61800 ERA Major Projects

Radiation Management Plan

Ranger 3 Deeps Exploration Decline

Centre	**ERA Major Projects**		
Effective date	5/06/2013	**Status**	Issued for Use
Document number	61800-0000-PL-HE-0003	**Revision number**	1
Approved by:	Heath Thorpe		

Contents page

Tables

Figures

1 Purpose

This Radiation Management Plan (RMP) has been prepared by Energy Resources of Australia Limited (ERA) in order to identify and appropriately manage all radiological risks associated with the Ranger 3 Deeps exploration decline project.

The RMP meets the requirements of:

- The Ranger Authorisation to Operate 0108 (most recent version)
- The Code of Practice for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing (The Code);
- The Northern Territory Radiation Protection Act; and
- The Rio Tinto B5 Radiation Standard.

This document will assist ERA in both compliance with all relevant radiation legislation and to keep radiation doses As Low As Reasonably Achievable, economic and societal factors being taken into account (ALARA).

This plan will be submitted to the regulatory authorities for approval, as per the requirements of The Code.

2 Scope

This RMP applies the management of radioactive material for the protection of workers, the public and the environment at the Ranger 3 Deeps exploration decline project.

3 Project Description

3.1 Project location and site plans

The Ranger mine is located within the Ranger Project Area (RPA) near Jabiru, approximately 260km east of Darwin in the Alligator Rivers Region, refer Figure 3.1. The RPA is surrounded by Kakadu National Park and access to the mine is via the Arnhem Highway.

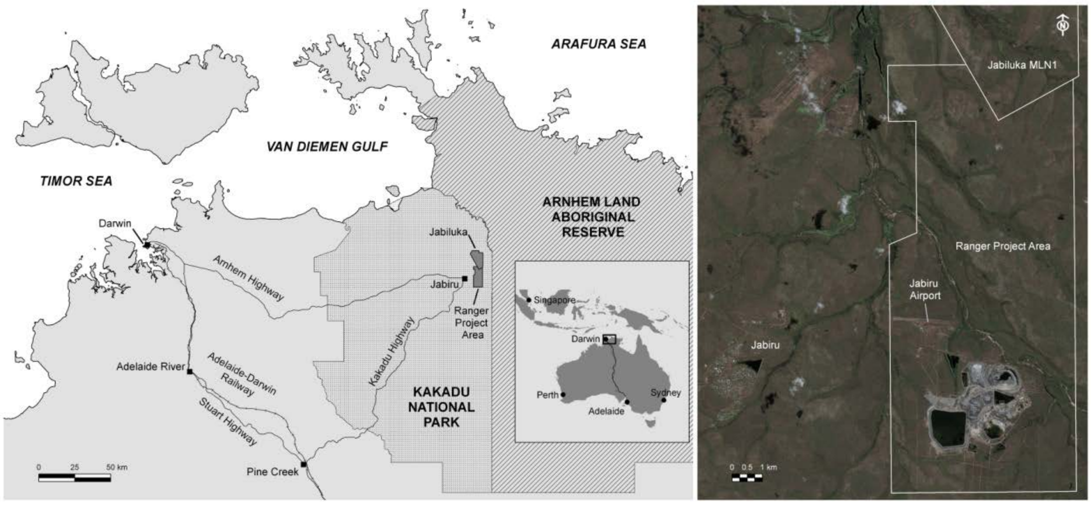

Figure 3.1 - Location of RPA in a regional context

The Ranger 3 Deeps exploration decline is being constructed within the RPA and the existing disturbed footprint of the mine. The project consists of an exploration decline, office areas and a ventilation shaft; refer Figure 3.2 and Figure 3.3.

3.2 Description of Operations

The Ranger 3 Deeps exploration decline project, in its entirety, involves the following key activities:

- Construction of a decline through non-mineralised rock, allowing access for exploration drilling into the Ranger 3 Deeps mineral resource.
- Construction of a ventilation shaft and installation of a ventilation system.
- Exploration drilling and extraction of core from the mineral resource.
- Construction of a small cross cut through the mineral resource and extraction of a bulk sample for metallurgical testing.

Further details of each activity have been provided in the following sections.

Figure 3.2 - Location of Ranger 3 Deeps surface infrastructure and outline of underground workings

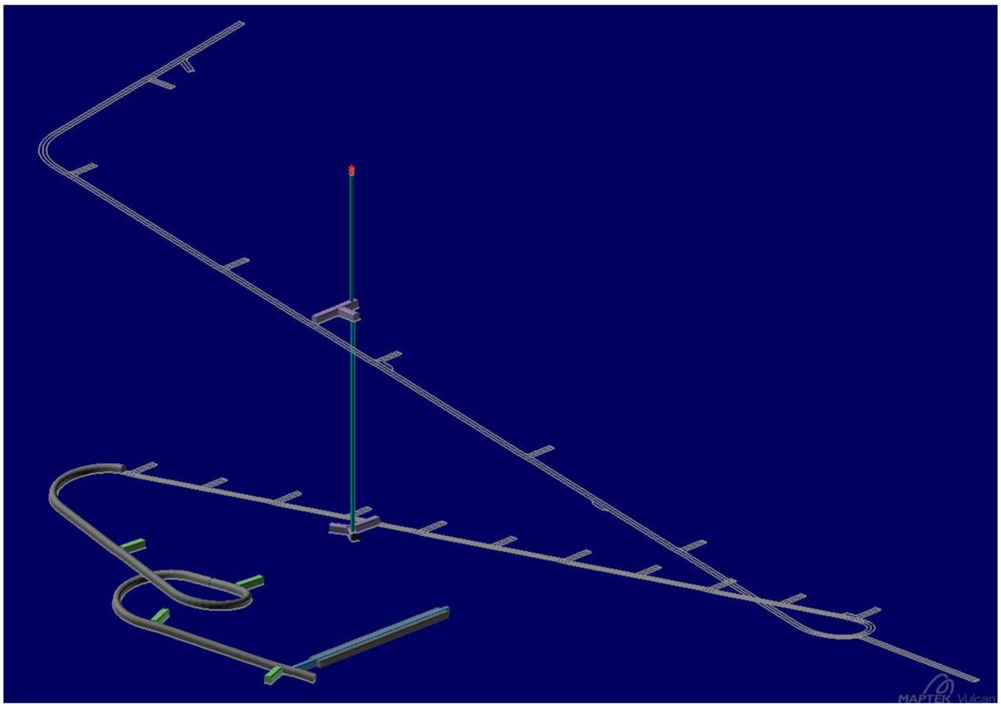

Figure 3.3 - Ranger 3 Deeps exploration decline underground development

3.2.1 Exploration decline development

ERA is currently constructing an exploration decline from a location immediately adjacent to Pit #3 to provide access for detailed exploration of the Ranger 3 Deeps mineral resource.

The decline with be of approximate size 5.5 m wide and 6 m high. It is being developed at a 1:6 grade and will extend to a length of approximately 2500 m, with an approximate depth of RL -400 m.

Construction will be predominately via drill and blast techniques with waste material being loaded and trucked to the surface stockpiles for storage.

As soon as possible after extending the decline, the walls and backs will be shotcreted to provide stabilisation and support.

Detailed exploration drilling from the surface has enabled the development of a mineral resource model with blocks of uranium mineralisation grade. The average grade for each section of the decline development has been provided in Table 3.1.

Table 3.1 - Average uranium mineralisation expected along sections of the decline

Length along decline (m)	Grade (% U3O8)
0-500	0.000
500-1000	0.000
1000-1500	0.003
1500-2000	0.002
2000-2500	0.002
North Drill Drive (130m)	0.001

3.2.2 Ventilation

A ventilation system has been installed to provide enhanced air quality to underground workers. The system initially has surface ventilation fans with a ducted bag system providing fresh air to the underground workings. After development of the decline progresses past the selected ventilation shaft location, the ventilation shaft will be installed, vent raise constructed and vent fans relocated to the underground workings. Ventilation bags will be used, as required, to deliver fresh air to the working location.

The selected preferred option for ventilation system has the system being installed in several legs. This means that as the project progresses each leg will be installed and the ventilation system changed to achieve the objective of providing enhanced air quality to underground workers.

3.2.3 Exploration drilling

Exploration drilling in the decline will be predominately by diamond drilling. Drilling will occur from cuddie's, cut in off the main decline, at set locations down the decline.

Drill cores extracted will be temporarily stored in the cuddie's and transported to the surface in batches for further processing and analysis.

Drill cores are expected to have large sections of barren rock or low grade material, with the small sections that intersect the mineral resource to have an average grade of 0.3% U_3O_8.

3.2.4 Ore cross cut and bulk sample

The exploration decline development will finish at the edge of the mineral resource. At this point development will change to drive a cross cut through the mineral resource, with the objective of obtaining a bulk sample for metallurgical testing and to gather further information about the resource.

Development of the cross cut will be the same as for decline development, predominately via drill and blast techniques. Mineralised material will be loaded and trucked to the surface for storage in a stockpile location, separate from the waste material stockpiles generated as part of decline development, ready for metallurgical testing.

The average uranium grade expected through the ore cross cut has been estimated from the mineral resource model, this information has been provided in Table 3.2.

