Appendix J – Radiation Management Plan

Arafura Resources

Nolans Project

Draft Radiation Management Plan

and

Radioactive Waste Management Plan

March 2016

Contents

1 Introduction

Arafura Resources (Arafura) is intending to develop the Nolan Bore rare earth project in the Northern Territory. The mineralisation contains elevated concentrations of thorium and uranium and therefore radiation protection of people and the environment is required.

This document should be read in conjunction with the radiation assessment provided in the environmental impact assessment of the Nolan Bore project.

It is also important to note that Arafura has been managing radiation exposures while conducting exploration works in the Nolan Bore area for more than 10 years and has an operational radiation management plan for the activities.

This draft Radiation Management Plan (RMP) has been developed and structured in accordance with the requirements of the Code of Practice on Radiation Protection and Radioactive Waste Management in Mining & Mineral Processing (ARPANSA 2005, also referred to as the 'Mining Code').

In section 2.7 of the Mining Code, the requirements for information to be supplied in RMP are specified. These are as follows:

- Description of operations, and of measures for control
- Demonstrated access to expertise
- Monitoring Plan and method for dose assessment
- Provision of appropriate and adequate equipment, staff, facilities and operational procedures
- Details of induction and training
- Details of record keeping and reporting
- Plan for dealing with incidents accidents and emergencies
- System of periodic assessment and review to achieve continual improvement

Section 2.8 of the Mining Code also provides the information required for a Radioactive Waste Management Plan and these are as follows:

- Outline of the process(es) generating the waste(s)
- Description of the environment including baseline radiological characteristics
- Description of the proposed system for waste management
- Predictions of environmental concentrations and doses
- Program for monitoring
- Contingency plans for dealing with accidental releases
- Schedule for reporting
- Plan for decommissioning
- Commitment to periodic assessment and review.

The broad RMP and RWMP requirements are covered in this document. This is because there is some overlap between aspects of monitoring, reporting and management requirements.

Note that this is a draft document aimed at providing a high level overview of RMP and RWMP and the Arafura approach. The final RMP and RWMP will be developed when further detail regarding the project is available and will be developed in consultation with the local competent authority as part of the project licensing and permitting prior to any construction activities.

2 Overview of Operations

2.1 Process Overview

The project comprises an open pit mine with adjacent beneficiation plant, a nearby chemical processing plant and associated infrastructure, including processing waste disposal facilities and waste rock stockpiles. The mine will excavate about 10 Mtpa of which 1 Mtpa will be ore, grading about 2.5% REEs, 2700 ppm Th, and 200 ppm U, with their decay products. The beneficiation plant will produce approximately 300,000 tpa of mineral concentrate. Radionuclide concentrations will upgrade in the concentrating process to approximately 5,000ppm Th and 400ppm U. The concentrate will be pumped via a slurry pipeline to a chemical processing plant which will produce approximately 40,000 tpa of mixed rare earth concentrate products.

Residues from the concentrator and processing plant will be deposited in dedicated surface disposal facilities.

The final product will be exported to overseas customers or a separation facility for further processing and will not be defined as radioactive.

2.2 Radiation Control Aspects

The radiation control aspects of the Project are expected to be very similar to the radiation control requirements in place for most medium-grade uranium mining and processing operations (example at Ranger Uranium Mine). The radiation controls and management are therefore well known.

Arafura will base its approach to radiation protection and management upon conventional hazard and risk management principles. The aim will be to ensure that radiation control features are considered at early stages of project development and in operational design studies and these would be updated as necessary. Designs and proposed operational management aspects will be reviewed to determine likely radiation sources and levels. Options for control will be identified for the potential sources, with the eventual controls selected on the basis of effectiveness, robustness and simplicity. The control philosophy would be based on the hierarchy of controls as far as possible, with substitution and engineering control prioritised before any administrative and personal protection controls.

The overall aim is to ensure that doses be kept As Low As Reasonably Achievable, social and economic circumstances being taken into account (also known as the ALARA principle), which is consistent with a continuous improvement management approach.

2.3 Sources of Exposure

Potential radiation sources associated with the project include;

Gamma Radiation

- Ore in pit and in the beneficiation plant
- Radioactive waste rocks
- Process materials in the processing plant
- Thorium rich residues
- Process control instrumentation (such as radiation density gauges).

