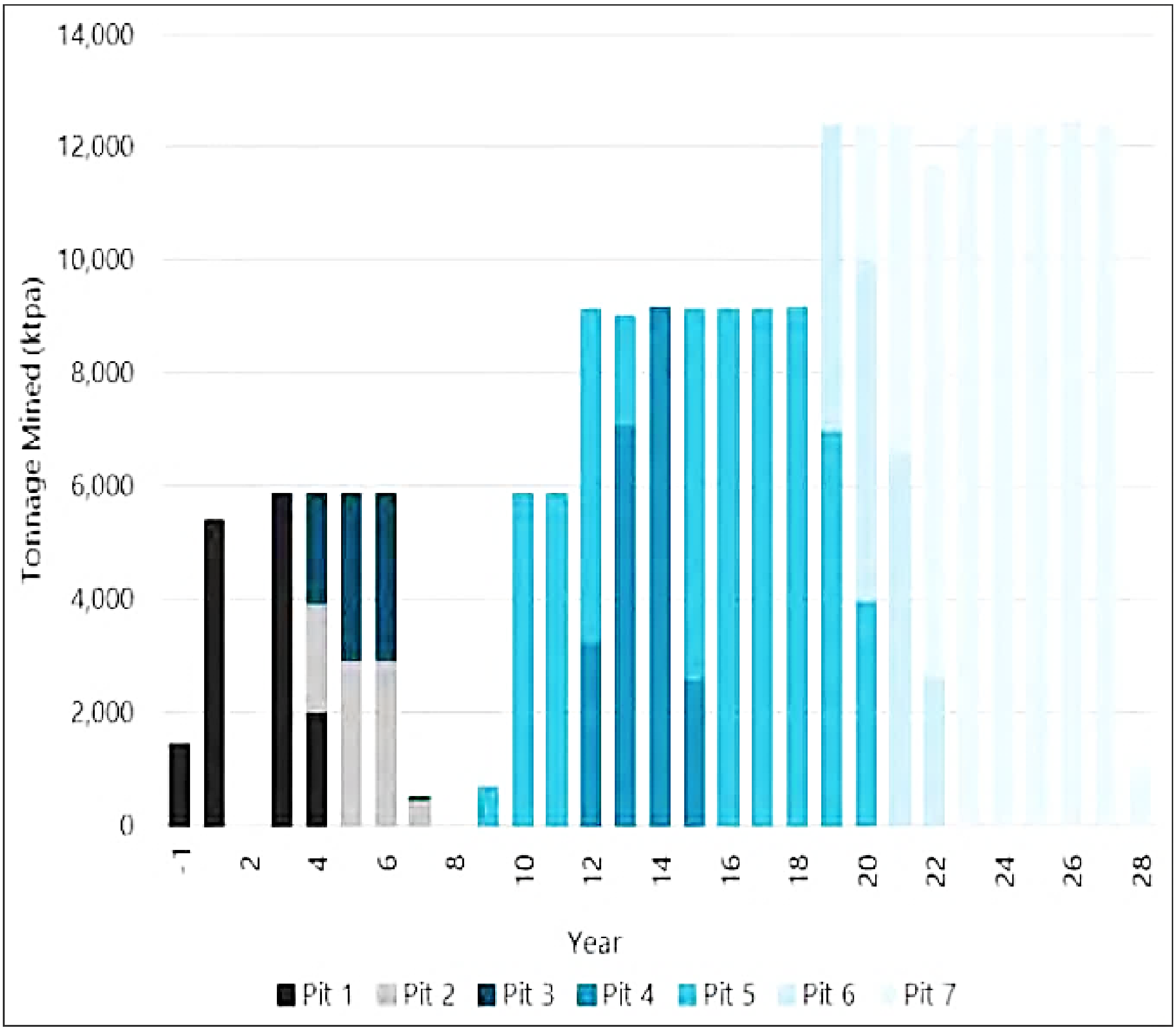


Figure 1-2 Mining Schedule (Mining Inventory)