3.3 Description of Workforce

The workforce at Ranger 3 Deeps, for the purposes of radiation protection, has been divided into two main categories:

- Designated workers
- Non-designated workers

Designated workers are defined as those that regularly work in controlled areas and have the potential to receive more than 5mSv per year. Non-Designated workers are all other workers on site.

The process of classification of designated workers and the current list of designated radiation work groups is provided in Section 7.3.2.

A complete list of which employees are designated is kept as part of the radiation dose spread sheet.

Table 3.2 - Uranium grade of mineralised material through ore cross cut

Length (m)	Grade (% U3O8)
0-10	0.01
10-20	0.01
20-30	0.11
30-40	0.69
40-50	0.53
50-60	0.31
60-70	0.25
70-80	0.32
80-90	0.41
90-100	0.52
100-110	0.28
110-120	0.18
120-130	0.22
130-140	0.25
140-150	0.21
150-157.5	0.08

3.4 Authorisation to Operate

ERA currently operates the Ranger mine under the most recent version of Ranger Authorisation 0108. This Authorisation to Operate is issued by the NT Department of Mines and Energy (DME) under the Mining Management Act (Northern Territory of Australia, 2012a). This document outlines the conditions under which ERA must operate the Ranger mine and outlines the statutory monitoring programs.

The Ranger 3 Deeps exploration decline was approved by the Ranger Mine Site Technical Committee (MTC) under this Authorisation to Operate. While many of the conditions from the Authorisation do not apply to the Ranger 3 Deeps operations, those that do apply and references to the sections demonstrating compliance have been provided in Table 3.3.

The statutory monitoring program outlined in the Authorisation, does not apply to the Ranger 3 Deeps operation, but has been used as a template for development of an appropriate monitoring program in Section 8.

Table 3.3 - Compliance with Radiation Conditions in Ranger Authorisation

Condition	Description	RMP Section
Schedule 3 Mining Operations		
3.2.3	In particular, the operator of the mine shall ensure that operations do not result in: an adverse effect on the health of members of the regional community by ensuring that exposure to radiation and chemical pollutants is as low as reasonably achievable and conforms with relevant Australian law, and in particular, in relation to radiological exposure, complies with the most recently published and relevant Australian standards, codes of practice, and guidelines;	4
Schedule 4 Treatment Plan Operations		
4.2	The operator of the mine shall ensure that:	-
4.2.4	where a potential exists for dust generation, such as at crushing, screening, and transfer points within the mill, dust control devices shall be installed and their functioning in accordance with specifications checked annually and after maintenance;	7.2
Schedule 6 Other Services, Operations and Requirements		
Staffing and Induction		
6.2	The company shall employ adequate numbers of competent, appropriately qualified and experienced staff to ensure that it can provide the required level of protection to the environment, human health, and Aboriginal culture and heritage.	13.1
6.3	All mine site employees shall attend an induction course, which shall explain the environment protection and monitoring programs, radiation protection and responsibilities, Aboriginal culture, and the plan of management of Kakadu National Park.	10.1
6.4	All mine site workers shall attend a radiation induction and shall have access to documents explaining the nature of the hazards associated with the handling of uranium ores and concentrates and the safe working procedures to be adopted.	10.1
Air Quality		
6.5	Emissions of gaseous and particulate contaminants shall conform with Australian law, and, taking into account the most recently published and relevant Australian standards, codes of practice, and guidelines, be managed to minimise the effects of particulate and gaseous contaminants from the point of view of all possible radiological, physical and chemical hazards.	3.2.2
Storage, use and Disposal of Hazardous Substances and Waste		
6.12	The company shall ensure that wastes will not result in any detrimental environmental impact outside of the Ranger Project Area, and that environmental impacts within the Ranger Project Area are as low as reasonably achievable.	7.4

Condition	Description	RMP Section
Schedule 9 Environmental and Radiation Monitoring and Reporting		
9.1	The operator of the mine shall implement a system to control the radiological exposure of people and the environment arising from its mining and milling activities. The system and the dose limits applied shall comply, at the minimum, with relevant Australian law taking into account the most recently published and relevant Australian standards, codes of practice, and guidelines. Subject to 9.2, the company shall achieve the following outcomes:	4
9.1.1	Radiation doses to company employees and contractors shall be kept as low as reasonably achievable and shall always remain less than the dose limit for workers.	4
9.1.2	Radiation doses to people who are not company employees or contractors shall be kept as low as reasonably achievable and shall always remain less than the dose limit for members of the public.	6.2
9.1.3	Ecosystems surrounding the Ranger Project Area shall not suffer any significant deleterious radiological impacts.	6.2
9.2	Radiation doses received from natural background sources or as the result of undergoing medical procedures are not subject to the system and are not to be included in the calculation of radiation doses.	9
Annex C Reporting Requirements		
	C.4 Annual Radiation and atmospheric monitoring interpretative report	
C.4.1	The operator of the mine shall submit, for approval by the Director, radiation and atmospheric monitoring interpretative reports…..	11.2

4 Radiation Management System

The system of radiation management at ERA's operations is based on the justification, optimisation and limitation principles established by the International Commission on Radiological Protection (ICRP), standardised by the International Atomic Energy Agency (IAEA) and adopted in a joint Australian Radiation Protection And Nuclear Safety Agency (ARPANSA) and National Occupational Health and Safety Commission (NOHSC) document.

These three ICRP principals and how they apply to the Ranger 3 Deeps operation are described in more detail in the following sections.

4.1 Principal of Justification

The principal of justification is stated by the ICRP to be "*Any decision that alters the radiation exposure situation should do more good than harm.*"

This means that by introducing a new radiation source one should achieve sufficient individual or societal benefit to offset the potential detriment it may cause.

In their discussion on the justification of a practice the ICRP recommends that when practices involving exposure, or potential exposure, to radiation are being considered, the radiation detriment should be explicitly included in the process of choice. The detriment to be considered is not confined to that associated with the radiation, it includes other detriment and the costs of the practice. Often, the radiation detriment will be a small part of the total.

Justification for the Ranger 3 Deeps exploration decline formed part of the original referral under the *Environmental Protection and Biodiversity Act, 1999* (EPBC Act) and the application submitted to the MTC. Approval to progress this development is taken as justification for the practice.

4.2 Optimisation of Protection

The Principle of Optimisation of Protection is stated by the ICRP to be that the likelihood of incurring exposure, the number of people exposed, and the magnitude of their individual doses should all be kept as low as reasonably achievable, taking into account economic and societal factors (ALARA).

The process of optimisation of radiation protection involves achieving the best level of protection under the prevailing circumstances. It is an on-going iterative process that over time will see exposures optimised to ALARA.

Dose constraints are used in conjunction with the optimisation of protection to restrict individual doses. The ICRP defines a dose constraint as a restriction on the individual dose which serves as an upper bound on the predicted dose. It is a level of dose above which it is unlikely that protection is optimised, and for which, therefore, action must almost always be taken. Dose constraints represent a basic level of protection and will always be lower than the pertinent dose limit.

Setting of appropriate dose constraints and keeping doses below this constraint is one step in demonstrating that doses at the operation are optimised.

The application of this process at Ranger 3 Deeps will involve the following steps:

- Undertaking a radiological risk assessment to determine all sources, pathways and potential exposures in all workplaces to all individuals.
- Setting of specific dose constraints (see Section 7.1) and trigger action response levels to form the upper bound for the optimisation process.
- Identifying all the controls for reducing exposures.
- Selecting the best set of controls for the operation using the hierarchy of controls (refer below) and also by considering the net exposure reduction versus the economic and societal factors.
- Implementing the selected options.
- Regular monitoring and review of the system.

As part of the application of optimisation, ERA has elected to follow the standard safety and risk management methodology termed “the hierarchy of controls”. This has been adapted to a radiation protection situation as follows:

- Elimination
    - Not exposing individuals to radiological risks so far as is practicable;
- Isolation
    - Isolating sources of radiation, so far as is practicable, through shielding, containment and remote handling techniques;
- Engineering
    - Providing engineering controls to reduce radiation exposures and radioactive contamination levels in workplaces;
- Administrative
    - Adopting safe work practices; and
- Personal Protective Equipment (PPE)
    - Providing personal protective equipment if other means of controlling exposure are not practicable or, where appropriate, to supplement these other measures.

4.3 Dose Limits

The principal of application of dose limits is stated by the ICRP as the total dose to any individual from regulated sources in planned exposure situations, other than medical exposure of patients should not exceed the appropriate limits specified by the Commission.

The dose limits recommended by the ICRP (ICRP, 2007) and adopted by the ARPANSA and NOHSC (ARPANSA and NOHSC, 2002) are applied to ERA's operations; these are provided in Table 4.1. These take into account the latest recommendations from ARPANSA concerning the equivalent dose to the lens of the eye (RHC, 2011).

These recommended dose limits are set at a level such that any continued exposure just above the dose limit would result in additional risks that could reasonably be described as unacceptable in normal circumstances. For radiation exposures near or just below the limit the risks are considered as tolerable. The dose level received by an individual, for which the risk could be considered acceptable, is that level at which a practice has firstly been justified, and then all possible optimisation has been effectively carried out, including the utilisation of best practicable technology and the implementation of the ALARA principles.