Radioactive Dusts;

- Crushing and grinding operations
- Drying of spillages
- Ore and waste rock handling

Radon and thoron (and therefore radon and thoron decay products) include;

- In pit
- Ore and waste rock stockpiles
- Tailings.

Controls are based on managing the sources at the origin, then through administrative controls and then by protection of the workers through personal protective equipment.

2.4 General Design Controls

Gamma doses are expected to be controlled through time limitation for workers on foot in the pit and shielding in certain parts of the processing plant that contain thorium rich residues. Elsewhere, gamma radiation levels are expected to be relatively low.

Dust levels will be controlled through standard dust controls which are relevant to all mining and processing operations. Controls include;

- ensuring that wet processes are used and where this is not possible, ensuring that adequate watering occurs to minimise dust generation,
- covering of conveyors,
- spillage management and control (to ensure that spillages do not become dust sources),
- all mining equipment would be fitted with air conditioned and air filtered cabins,
- watering of roads and ore stockpiles.

Radon and thoron emission levels are difficult to control during operations however the dose estimations conducted for the Environmental Impact Statement (EIS) have shown that potential

doses will be low and well controlled. A regular monitoring program will be undertaken to confirm these predictions. During times of very stable atmospheric conditions, radon and thoron concentrations may increase and additional controls such as ensuring that air conditioning on equipment is used or use of personnel protection equipment would be employed.

2.5 General Operational Controls

The following general operational controls will be implemented for radiation management;

- All maintenance work (including identified clean-up work) within a Controlled Area will be carried out under a Radiation Safe Work Permit.
- Equipment exiting the Supervised Areas will first require formal decontamination clearance. This will require a concreted clean-down area with water supply and sump.
- All workers working in the Supervised Areas will shower at end of shift before leaving the site. Change rooms will be located at a Clean / Dirty boundary. Work clothes will be laundered on site, with a laundry located adjacent to the main change room.
- Movements of vehicles through the Clean/Dirty boundary will be kept to a minimum, with wash down bay and facilities provided.

2.6 Access Controls

Operational areas will be defined as 'Supervised Areas', which are areas in which radiation conditions are monitored and workers are supervised but specific actions are not required to ensure doses are kept below the legislated annual limit.

Within the Supervised Areas, there are smaller enclaves where higher levels of control are necessary for radiation management purpose. Additional specific controls are necessary, individual doses are monitored and access is controlled. These areas are called 'Controlled Areas'.

Controlled Areas are subject to the following rules:

- Access is limited to those persons required to work, or perform any duty in the area
- The boundaries of the area are clearly delineated and are made known to employees

Any person entering the area has received appropriate instructions about the nature of the radiation hazards in the area.

Supervised Areas will include the mine and waste rock areas, the beneficiation and processing plants, tailings and residue disposal areas, offices, laboratories, maintenance workshops, and core farm.

Controlled areas are the pit and processing plant.

2.7 Designated/non-designated

Workers in the mine, the beneficiation plant or processing plant will be 'designated radiation workers' and will have individual dose assessments kept.

Other workers including office and support services (including transport) personnel will be defined as non-designated workers.

3 Monitoring Plan and Method of Dose Assessment

3.1 Overview

This section outlines the proposed occupational radiation monitoring program and the methods for dose assessment. The final program will depend upon the final project design.

3.2 Purpose of Radiation Monitoring

There are several reasons for carrying out workplace monitoring programs, as follows;

- provide day-to-day engineering feedback and operational control - this requires rapid reporting of high readings to relevant supervisors and senior management,
- in fulfilment of operating licence conditions - regulators will generally require periodic workplace monitoring data that gives them an ongoing auditing capability,
- provide input for personal dose assessments - these are required under the Mining Code with the results also informing long-term dose control actions including strategic changes in engineering, procedures, and personal protective measures,
- for input to future epidemiological studies; for example, the Australian National Dose Register.

The monitoring program aims to address the radiation exposure pathways and to provide sufficient information to achieve the overall purpose.

3.3 Workplace and Personal Monitoring

Routine occupational radiation monitoring will cover gamma, airborne dust, airborne radon and thoron decay products and surface contamination. Table 1 provides indicative methods for monitoring.