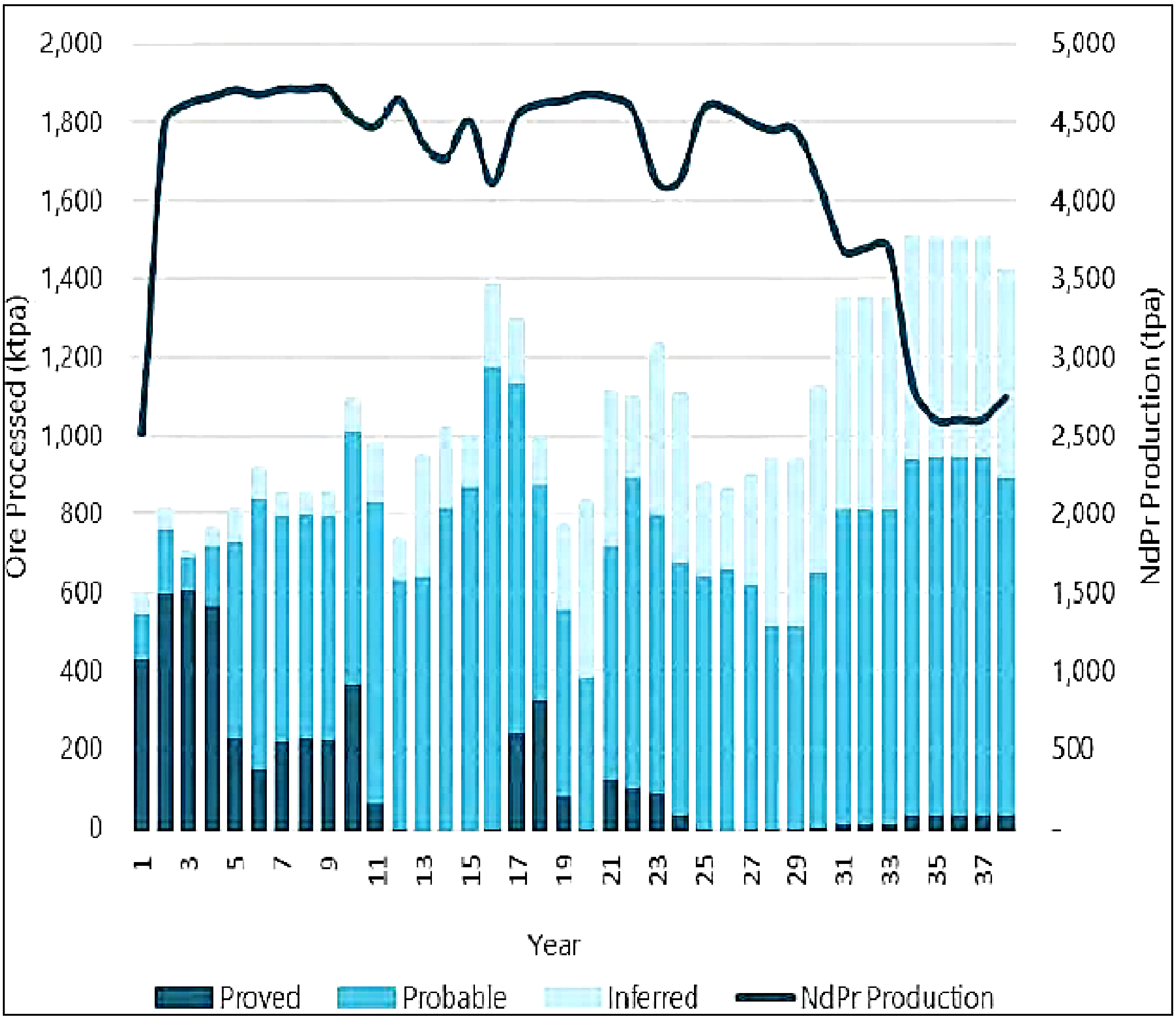


Figure 1-3 Production Schedule (Mining Inventory)

APPENDIX O CLOSURE KNOWLEDGE GAPS

MINE CLOSURE PLAN KNOWLEDGE GAPS

The risk assessment completed for the Project MCP identified a number of knowledge gaps that will be addressed through the initiation of technical investigations and rehabilitation trials.

A number of trials and investigations are to be carried out during the operational life of mine. The results of these trials will be used to inform final landform designs and rehabilitation proposals. Table C below summarises the currently envisaged program. This is to be reviewed and updated as part of triennial reviews of Project MCPs during the operational phases of the Project.

Table C: Pre-closure trials and investigations to address knowledge gaps

Topic	Information Gap / Uncertainty	Description
Vegetation Trials	Optimum seed planting mixes for rapid establishment under local climatic and soil conditions and on post-closure landforms.	Undertake trials of soil covers and vegetation recruitment on WRDs and other disturbed surfaces. Undertake topsoil stockpile seedbank trials.
Progressive Rehabilitation Trials	Optimum WRD cover design for maximum stability and vegetation establishment success.	Large-scale field trials of soil profile, erosion and vegetation recruitment.
Rehabilitation and closure materials	Availability of suitable cover material for closure.	Cover materials resource assessment: Undertake further detailed geotechnical and geochemical studies to locate and characterise sufficient quantities of rehabilitation cover materials. This should include timing of material availability in relation to progressive rehabilitation.
Residue Storage Facility Covers and Rehabilitation	Stable covering for RSF appropriate to determine appropriate capping design.	Trials of rehabilitation vegetation and soil types on capped and covered surfaces.
Waste	Opportunities for material and equipment reuse.	Investigate the potential for sale and/or transfer of plant and equipment.
Geochemical studies	Ongoing sampling and NAPP/NAG testing of tailings and process residues and selected waste rock lithologies.	Ongoing kinetic leach tests of waste products in WRD and RSF. Ongoing NAF/PAF and compositional analyses.
Radiological testing	Suitability of encapsulation design of radioactive materials in the long-term.	Operational phase monitoring associated with radiation, which can be applied to closure designs. Monitoring will include gamma shine and inhalation as per type and frequency listed in the RPRWMP.

Topic	Information Gap / Uncertainty	Description
Groundwater Resources	Impact on groundwater levels and chemistry.	Ongoing monitoring of groundwater levels and chemistry and reviewing of model predictions over time.
Long-term Pit Lake Behaviour	Overall water balance.	Ongoing review of predicted pit lake levels to address any modification of rehabilitation options.
Ecology and Weeds	Assess quality of remaining vegetation communities and fauna habitat in and around site to target ecological rehabilitation.	Conduct pre-closure ecology condition survey. Assess analogue sites for post-closure rehabilitation monitoring and assessment. Conduct detailed assessment of weeds in all domains. Planned periodic surveys of site fauna to assess Project impacts.
Soil Contamination	The extent of soil contamination and remediation will only be apparent close to closure.	Conduct contaminated soil investigation of all domains where potentially contaminative activities have taken place.
Kerosene Camp Creek Diversion	Performance and impacts of the diversion in relation to hydrology, erosion/sedimentation processes and long-term stability.	Hydrological assessment of diversion performance informed by planned monitoring of water and stream bed load behaviour. Planned periodic surveys of site fauna to assess Project impacts.