Table 4.1 - Dose Limits recommended by ARPANSA

Application	**Occupational Dose Limits[1]**	**Public Dose Limits[1]**
Effective dose	20 mSv per year, averaged over a period of 5 consecutive calendar years[2]	1 mSv in a year[4]
Annual equivalent dose in:		
- the lens of the eye	20 mSv in a year, averaged over defined periods of 5 years, with no single year exceeding 50 mSv	15 mSv
- the skin[5]	500 mSv	50 mSv
- the hands and feet	500 mSv	–

1. The limits shall apply to the sum of the relevant doses from external exposure in the specified period and the 50-year committed dose (to age 70 years for children) from intakes in the same period.
2. With the further provision that the effective dose shall not exceed 50 mSv in any single year. In addition, when a pregnancy is declared by a female worker, the embryo or foetus should be afforded the same level of protection as required for members of the public.
3. (DELETED)
4. In special circumstances, a higher value of effective dose could be allowed in a single year, provided that the average over 5 years does not exceed 1 mSv per year.
5. The equivalent dose limit for the skin applies to the dose averaged over any 1 cm^2 area of skin, regardless of the total area exposed.

NOTE 1: The above dose limits table is directly extracted from ARPANSA's Recommendations for limiting exposure to ionizing radiation (1995), however the Radiation Health Committee now advises that the exceptional circumstances clause in note 3 of the table has been deleted.

NOTE 2: Exposure to radiation from natural sources is generally excluded from occupational or public exposure, except when the exposure is a direct consequence of a practice or is specifically identified by the appropriate authority as requiring control through the implementation of a program of radiation protection. Medical exposure includes doses received by patients undergoing medical diagnosis or therapy, doses received by volunteers in medical research, and doses received knowingly and willingly by persons other than health care workers as a consequence of their proximity to an exposed patient. Dose limits do not apply to exposures from natural sources, except as described above, or to medical exposures.

4.4 Accountabilities

Activity	Accountability
Employ an appropriately qualified Senior Radiation Advisor.	General Manager
Construct and operate the site in accordance with the radiation management plan.	
Provide adequate resources and equipment to allow the workplace to be monitored for radiological contaminants and radiation exposures to be calculated and recorded.	
Keep the Senior Radiation Advisor informed of the various procedures in the operation and of any changes occurring, so that appropriate advice can be provided to minimise exposure of workers and the environment to radioactive material at all stages of development and operation of the mine and whenever abnormal conditions may arise.	
Obtain approvals from the regulatory authority for: • the radiation protection program for their site; • any part of the mine, processing plant or waste management facility prior to: o construction; o operation; or o decommissioning. • any significant changes to any part of the operation to which the radiation protection program applies; • removal from or introduction of any radioactive material (as defined by the National Directory (ARPANSA, 2011) to their site;	
If radioactive gauges are used at the site, hold the appropriate license for these sources.	
Report any unauthorised effluent discharges to stakeholders.	
Notify the stakeholders of any changes to operating conditions that may increase radiation exposures.	
Identify, assess and manage all radiation hazards.	Managers, Superintendents and Supervisors
Ensure that workers on site are competent to perform their duties.	
Ensure all workplace infrastructure or equipment, installed for the purposes of controlling radiation exposures or risk to the environment, are functioning correctly.	
Ensure all workers are properly instructed on the radiological risks in their work areas and in the use of equipment for the purposes of radiation protection.	
Investigate any failures to radiation protection controls and implement appropriate actions promptly.	
Workers who may be exposed to radioactive material, or perform duties which may affect the radiation exposure of others, must to the extent to which they are capable, comply with all reasonable measures to control and assess exposure to radioactive material, or to manage radioactive waste.	Workers

Activity	Accountability
The worker must: • follow radiation protection and waste management practices specified in approvals or authorisations, and other regulatory requirements; • comply with the legitimate instructions of the employer, or his agents; • participate in training programs required under The Code, and make proper use of such training; • make proper use of plant and equipment supplied for radiation protection, or for the monitoring or assessment of radiation exposures; • not engage in any careless or reckless action which might result in unnecessary radiation exposure to themselves or others, or compromise the management of radioactive wastes; • report to the employer any defects of which they become aware, in plant equipment or procedures, which may compromise radiation protection or the management of radioactive wastes; • report all incidents or accidents to the employer; • advise the employer of previous employment involving occupational exposure to radiation, and cooperate in obtaining records of such previous exposure.	
Female workers are encouraged to notify their supervisor if they become pregnant.	
Implement the radiation management plan.	Senior Radiation Advisor with the assistance of Radiation Technicians
Provide advice on all aspects of radiation protection.	
Provide radiation protection training to workers.	
Conduct the statutory radiation monitoring program.	
Conduct investigation monitoring to determine the efficiency of the hierarchy of controls in keeping radiation doses as low as practicable.	
Implement an appropriate quality assurance program for all radiation instruments and monitoring.	
Report on the radiation protection program to stakeholders.	
Determine radiation doses to designated workers, non-designated workers and members of public.	
Maintain a record of personal doses and radiation history.	
Implement a respiratory protection program in accordance with recommended standards.	
Assist in design and/or alteration to facilities that may influence radiological exposure to workers or members of the public.	
Provide advice and direction on actions to be taken in the event of planned special exposures, and emergency and accidental exposures.	
Determine whether a radiation incident requires a report to any statutory authority and to prepare such reports.	

Activity	Accountability
Maintain files of all applicable licences and registrations, and ensure that renewals are processed when required.	
Supervise and assist in disposal of radioactive waste.	
Supervise and provide advice for clean-up and decontamination of radioactive material spills.	
Maintain a register of all radioactive sources and irradiating apparatus on site.	
Advise management on compliance with all Territory and Commonwealth laws and regulations relevant to radiation protection.	
Be aware of current international standards and publications.	
Promote awareness of radiation protection issues.	
Monitor and review the effectiveness of this RMP.	

5 Risk Assessment

Risk assessments at ERA Major Projects are all conducted according to the *Hazard Identification and Risk Management Procedure (91800-0000-WP-HE-0141)*.

In conducting the risk assessment it was necessary to identify all the sources of radiation and pathways for exposure and to evaluate the characteristics of the workplace environment and potential for radiological exposure. This included identifying the radionuclides and radioactive materials present, their chemical and physical form, their location relative to occupied areas and the possible pathways for exposure. These radiation sources and pathways have been documented in Section 6.

All identified radiological hazards and risks were then be ranked using the *HSEQ risk matrix (61800-0000-FM-HE-0004)*. To assist in the appropriate ranking and management of radiological risks, ERA has developed a set of radiation specific consequence descriptors relevant to its operations. These have been provided in Table 5.1 and when joined with the risk matrix likelihood descriptors for frequency and emissions provide a radiation specific risk matrix, refer Appendix 1.

Table 5.1 - Radiation consequence descriptors for risk assessment

Consequence	Radiation exposure descriptor
MINOR	Slight increase in radiation dose with outcomes remaining below dose constraints.
MEDIUM	Increase in radiation dose above the dose constraints but still below international limits.
SERIOUS	Increase in radiation dose to above international limits.
MAJOR	Radiation doses above 100 mSv to an individual and likely to significantly increase the risk of cancer to that individual.
CATASTROPHIC	Radiation doses to multiple individuals above 100 mSv or acute radiation syndrome to an individual.

The emissions likelihood descriptor uses the hygiene term “Occupational Exposure Limit” or OEL. The OEL for radiation is 20mSv; however, this is the occupational limit and does not allow for the risk assessment to be applied as part of the optimisation process.

For this radiation risk assessment, the OEL will be replaced with an exposure rate or airborne concentration that has been calculated from the site specific dose constraint.

The site specific values that will be used for the Ranger 3 Deeps risk assessment have been calculated assuming a dose constraint of 5mSv, a working year of 2000 hours and Dose Conversion Factors (DCF’s) for Long Lived Alpha Activity (LLAA) and Radon Decay Products

(RDP) of 0.0057 mSv/Bq and 0.0014 mSv/µJm^{-3} respectively. This then gave the following values[1]:

- Gamma: 2.5 µSv/h
- RDP: 1.8 µJm^{-3}
- LLAA in dust: 0.37 Bqm^{-3}

The assessment was then conducted using the method:

- Each activity or location is listed.
- For each of these activities or locations list all the radiation hazards for that area, for example dust generated from drilling.
- Identify the radiological risk:
    - inhalation of radon decay products;
    - inhalation of long lived alpha activity in dust;
    - external exposure to gamma radiation; and
    - ingestion of radioactive materials.
- Allocate a consequence and likelihood to determine the risk ranking.
- Based on the ranking implement appropriate controls.
- Determine an appropriate monitoring program, see Section 8.

The completed risk assessment for the Ranger 3 Deeps exploration decline project has been provided in Appendix 1. Steps identified in dot points (one through four) are essentially the identification of sources and pathways, a list of these has also provided in Table 6.1.

[1] Refer to Section 9 for details of the dose calculation methods that were used in reverse to obtain these values.