Table 1: Occupational Radiation Monitoring Plan

Radiation type	Measurement Method	Application
Gamma	Thermoluminescent dosimeter (TLD) badges	To determine workers doses
	Electronic Personal Dosimeters (EPDs)	Used for specific maintenance tasks
	Gamma survey meters	For routine surveys and for investigative purposes
Inhalation LLα dust	Personal Air Samplers (PAS) plus drawer assembly	Issue to determine inhalation doses and also used for investigative purposes

Radiation type	Measurement Method	Application
Inhalation of radon and thoron decay products	Grab samples (Borak, Rolle)	For assessment of doses and investigative purposes
	Continuous radon, thoron and decay product monitors	Continuous in-pit, in-plant, for real time control
Surface alpha contamination	Large-area alpha probe, survey	Workplace and control room and lunch room checks
		Equipment and outgoing checks

3.4 Method of Dose Assessment

Personnel doses will be assessed in line with advice of the local competent authority and with reference to ARPANSA RPS 9.1 (Safety Guide for Monitoring, Assessing and Recording Occupational Radiation Doses in Mining and Mineral Processing (2011)).

Specific Dose Conversion Factors (DCFs) would be developed (in consultation with the competent authority) for determination of doses from ore dust and from process plant dust.

Assessment of radionuclide deportment through the processing plant will provide information on radionuclide content of various dusts.

3.5 Action Levels

Arafura will develop radiation action levels that will be used to trigger internal investigations or other controls based on the results of the routine monitoring.

4 Equipment, Staff, Facilities, Procedures

4.1 Radiation Protection Staff

Arafura is will provide appropriate equipment, staffing, facilities and operational procedures for the implementation of the RMP. An appropriate management and reporting structure will be established to ensure the effective compliance with the RMP and all statutory and corporate reporting requirements.

Arafura has in-house technical personnel and external consultancy service providers. This will continue and will be strengthened to match the growing design, implementation, and servicing requirements of the project. The external consultants provide advice and assistance to Arafura Resources personnel.

To provide adequate ongoing radiation protection services, an accredited Radiation Safety Officer (RSO) with adequate occupational hygiene experience and technical assistants will be employed.

The routine monitoring duties of the radiation officers and support technicians will comprise:

- preparation,
- issue, retrieval, and counting of Personal Air Samplers,
- equipment clearances,

- surveys (gamma and surface contamination),
- preparation of talks / inductions / briefings to workers,
- preparation of briefings and reports to management,
- preparation of formal routine and specific reports for issue to regulators,
- assisting with preparation of job safety analyses and safe work permits
- specific investigations
- quarterly and annual dose calculations and reports.

4.2 Equipment

Radiation monitoring equipment is subject to the final monitoring program and is likely to include:

- Gamma monitors
- Dust pumps (including high volume samplers)
- Alpha slide drawer assemblies
- Dust deposition gauges
- Real time radon and thoron monitors

A program of calibration and equipment maintenance would be established to support the instrumentation.

4.3 Radiation Facilities

Facilities will be established together with laboratory space for maintenance, storage and calibration of site monitoring equipment, including occupational hygiene equipment.

4.4 Operational Procedures

4.4.1 Work Permits and Job Safety Analysis (JSA)

Standard Operating Procedures will be written for all normal operations, and will specifically include instructions for active radiation control, where needed.

As well as the normal hazardous work permits (heavy voltage work, working at heights, confined spaces, hot work) there will be a Radiation Work Permit. This permit will specifically 'flag' potential unusual radiation exposure situations, such as

- maintenance in the residue handling area and other defined high activity concentration areas,
- entry into enclosed vessels where Rn/Tn concentration could require active control,
- entry into the pit in periods of high RnDP / TnDP levels.

Any unusual or 'first time' tasks will require the preparation or revision of a JSA for the task with specialist input on potential radiation hazards.

4.4.2 Radiation Clearances

All vehicles, equipment, packages, and material leaving the site will be controlled if they have been potentially in contact with or contain radioactive material. This will involve specific 'Control' at the Control Point boundary. Prior to leaving the site all vehicle and equipment will be thoroughly washed and surfaces scanned and certified before release. These checks will be undertaken using a surface alpha contamination monitor and will be formally recorded.