6 Sources and pathways for exposure

There are three major pathways in which exposure to radioactive material can occur in the exploration decline include:

- **Internal exposure from inhalation of radioactive dusts.** Uranium mineralisation contains a number of radioactive isotopes, if mineralisation is encountered in the exploration decline or within the ore cross cut and dust becomes airborne, it can be inhaled, and lodge in the lung. The radioactive isotopes may remain in the lung, or they may dissolve in lung fluid and be transported to other parts of the body. If they decay before the body excretes them, then they will irradiate the surrounding tissue. By far the most important radioisotopes for this type of exposure are the long lived alpha emitters, including isotopes of uranium, thorium, radium and polonium (^{238}U, ^{234}U, ^{230}Th, ^{226}Ra and ^{210}Po).
- **Internal exposure from inhalation of radon decay products.** One of the decay products in the uranium decay chain is the radioactive gas radon (^{222}Rn). It is produced by decay of radium contained within the uranium mineralisation. Being a gas it can diffuse out of the rock and into the air, where it can be inhaled. Radon is not reactive, and is not retained in the lung, but is immediately exhaled, and so the resulting radiation dose from inhalation of radon is quite small. Radon however decays to radon decay products (RDP), often referred to as "radon daughters" (^{218}Po, ^{214}Pb, ^{214}Bi, ^{214}Po). These are metals, and if inhaled are retained in the lung, and their subsequent decay can result in quite large doses to the lung. If areas of the decline become poorly ventilated then radon has time to decay to RDP increasing the radiation exposure of any workers in that area.
- **External exposure from gamma radiation.** Some of the isotopes in uranium mineralisation emit gamma rays which can irradiate people nearby. Work areas underground that have exposed areas of uranium mineralisation and stockpiles of mineralised material will have elevated gamma radiation.

There are two other possible exposure pathways which are minor, and can easily be controlled. The first is ingestion (swallowing) of radioactive material. This usually occurs by hand to mouth transfer when food is eaten with dirty hands. It can easily be controlled by washing hands before eating or drinking. The second is wound contamination where radioactive material can enter the body through cuts and scratches. Covering the wound with a dressing will minimise this pathway.

The specific sources and pathways from Ranger 3 Deeps, for both occupational and environmental exposures, are provided in the following sections.

6.1 Occupational Exposure Pathway

For the Ranger 3 Deeps exploration decline project the significant potential sources of exposure are:

- Direct gamma irradiation from uranium series radionuclides in the host material;
- The inhalation of radon decay products (RDP) present from the decay of radon (^{222}Rn) which enters the air by either emanation from the rock surfaces or is carried in with ground water inflow.; and
- The inhalation of long lived alpha activity (LLAA) in airborne dusts.

There is also a minor pathway from the potential ingestion of radioactive material transferred to hands and mouth from surface contaminated plant and equipment.

The radiation risk assessment conducted for the project, refer Section 5, identified each of the potential radiation sources and pathways for exposure for each activity and work group. A summary of these has been provided in Table 6.1.

6.2 Environmental Exposure Pathway

The environmental radiation exposure pathways for members of the public as a result of the Ranger 3 Deeps exploration decline are very minor. The majority of environmental radiation risks are managed by the main Ranger operations RMP.

The only potential source for environmental transport and member of the public exposure is through radon and dust emissions from the ventilation stack once installed. The principal radiation emission sources from the ventilation system are:

- Underground blasting; and
- Radon emissions from mineralised rock faces.

Exposure to gamma radiation is not a pathway for members of the public since gamma dose rate decreases by the square of the distance from the source. Gamma dose rates in the nearest occupied areas will not be detectable above background levels.

The pathway for exposure of non-human biota will be predominately via dust deposition from blast dust emission out of the ventilation stack.

Table 6.1 - Occupational exposure sources and pathways at Ranger

Activity	Workgroup	Job/Task	Sources	Pathways
Exploration decline development	Jumbo Operators and offsiders	• Drilling holes in face for blast • Rock bolting • Scaling • Charge of face • Underground vent workings installation	Dust generated during various activities	Inhalation of LLAA
			Release of radon from groundwater intersected during drilling	Inhalation of RDP
			Contaminated surfaces	Ingestion
			Radon emanating from exposed uranium mineralisation	Inhalation of RDP
			RDP building up during periods of ventilation maintenance	Inhalation of RDP
			Gamma radiation from exposed uranium mineralisation	Gamma exposure
	Bogging and Trucking	• Truck Loading • Truck or bogger transport to surface or stockpile cuddy • Truck or bogger dumping	Dust generated during activity	Inhalation of LLAA
			Contaminated surfaces	Ingestion
			Radon emanating from exposed uranium mineralisation	Inhalation of RDP
			Gamma radiation from exposed uranium mineralisation	Gamma exposure
	Shotcrete operators	• Shotcrete walls and backs	Dust generated during activity	Inhalation of LLAA
			Contaminated surfaces	Ingestion
			Radon emanating from exposed uranium mineralisation	Inhalation of RDP
			Gamma radiation from exposed uranium mineralisation	Gamma exposure
Cross cut development	Jumbo Operators and offsiders	• Drilling holes in face for blast • Rock bolting • Scaling • Charge of face	Dust generated during various activities	Inhalation of LLAA
			Release of radon in groundwater intersecting during drilling	Inhalation of RDP
			Contaminated surfaces	Ingestion
			Radon emanating from exposed uranium mineralisation	Inhalation of RDP
			Gamma radiation from exposed uranium mineralisation	Gamma exposure

Activity	Workgroup	Job/Task	Sources	Pathways
	Bogging and trucking	• Truck Loading • Truck or bogger transport to surface or stockpile cuddy • Truck or bogger dumping	Dust generated during activity	Inhalation of LLAA
			Contaminated surfaces	Ingestion
			Radon emanating from exposed uranium mineralisation	Inhalation of RDP
			Gamma radiation from exposed uranium mineralisation	Gamma exposure
	Shotcrete operators	• Shotcrete walls and backs	Dust generated during activity	Inhalation of LLAA
			Contaminated surfaces	Ingestion
			Radon emanating from exposed uranium mineralisation	Inhalation of RDP
			Gamma radiation from exposed uranium mineralisation	Gamma exposure
Exploration drilling	Drillers and offsiders	• Drilling into mineral resource	Dust generated during activity	Inhalation of LLAA
			Release of radon from intersected groundwater	Inhalation of RDP
			Contaminated surfaces	Ingestion
			Radon emanating from core	Inhalation of RDP
			Gamma radiation from exposed uranium mineralisation in cuddy	Gamma exposure
			Gamma radiation from core	Gamma exposure
		• Sampling and handling of mineralised core • Transport of core to surface	Dust generated during activity	Inhalation of LLAA
			Gamma radiation from core	Gamma exposure
			Contaminated surfaces	Ingestion
Core handling on surface	Exploration technicians and Geologists	• Handling of core during transport and storage • logging core • Cutting core	Gamma radiation from core	Gamma exposure
			Contaminated surfaces	Ingestion of radiation
			Dust generated during activity	Inhalation of LLAA

Activity	Workgroup	Job/Task	Sources	Pathways
Stockpiling on surface	Truck operators	• Transport of cross cut mineralised material to stockpile • Dumping mineralised material on stockpile • Dozing up stockpiles • Grading and other road and stockpile maintenance	Gamma radiation from uranium mineralisation in stockpile	Gamma exposure
			Dust generated from hauling and dumping	Inhalation of LLAA
Maintenance	Surface maintenance crew	• Maintenance to light and heavy equipment in surface workshop	Contaminated surfaces	Ingestion
			Dust Generation from working on dirty equipment	Inhalation of LLAA
	Underground maintenance crew	• Breakdown maintenance to underground equipment • Underground electrical work	Dust Generation from working on dirty equipment	Inhalation of LLAA
			Contaminated surfaces	Ingestion
			Working in cross cut with no shotcrete and outside cabins	Gamma exposure
General Surface work	All other workers (non-designated)	General work inside the controlled area on the surface	Contaminated surfaces	Ingestion
			Dust generated from general wheel traffic	Inhalation of LLAA

7 Control Measures

7.1 Dose constraints and Trigger Action Response Levels

An initial dose constraint for Ranger 3 Deeps exploration decline project will be set at 5mSv per year from all pathways. In addition to this a dose constraint of 2mSv per year will be set for non-designated workers, consistent with the main Ranger Operations.

For comparison, a summary of the dose constraints for other uranium mining activities is as follows:

- Olympic Dam (Australia) – 10 mSv/y
- McArthur River (Canada) – 10 mSv/y
- Rabbit Lake (Canada) – 16 mSv/y

In addition to the dose constraint, trigger action response levels have been set to assist in keeping doses optimised and below the site dose constraint. These control levels have been set for each of the different monitoring performed around site and are outlined in Table 7.1.

Table 7.1 – Trigger Action Response Plan for Ranger 3 Deeps exploration decline

Hazard	Trigger	Response	Comments
RDP	PAEC[1] >1.8µJ/m³	Work continues; Monitoring regime increased; Ventilation inspected.	
	PAEC[1] >5µJ/m³	Notify Project Manager of increasing trend and actions taken.	
	PAEC[1] >7µJ/m³	Normal work activities to cease following confirmation measurement, until ventilation restored and levels returned to below 1.8µJ/m³.	Remediation work to be with PPE (eg Airstream helmets)
Gamma	> 100 µSv/shift	Investigation monitoring to identify source; consider need for added shielding/ shotcrete or to minimise time exposed.	Trigger related to EPD results
	>10 µSv/h	Notify Project Manager, increase shotcrete to elevated gamma dose area	Trigger related to underground area gamma surveys.
LLAA	>0.15 Bq_α/m³	Increase water suppression in areas where dust created.	
	>0.5 Bq_α/m³	Respiratory protection required while working in non-filtered environment; Notify Mine manager of emerging dust issue	
	>0.8 Bq_α/m³	Respiratory protection required until levels below 0.5 Bq_α/m³	(e.g. Airstream Helmet)

1 – Potential Alpha Energy Concentration, measurement for Radon Decay Product concentration in air.

7.2 Engineering controls

The most effective way of controlling radiological exposures to workers, the public and the environment is through the use of the first three levels in the hierarchy of controls, collectively referred to as Engineering Controls.

Elimination can be applied by restricting the number of people who could be exposed. For Ranger 3 Deeps this has been achieved through designing the exploration decline so that it traverses non mineralised zones.

Isolation can be applied by preventing people being exposed to radiation and radioactive material, examples of how this will be applied are:

- Using remote handling techniques and cameras to operate machinery if radiation monitoring identifies this is required.
- Using well sealed cabins with filtered air-conditioning systems on equipment where possible to isolate workers from dusty atmospheres, RDP in decline air and shield them from gamma radiation.

Engineering controls will be implemented wherever possible, initially these include:

- Underground ventilation systems;
- Shotcreting of walls and backs;
- Water trucks to spray roads in the mine to prevent dust rising; and
- Continuous RDP monitoring with alarm system in decline air.

All engineering controls implemented will meet the criteria for Best Practicable Technology, as defined by the Supervising Scientist Division in Appendix 1 of their Annual report 2000-2001 (2001).

All engineering controls will be maintained and tested according to manufacturer's instructions to ensure they continue to provide adequate radiation protection to workers.

7.3 Administrative Controls

Administration controls are used to further prevent exposure, those that will be adopted at the Ranger 3 Deeps exploration decline project for optimization of radiation exposures are summarised in this section and include:

- Trigger Action Response Plan
- Classification of work areas
- Classification of workers
- System to Manage Surface Contamination
- Standard Operating Procedures
- Job Hazard Assessment

- Housekeeping and Personal Hygiene
- Signage
- Training and Awareness
- Personal Protective Equipment

7.3.1 Classification of work areas

Work areas will be classified according to the radiological risk as either a controlled area or supervised area. The definition of these as given in The Code (ARPANSA, 2005) is provided below.

*A **controlled area** is an area to which access is subject to control and in which workers are required to follow specific procedures aimed at controlling exposure to radiation.*

*A **supervised area** means an area in which working conditions are kept under review but in which special procedures to control exposure to radiation are not normally necessary.*

The Ranger 3 Deeps exploration decline project has adopted a controlled area procedure that outlines how controlled and supervised area will be managed on the project. Refer document *61800-0000-WP-HE-0162*.

7.3.2 Classification of workers

All workers will be classified as either a “Designated” radiation worker or a “Non-Designated” worker.

Designation is based on workgroups and will be reviewed annually following the completion of the annual dose calculations. A workgroup will be designated if there is the ***potential*** for an individual in that workgroup to receive an annual effective dose greater than 5 mSv or pro-rata of this amount for short term contractors.

By definition, designated workers are essentially those persons working regularly in controlled areas.

The a priori method of predicting designated workers will be based on the same system used by the main Ranger Operations:

- If a worker received an effective dose in excess of 5 mSv in the previous year, and is likely to pursue the same work patterns in the coming year.
- Similarly if an existing worker or a new worker is to work, in the coming year, in conditions where other workers received in excess of 5 mSv in the previous year.
- Where a worker is required to work for a considerable proportion of their annual working hours in an area where the dose rate arising from gamma radiation is 2.5 µSv/h or more.

- Where a worker is required to work for a considerable proportion of their annual working hours in a workgroup that was assessed from the previous year's monitoring program, as being exposed to a mean airborne alpha activity concentration equivalent to or in excess of one quarter of the derived limit for airborne concentration.
- Any combination of the above criteria that may result in the annual effective dose exceeding 5 mSv.

All designated workers will be monitored individually for radiation exposure and have their total annual effective dose recorded and reported.

All designated employees will be required to shower and change out of their work clothes and PPE at the end of each shift. These worn clothes must be laundered on site and their PPE is not to leave site.

All other workers will be classified as non-designated and have a maximum potential dose determined but no individual dose recorded.

Non-designated workers are expected to ensure there is no observable or measurable contamination upon their work clothes, including personal protective equipment, before leaving site.

Currently there are a number of designated workgroups allocated for the Ranger 3 Deeps exploration decline project, these are provided in Table 7.2.

Table 7.2 - Designated Workgroups at Ranger 3 Deeps

Radiation Workgroup	Includes
UG Decline Development	Jumbo operator, off-siders, truck drivers, charge-up team, shotcrete team, Bogger operator
UG Maintenance	Fitters and electricians underground
UG Diamond Drilling	Exploration drillers underground
UG Technical Support	Surveyors and Geo-technicians

The hypothetical maximum dose to Non-Designated Workers will be calculated using the maximum potential exposure for each of the three exposure pathways. The monitoring currently used is listed in Table 7.3.

Table 7.3 - Non-Designated Workers' Pathway for Most Exposed Groups

Pathway	Group
External Gamma Radiation	Selection of members from HSEC and Owners team that spend time underground
Radon Decay Products	Area monitoring at Ranger 3 Deeps office
Long Lived Alpha Activity	Area monitoring at Ranger 3 Deeps office

7.3.3 Surface Contamination Management and Clearances

In order to prevent radioactive contamination leaving site and minimise the spread of contamination out of controlled areas, a controlled area procedure has been developed (*61800-0000-WP-HE-0162*). This document provides specific details on the management of surface contamination at the Ranger 3 Deeps and has the following key elements:

- All radioactive material will be contained within controlled areas.
- No fixed or mobile plant or equipment, that has entered a radiation controlled area, or come in contact with radioactive material, can leave the Ranger site without being tested for surface contamination and issued with a radiation clearance certificate. The only exception being for the transport of Ranger 3 Deeps drill core that is being moved from the exploration decline to exploration yard at Jabiru East. This transport will occur in specially constructed containers that will not enter into a controlled area and be cleaned prior to leaving the Ranger front gate. A procedure will be developed for this process.
- Any item that has been in a controlled area must be cleaned prior to leaving and going to a supervised area.
- Boot washes will be installed at all foot exits from controlled areas.
- Only controlled vehicles can enter controlled areas, these vehicles will be registered and clearly marked.
- Workers who enter controlled areas will be required to adhere to hygiene requirements to minimise both the spread of contamination and their potential to ingest radioactive material.
- Crib rooms, offices, vehicles and work areas will be regularly checked for surface contamination.

A radiation clearance procedure (*61800-0000-WP-HE-0051*) has been developed for the Ranger 3 Deeps project. The surface contamination limit for release of material from site has been set at 0.4 Bq/cm^2 alpha.

7.3.4 SOP, JHA's and Permits

All routine tasks performed at Ranger 3 Deeps exploration decline project will have work procedures (WP) or work instructions (WI) written to inform workers of the hazards associated with completing the tasks. Radiological hazards will be included in these documents.

In addition to these documents, all personnel working at the Ranger 3 Deeps exploration decline project will be required to conduct regular pre-task hazard assessments, in the form of Take 5 or Job Hazard Analysis (JHA). The process for conducting these is outlined in the *Hazard Identification and Risk Management Procedure (61800-0000-WP-HE-0141)* and the *Pre Task Hazard Assessment (Take 5 and JHA) Work Instruction (61800-0000-WI-HE-0009)*. Once again radiological hazards are included as part of the risk assessment process.

All work that has been identified as a higher risk than normal every day operations, for example any work that requires isolations or entry into a confined space, is required to have a Permit to Work. The permit to work, outlined in the *Permit to Work Procedure (61800-0000-WP-HE-0063)* and associated *Permit to Work form (61800-0000-FM-HE-0040),* has a section that asks if radiation clearance or monitoring is required. If this box is ticked "Yes" then the radiation team must be involved in the JHA for the task.

Input from the Radiation section will be in the form of advising on appropriate radiological controls, conducting pre-task monitoring and issuing of appropriate personal monitoring equipment.

7.3.5 Housekeeping and personal hygiene

Good housekeeping and personal hygiene forms the basis for control of the ingestion pathway for radiological exposure. The following general housekeeping and hygiene requirements will be implemented at the Ranger 3 Deeps exploration decline project.

General housekeeping requirements:

- Regular cleaning of all work areas, crib rooms, offices and change rooms.
- Use of boot washes before leaving controlled area.
- Surface contamination monitoring and feedback to relevant work groups.
- Restriction of the movement of items out of controlled areas.
- Special work procedures for maintenance conducted in the workshops on equipment from controlled areas.