Any radioactive samples leaving site will be monitored to determine the packaging and labelling requirements under the Radioactive Materials Transport Code, and to fill out the Dangerous Goods Shippers Certificate as required.

5 Induction and training

A basic radiation safety briefing will be incorporated into the site induction. It will be mandatory for all employees, contractors to go through the induction process and at completion of the induction it will be recorded.

Ongoing training will be provided through a range of topics at toolbox and other meetings, as part of the broader safety portfolio.

6 Record-keeping & Reporting

All occupational (personal and workplace) monitoring will be recorded. All site equipment clearance monitoring will also be recorded and feedback provided to site personnel. An appropriate feedback reporting mechanism will be developed that meets the needs of the various workgroups to ensure all site personnel receive information about monitoring results relevant to themselves.

In addition to this there will be management and statutory reporting requirements which will be required, scheduled and completed.

7 Incident, Accident and Emergency Response

Radiological accidents or emergencies are unlikely in rare earths mining or processing, however plans will be prepared to identify appropriate response requirements for unexpected loss-of-control situations. These will include:

- Advice to first aid / firefighting /emergency responders
- Evacuation of non-essential personnel and boundary control
- Containment of the situation
- Dose estimation and controls
- Decontamination and debriefing of affected personnel
- Recovery planning, implementation and reinstitution of control
- Post recovery investigation, root cause analysis, actions to prevent recurrence, and follow-up counselling.

8 Review of RMP

The Mining Code requires 'a system of periodic assessment and review of the adequacy and effectiveness of procedures instituted under the Radiation Management Plan and Radioactive Waste Management Plan. This ensures currency, makes improvements and updates the plan so it is consistent with best practicable technology.'

Arafura will institute an annual review of the plans adequacy and effectiveness. This will be undertaken in parallel with the annual data reporting proposed earlier in this text.

9 Radioactive Waste Management Considerations

9.1 Introduction

As required in the Mining Code, Arafura would develop a Radioactive Waste Management Plan (RWMP) for the management of radioactive waste arising from the mining and processing operations.

The RWMP will be developed in consultation with the competent authority in accordance with the requirements of section 2.8 of the Mining Code.

An overview of the key aspects of the RWMP are as follows.

9.2 Description of Waste

9.2.1 Waste Types

Arafura has identified a number of radioactive waste streams that will be managed accordingly as follows;

- waste rock generated from mining,
- processing tailings and residues,
- various plant contaminated wastes (if unable to be recycled),
- contaminated rainfall runoff.

9.2.2 Waste Rock

Arafura has conducted extensive waste rock characterisation.

Waste rock containing more than 1Bq/g (based on a weighted combination of uranium and thorium content) will be managed by placing it within the broader waste rock dumps and covering it with benign waste rock. Testwork indicates that one metre of benign material is more than adequate to encapsulate and shield radioactive material within the waste rock stockpiles.

9.2.3 Processing Tailings Residues

The mine tailings and processing residues would be delivered to the disposal facilities via pipelines contained in bunded corridors. Flow monitoring and visual inspections would be used identify any failures in the delivery systems.

The mine tailings would be deposited from spigots from the outer walls of the facility cells. Discharge from the spigots would be rotated around the cell walls in order to achieve an even spread of tailings

within the walls. The discharge will form a tailings beach, with larger particles depositing close to the cell wall and smaller particle being carried with the liquor to the centre of the cell. A supernatant pond in approximately the centre of the cell would form.

The overall aim of the mine tailings facility is to use natural evaporation to remove the liquid portion of the tailings stream and allow the solids portion of the tailings to consolidate. Once operations and deposition of mine tailings ceases, the tailings in the cell will consolidate through settling and evaporation and be safe for heavy vehicle access. This is necessary for the final placement of the capping.

The processing residues facility would operate slightly differently to the mine tailings facility. A ring distribution discharge system would be employed from which the processing residues would be discharged. Solids in the processing residues would behave similarly to the mine tailings, however, as the supernatant pond evaporates, additional solids would precipitate.

The processing waste cells would be rehabilitated as per the mine tailings cells.

9.2.4 Waste Water Management

Water that has come in contact with mineralised material, such as stormwater runoff from the ore stockpile or the mineralised overburden stockpile may contain entrained radioactive dusts and sediments. The site will be designed to retain surface water runoff from a significant storm event on site. The method of control will involve the construction of sedimentation and evaporations ponds, and appropriate collection bunds and channels.