General hygiene requirements include:

- Designated workers showering and changing at the end of shift.
- No eating, drinking or smoking in controlled areas, except where drinking is identified in a specific risk assessment to minimise the effects of thermal stress and must include methods of minimising the potential for radioactive contamination.
- Use of gloves, disposable overalls and other PPE when handling certain types of radioactive materials.
- Washing of hands and face before eating, drinking and smoking.
- Checking hands for contamination prior to eating.
- Eating only in crib rooms or clean office areas.
- Minimising the number of crib rooms located inside controlled areas.

7.3.6 Signage

All radiation areas or locations of potential elevated radiation levels will be clearly marked with safety signs that conform to the Australian Standard *AS 1319-1994 Safety Signs for the occupational environment*.

As a minimum, radiation signs will be installed at the following locations:

- Entry into all radiation controlled areas; and
- All radioactive material stores.

7.3.7 Personal Protective Equipment (PPE)

Radiation controls often require the use of PPE in addition to engineering and administrative controls as an additional safeguard against radiological exposure. PPE requirements may include, but are not limited to:

- Gloves to prevent hand contamination.
- Respiratory protection in times of high RDP concentration, for example during ventilation maintenance.
- Respiratory protection for any dusty tasks with the potential for high radiological exposure.
- Rubber gum boots for entry underground, for ease of cleaning when exiting the controlled area.
- Disposable overalls for dirty jobs to prevent the spread of contamination.

All PPE issued and used must comply with the site PPE standard outlined in the personal protective equipment procedure (*61800-0000-WP-HE-0143*).

7.4 Waste Management

The management of waste will be conducted in accordance with the Rio Tinto Environment Standards. Management of radioactive waste will be included as part of relevant documents (e.g. procedures, work instructions and forms) prepared under the following standards:

- E5 Hazardous Material and Contamination Control
- E7 Non-Mineral Waste Management
- E8 Mineral Waste Management

7.5 Transport of Radioactive Material

The transportation of all radioactive material will be completed in accordance with the Code of Practice for Transport of Radioactive Materials (ARPANSA, 2008).

Ranger main operations have developed transport procedures that comply with this code of practice (*RAP026 Transport of Samples & Other Materials off Site* and *RAP024 Consignment of Radioactive Material*). Ranger 3 Deeps will transport all radioactive material according to these procedures.

7.6 Sealed sources and irradiation apparatus

In industry, small but highly radioactive sources are used in many different applications. It is important that these sources are managed according to the relevant code of practice to minimise the risk to workers.

The types of industrial gauges that may be used at the Ranger 3 Deeps operation are soil/moisture density gauges, industrial radiography gauges or borehole logging sources. The codes of practice relevant to these sources are:

- Code of Practice and Safety Guide on Portable Density/Moisture Gauges Containing Radioactive Sources (ARPANSA, 2004)
- Code of Practice for the safe use of sealed radioactive sources in borehole logging (NHMRC, 1989b)
- Code of Practice for the safe use of industrial radiography equipment (NHMRC, 1989a)
- Code of Practice on Security of Radioactive Sources (ARPANSA, 2007)

Prior to any gauges or sources being bought onto the Ranger 3 Deeps exploration decline project site the radiation team will confirm that all sources have a current NT Certificate of Compliance and all operators of the sources have current NT certificates of registration.

All sources will have details entered into the Source Register for the full duration they are on site, and will be removed from the register once they leave.

When not in use, all sources shall be kept locked and in a safe storage location that meets the requirements of the Code of Practice on the Security of Radioactive Sources (ARPANSA, 2007). The storage facility shall have a sign bearing the word *'CAUTION'* and a radiation hazard warning symbol and lettering that make it clear that it is a store for radioactive substances.

Prior to operation of any gauges, relevant work procedures or work instructions shall be developed that comply with the appropriate code of practice. If contractors are engaged to undertake the work then their procedures shall be reviewed for compliance with the Code of Practice prior to commencing operation.

In the event of an incident or emergency situation occurring with the source, the area shall be evacuated and the Senior Radiation Advisor shall be notified immediately. The Senior Radiation Advisor will provide advice on any monitoring requirements and appropriate actions, including the activation of the Business Recovery and Resilience Plan and reporting to regulatory authorities, if necessary. Full details of incident and emergency management and reporting requirements are provided in section 12.

8 Radiation Monitoring Program

A risk based radiation monitoring program has been designed for the Ranger 3 Deeps exploration decline project. The monitoring program has the following objectives:

- demonstration of compliance with regulatory limits;
- Supply data for dose assessments of workers; and
- Confirm the effectiveness of engineering and procedural control measures to keep radiation doses to workers ALARA.

The radiation risk assessment conducted for the project (refer Section 5 and Appendix 1) has been used to determine the locations, types of monitoring and frequency for the monitoring program. The frequency was determined using final risk rank as outlined in Table 8.1, with the final monitoring program provided in Table 8.2. The layout of this table has been made consistent with that of the Ranger Authorisation Radiation Monitoring Program for the main Ranger operations, refer Section 3.4.

The monitoring methods that will be used on the project are summarised in the following sections.

Table 8.1 - Monitoring frequency based on risk ranking

Rank	Monitoring frequency
Low	Monthly
Moderate	Weekly
High	Daily
Cirtical	Continuous

Table 8.2 - Ranger 3 Deeps exploration decline radiation monitoring program

Pathway	Workgroup or location	No Samples	Frequency	Method/Comments
External Gamma	Designated Workers	Each worker	Monitors worn for up to 3 months	Assessed via individual PRDs[2] or (if unavailable) using time-weighted average of Workgroup dose.
	Decline development workers	3 randomly selected workers	Weekly	Monitored using EPD (Used to identify any mineralised zones).
	Cross-cut development workers	All workers spending the majority of their shift within the cross cut	Daily	Monitored using EPD with a total shift dose trigger.
	Non-Designated workers	Most exposed group	Monitors worn for up to 3 months	Used to determine non-designated worker maximum dose.
	New developed areas in decline	1	Weekly	Used to identify any mineralised zones
	New developed areas in Cross-cut	1	Daily	Demonstrate effectiveness of shotcrete in shielding gamma dose rate to work areas.
RDP	Exploration decline first cuddy	1	Continual[3]	Data logging RDP monitor with traffic light system to worn workers if RDP concentration raise above the trigger levels

[2] Personal Radiation Dosimeters (PRDs) may be TLDs, EPDs, Optical Stimulation Dosimeters, film badges and/or pen electroscopes.
[3] Removed weekly for download and occasionally for maintenance and calibration

Pathway	Workgroup or location	No Samples	Frequency	Method/Comments
	Working areas underground	Each active work area	Daily	RDP grab samples. Used to provide work area concentrations for designated worker dose estimates and confirm ventilation is working adequately.
	Office area inside and outside	1 inside, 1 outside	Weekly	RDP grab samples Used to determine non-designated worker maximum dose.
LLAA	Designated Workers	3 randomly selected workers	Weekly	Used to provide workgroup averages for designated worker dose estimates
	Office area outside	1	Monthly	Area sampling for a full day shift. Used to determine non-designated worker maximum dose.
Alpha surface contamination	Plant, including vehicles and equipment and underground PPE	Randomly selected items stored or located within the surface controlled area, equipment in the workshop area, controlled and supervised vehicles and underground PPE hanging on the board	Monthly	To confirm controls are working for minimising ingestion dose pathway.
		All that have entered into a controlled area	Prior to leaving site	As per the radiation clearance procedure
	Accessible surfaces in offices, crib rooms and ablutions	1 randomly selected office, 1 ablution block and the crib room	Monthly	To confirm controls are working for minimising ingestion dose pathway.

8.1 Radon Decay Products

Continuous RDP monitoring will be conducted in the first cuddy with an attached traffic light system as a visual warning to workers that the air quality is of a quality to allow entry underground. The monitoring equipment will run continuously with the occasional down time for data download, maintenance and calibration. RDP data will be logged as a direct measurement of Potential Alpha Energy Concentration (PAEC) in either Working Level (WL) or $\mu J/m^3$.

Underground RDP grab samples will be predominately taken using the Borak 3-3-3 method (Borak, 1987). This involves the sampling of the air onto a 0.8 µm membrane filter (or equivalent) for 3 minutes at a known flow rate, then waiting 3 minutes and then counting the filter in an alpha counter for 3 minutes. The RDP concentration is then obtained through the Equation 8.1.

Equation 8.1

$$[\mathrm{RDP}]\ (\mu\mathrm{J m^{-3}}) = \frac{20.8 * \text{Net Counts}}{\varepsilon * \mathrm{VPM} * \mathrm{ST} * \mathrm{CT} * \mathrm{K}}$$

Where: ε – Alpha counter efficiency

VPM – air sample flow rate (l/min)

ST – Sample time (min) = 3

CT – Count time (min) = 3

K – Conversion factor = 297 for (3-3-3)

8.2 LLAA in dust

LLAA in dust will be measured using Personal Air Samplers (PAS) operating at a flow rate of approximately 2 l/min. Samples will be collected onto a 0.8 µm membrane filter (or equivalent). Filters are then left in a dry dust free environment for at least 2 days to allow for any short lived alpha radionuclides to decay. The LLAA is then obtained through analysis in an alpha counter.