All operational areas in the plant will be bunded with facilities for collecting spillage and returning it to the processing vessels or storage areas.

Waste water (water contaminated by contact with radioactive material) collected from the site including wash down areas and clean-up water would be either reused in the beneficiation or processing plants or evaporated.

9.2.5 Miscellaneous Waste Control

This material includes contaminated equipment and wastes from operational areas that would be disposed in an approved manner. A system of separate collection of potentially contaminated wastes from operational areas will be instituted. Where practical, potentially contaminated wastes will be decontaminated and disposed of with normal waste streams. Contaminated waste will be collected and initially held in a secure, bunded area. Depending on the nature of the waste several disposal options will be available. These include:

- disposal within the tailings or residue disposal facilities,
- disposal in the wast rock stockpiles in a similar manner to mineralised overburden;
- disposal into the mine pit at the end of operations; or
- storage on a purpose built pad and encapsulation within the footprint of the waste rock landform at the time of mine closure.

In all cases records of the disposal, including type of material, quantities and locations will be kept.

10 Environmental Radiation Impacts

The environmental baseline monitoring has shown that the entire region around the project has naturally occurring elevated levels of radioactive elements present in soils and the groundwater.

The modelling undertaken for the EIS has shown that radiological impacts to the environment would be low. The nearest critical groups (or representative most-exposed persons) for assessment of radiation doses to members of the public, are people living at Aileron and at Alyuen, approximately 15 km form the project area. The modelling has shown that potential radiological impacts are negligible.

Impacts to flora and fauna have been modelled and shown to be low and indistinguishable from natural background.

11 Environmental Monitoring Program

In addition to the occupational monitoring program, an environmental radiation monitoring program will operate during operations. The aims of this program are to provide data for the assessment of doses to the public, to measure any radiological impacts on the off-site environment, and to ensure that the radiation controls for off-site impacts are effective.

A draft environmental radiation monitoring plan will be prepared for approval prior to construction commencing and an outline of the elements of such a plan is shown in Table 2.

Table 2: Outline environmental Radiation Management Programme

Environmental Pathway	Measurement Method	Location and Frequency
Direct (external) gamma	Handheld environmental gamma monitor Passive environmental monitors	Annual survey at perimeter of operational area Monitors placed at environmental monitoring sites quarterly
Radon and Thoron Gas Concentrations in Air	Passive Environmental Monitors	Monitors placed at environmental monitoring sites quarterly
Radon and Thoron Decay Product Concentrations	Real time monitors	Monitor will rotate between off-site locations.
Dispersion of dust containing long-lived, alpha-emitting radionuclides	High volume samplers	Monitors will rotate between approved off-site locations
	Dust deposition gauges	Sampling at identified locations. Samples composited for one year, then radiometrically analysed
Seepage of contaminated water	Groundwater sampling from monitoring bores	Representative monitoring bores will be sampled annually and analysed for radionuclides
Run off of contaminated water	Surface water sampling	Opportunistic surface water sampling will occur following significant rainfall events
Radionuclides in potable water supplies	Sampling and radiometric analysis	Annually

A Mine Closure and Rehabilitation Plan for the operation will be submitted to the competent authority for approval before commencement of operations. The radiation closure design aim is to ensure that all mined radioactive material is contained in the long-term so that radiation exposures are consistent with natural background levels.

At the end of mining, all equipment will be tested for contamination. Where recycling is practicable, items will be decontaminated to approved radiation levels before leaving site. Items that cannot be properly decontaminated, or where recycling is impracticable, will be disposed in an approved manner.

The tailings will be allowed to dry sufficiently and then covered with inert waste rock to a depth agreed to minimise the emanation of radon. A detailed mine closure plan for the facility will be included in the Conceptual Mine Closure Plan.

The site will be monitored after rehabilitation to ensure that it is free of contamination above the pre-existing natural background levels. Monitoring, including surface monitoring and monitoring of

groundwater would continue for a period of time post-closure until agreed Completion Criteria had been achieved to the satisfaction of the regulators.

It is expected that under those conditions radiation exposures to the public would be minimal, and certainly significantly less than those during operation.