The count time selected is dependent upon the required minimal detectable activity and available time for counting. Initially 100 minutes (or 6000 seconds) will be selected as a good balance between detection limit and ability to complete all analysis in a timely manner. This will be reviewed and adjusted as required.

Long lived alpha activity is then determined using Equation 8.2.

Equation 8.2

$$[\mathrm{LLAA}](\mathrm{Bq}_{\alpha}\mathrm{m}^{-3}) = \frac{\text{Net counts}}{\varepsilon * \mathrm{CT} * \mathrm{ST} * \frac{\mathrm{VPM}}{1000}}$$

Where: ε – alpha counter efficiency

VPM – air sample flow rate (l/min)

ST – sample time (min)

CT – count time (seconds)

8.3 External gamma radiation

External exposure to gamma radiation will be measured through both personal monitoring to determine dose to designated workers and through area monitoring to confirm that shotcrete is working effectively and to identify any mineralised areas with elevated gamma radiation.

All designated workers will be monitored for personal exposure to external gamma radiation using personal thermoluminescent dosimeter (TLD) badges obtained from an external supplier and/or Electronic Personal Dosimeters (EPD)[4].

Short term contractors working predominately underground will be issued EPDs.

Non-designated workers that have the highest potential gamma radiation dose will also be monitored using TLD badges or EPDs, refer Section 7.3.2.

Area gamma surveys will be conducted using a gamma instrument calibrated for Hp (10) to provide an indication of the whole body risk to workers.

8.4 Alpha surface contamination

Monitoring for radioactive contamination will be conducted using surface contamination monitors calibrated to measure alpha surface contamination.

Regular random checks for contamination will be conducted in crib rooms, offices, change rooms, work areas and vehicles. Any areas identified to have elevated contamination levels will be cleaned to the following standards:

[4] The assessed dose reported from TLD badges gives values for strongly (Hp(10)) and weakly (Hp(0.07)) penetrating radiation. The values assessed for Hp(10) gives whole body effective dose in accordance with ICRP recommendations. The Hp(0.07) results gives an indication of skin equivalent dose. The EPD provide a direct reading for Hp(10).

- Crib rooms, offices and supervised vehicles to be below 0.4 Bq/cm^2 alpha (total fixed and removable).
- Supervised work areas to be below 0.4 Bq/cm^2 alpha, with a further allowance up to a total alpha of 4 Bq/cm^2 if contamination is fixed.
- Controlled work areas and controlled vehicles to be below 4 Bq/cm^2 alpha, with a further allowance up to a total alpha of 10 Bq/cm^2 if contamination is fixed.

8.5 Health Surveillance

ARPANSA and NOHSC (ARPANSA and NOHSC, 2002) state:

> *Except in the case of accidental exposure to high doses, no specific radiation-related medical examinations are normally required for persons who are occupationally exposed to ionizing radiation, as there are no diagnostic tests which yield information relevant to exposure at low doses. Where required, health surveillance should follow general occupational medical practice for determining fitness for work.*

ERA will conduct health surveillance only in the case of accidental high exposures. The Senior Radiation Advisor will determine the most appropriate monitoring for the particular situation.

9 Dose Assessment

9.1 Dose Assessment Methods

The total effective dose to designated workers will be the sum of the dose from three exposure pathways:

- External gamma radiation;
- Inhalation of radon decay products; and,
- Inhalation of long lived alpha activity in dust.

Doses will be estimated for each individual designated radiation worker and collectively as a worst case dose to the group of non-designated workers.

9.1.1 External Gamma

The effective dose from external gamma radiation will be obtained directly from the personal monitoring using either TLD badges or EPD, refer Section 8.4.

Workers who lose their TLD, or are present for only a limited portion of the wearing period are assigned a pro rata dose based on the average for their workgroup.

The effective dose to the non-designated work group will be determined using the maximum dose received from personal monitoring of the group of most exposed of these workers, refer Section 7.3.2. This will provide a worst case maximum possible dose to the entire workgroup.

9.1.2 Radon Decay Products

The average underground RPD concentration for the quarter will be determined from the RDP grab sampling program. The effective dose due to inhalation of RDP will then be calculated using Equation 9.1.

Equation 9.1

$$E_{RDP} = \sum_{\text{Radiation Areas}} h_{RDP} \, . [RDP] . \; IT$$

Where:

E_{RDP} - the effective dose due to inhalation of RDP (mSv)

h_{RDP} - dose conversion factor for RDP (mSv / μJ h/m^3)(see Table 9.1)

[RDP] - Average RDP concentration (μJ/m^3) underground for the quarter

IT - inhalation time (h) for quarter.

The inhalation time is equal to the hours worked underground for the quarter.

9.1.3 Inhalation of Long Lived Alpha Activity

The average LLAA for each designated radiation workgroup for the quarter will be determined from the personal air sampling program. The effective dose due to the inhalation of LLAA will then be determined using Equation 9.2.

Equation 9.2

$$E_{LLAA} = \sum_{DWC} h_{LLAA}.[LLAA].BR.IT$$

Where:

E_{LLAA} - effective dose due to inhalation of LLAA (mSv).

h_{LLAA} - dose conversion factor for relevant LLAA (mSv/Bqα) (see Table 9.1).

[LLAA] - quarterly average concentration of LLAA in air (Bqα/m^3) for workgroup.

BR - breathing rate for light activity (assumed to be 1.2 m^3/h) 5.

IT - inhalation time (h), or time working in workgroup for the quarter.

9.1.4 Non-Designated Workers

The dose to the group of non-designated workers will be determined by calculating a hypothetical maximum dose that a non-designated worker may receive from each of the three exposure pathways.

The hypothetical dose will be calculated assuming a working year of 2000 hours and the dose conversion factors listed in Table 9.1.

Table 9.1 - Dose Conversion Factors

Inhalation Parameter	Dose Conversion Factor
Ore Dust	0.0057 mSv/Bq_{α}
Radon 222 decay product for workers	0.0014 mSv/(μJ.h/m^3)
Radon 222 decay product for members of the public	0.0011 mSv/(μJ.h/m^3)

[5] The breathing rate used for dose assessment of inhaled LLAA for workers originates from the ICRP Human Respiratory Tract Model where a worker occupationally exposed doing light work (5.5 hours light exercise + 2.5 hours rest, sitting) breathes 9.6 m^3 of air that is equivalent to a breathing rate of 1.2 m^3/h.

9.2 Predicted Occupational Doses

The total effective radiation dose to designated workers on the Ranger 3 Deeps exploration decline project has been estimated using a number of methods, including calculation from first principals and comparison with previous operations. Details of how the dose for each significant pathway was determined are provided in the following sections. All doses were calculated using the methods detailed in Section 9.1.

All general assumptions used for calculating the doses are provided in Table 9.2 and the estimated doses for each designated work group are provided in Table 9.3. This shows that the maximum doses to all work groups will be well below the dose limits outlined in Section 4.3 and the majority of work groups will be below the design dose constraint of 5mSv per year.

The exception to this was the Offsiders that are predicted to have a maximum dose at or just slightly above the dose constraint. The dose to these workers will be predominately from gamma exposure from the cross cut walls and floor. These workers will spend the majority of their time outside of a cabin and it has been assumed that they will be standing in areas without shotcrete. During operations their gamma dose can be managed on a shift by shift basis with various engineering and administrative controls available as options to keep their doses as low as reasonably achievable and below the dose constraint.

Table 9.2 - General assumption for designated worker dose estimates

Parameter	Assumed Value	Comments/Source
Work hours per year	1825	10 hours underground per day even time roster
Ore grade % U3O8 decline	0.00145	Mine design team [Gleeson 22/1/13]
Ore grade % U3O8 cross cut	0.274	Mine design team [Gleeson 22/1/13]
Cross cut development duration	2 months	Taken from development schedule (maximum)
Gamma shielding factors		
50mm of shotcrete	50%	(Sonter, 2000) Jabiluka underground test work
Underground vehicle cabin	40%	(Sonter, 2000) taken as worst case 40-65%
Gamma dose rate conversion	70	$\mu Sv/h/\%U_3O_8$ from (Sonter, 2000)
Radon emanation rate conversion	15	$Bq/m^2/s/\%U_3O_8$ from (Sonter, 2000)
Maintenance time underground	70%	Obtained from work crews estimates
Technical support time underground	30%	Obtained from work crews estimates

Table 9.3 - Estimated maximum total effective dose to designated workers

Workgroup	Maximum Annual Dose (mSv)			
	Total	Gamma	RDP	LLAA
UG Decline Development team				
Jumbo Operator	3.3	2.1	0.87	0.30
Bogger Operator	3.5	2.3	0.87	0.30
Offsiders	5.3	4.1	0.87	0.30
Shotcrete	3.4	2.2	0.87	0.30
Truck drivers	1.9	0.77	0.87	0.30
UG Maintenance	3.2	2.1	0.87	0.30
UG Diamond Drilling	1.3	0.09	0.87	0.30
UG Technical Support	2.1	0.89	0.87	0.30

9.2.1 Potential Gamma Exposure

Gamma exposure to workers is predicted to be the most significant exposure pathway underground.

Gamma dose rates were predicted using factors previously developed during test work conducted in 1999 as part of the Jabiluka underground decline development (Sonter, 2000). This work determined that gamma dose rate was dependent upon average uranium mineralisation in the vicinity in the relationship of 70 µSv/h/%U_3O_8. It also determined that both shotcrete and underground equipment provided some manner of gamma shielding for workers. The shield factors reported were 50% reduction in gamma dose rate for 50mm of shotcrete and between 40% and 65% reduction in gamma dose rate for workers inside cabins of underground equipment. For this assessment the worst case rate of 40% was utilised. Where workers received both a reduction for shotcrete and equipment a factor of 70% was applied.

The highest gamma dose is expected to occur during the cross cut operations. In order to accurately predict gamma exposures during the 2 months of scheduled operations in the decline, a detailed breakdown of work activities and time has been supplied by the development team. This allows for an accurate determination of both hours in the cross cut and hours in unshielded locations for each of the various workers within the development crew. These hours are provided in Table 9.4.

The gamma dose to various work groups was calculated using these values and the other assumptions provided in Table 9.2. The different gamma dose rates predicted to the decline development crew were as a result of the different shielding factors that were applied. Those workers that spend the most time at the un-shotcreted face receive the highest dose rate. These include the Jumbo and Bogger operators, their off-siders, shotcrete crew and underground maintenance. Off-siders have the potential to receive a high dose than predicted if not properly managed and if allowed to stand outside cabins near un-shotcreted locations.

Table 9.4 - Development team estimated hours in cross cut

UG Decline Development team	Unshielded	Shielded (cabin)
Jumbo Operator	31.2	120.25
Bogger Operator	31.2	136.5
Offsider	190.45	26
shotcrete	89.7	26
truck driver	37.7	0[6]

9.2.2 Potential Radon Decay Product Exposure

RDP concentrations in the underground workings as a result of exposed mineralisation from the ore cross cut have been estimated by Ozvent Consulting using the “Complex Mine Model” software from Environmental Instruments Canada Inc. (Derrington, 2013). Previous modelling was also conducted by Ozvent to estimate RDP concentration in the un-mineralised exploration decline this showed the maximum possible RDP concentration to be 0.3 μJ/m^3 at the exit of the decline, with the primary source of this being from potential radon in groundwater (Jacobsen, 2011).

The model breaks the secondary ventilation leg[7] of the decline up into four 250 m segments, with a further 140 m segment to represent the ore cross-cut, refer to Figure 9.1. The uranium mineralisation was taken as an average for each section and the air flow rates obtained from the Ventsim modelling software package.

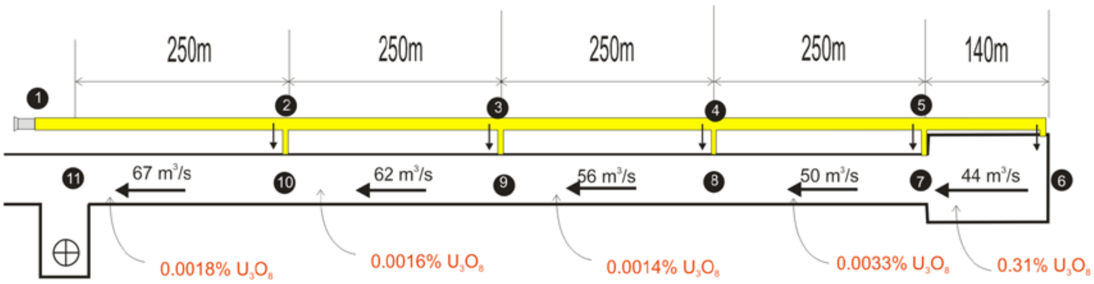

Figure 9.1 - Schematic layout of U3O8 grads and airflow for RDP model

---

[6] Truck drivers will spend the majority of their hours in shielded cabins outside of the cross cut. The unshielded hours shown in this table are from other tasks including charge & fire. They will spend no hours in the cross cut within cabins.

[7] Section of decline from the ventilation exhaust raise at -256RL to the end of the cross cut.

Radon source term inputs for the model were emanation from mineralised material and groundwater flow into the underground workings.

An emanation grade factor of 15 Bq/m^2/s per 1% U3O8 (Sonter, 2000) and the average grade for that section, refer Figure 9.1, was used to estimate the radon emanation from the decline or cross cut walls. Radon emanation from broken rock at the ore cross-cut face was also determined assuming the average cross cut grade and that the blasted rock originated from a half-face cut (6 m x 6 m x 4 m).

Radon contained in groundwater was determined assuming 100% of radon is released from the groundwater inside the cross cut. The groundwater inflow is 2 l/s and the groundwater radon concentration is 760 Bq/l.

The RDP concentration of the air entering the inlets of the secondary ventilation fans was assumed to be negligible. This is held to be a reasonable assumption based on the very low uranium mineralisation in the primary ventilated section of the decline and also given the short residence in the decline before the intake air from the surface reaches the secondary fan inlets (less than seven minutes).

The predicted maximum RDP potential alpha energy concentration (PAEC) is shown in Figure 9.2. The maximum PAEC of 0.47 μJ/m^3 occurs with the oldest air at the -256RL exhaust raise connection.

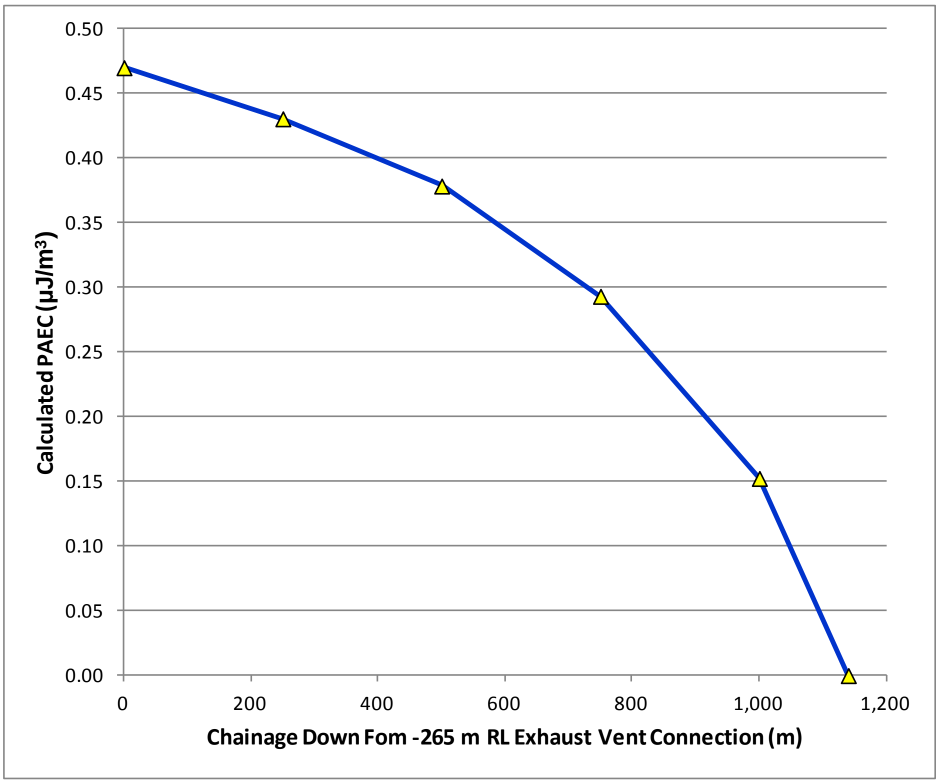

Figure 9.2 - Radon Decay Product modelling results

Radiation doses to workers were then estimated assuming this worst case concentration of 0.47 µJ/m^3 over the entire decline for the 300 hours of estimated cross cut activities and the previous maximum estimate of 0.3 µJ/m^3 for the remainder of the year (1525 hours). This gave an estimated maximum effective dose to underground workers from inhalation of RDP of 0.87 mSv.

9.2.3 Potential LLAA in Airborne Dust

It is expected that the exposure to LLAA in airborne dust will be the least significant of the exposure pathways for the exploration decline.

Previous experience obtained from the Jabiluka decline and other operating underground uranium mines show LLAA to be well controlled with the ventilation system, shotcrete and the general wet nature of underground operations.

Dust concentrations were previously reported in Jabiluka decline annual reports; these are shown in Table 9.4. Similar to the Ranger 3 Deeps exploration decline project, the Jabiluka decline project had a section of decline development that was predominately in barren rock and a cross cut through the ore material (880 Development). This data was used to predict the LLAA concentration to workers on the Ranger 3 Deeps exploration decline project. Average concentrations in the decline were assumed to be the same as at Jabiluka, average concentrations in the cross cut were adjusted for average ore grade on each project.[8]

The estimated dose to designated workers from LLAA for the Ranger 3 Deeps exploration decline development project was 0.3 mSv per year. This assumes that the cross cut development will occur for 2 months and the rest of the time is spent with decline development.

Table 9.5 - LLAA in dust results for underground workers at Jabiluka during 1999.

Work Group	Number	Max	Min	Average	Stdev
Underground Crew - Decline Development	14	0.056	0.000	0.025	0.019
Underground Crew - 880 Development	22	0.264	0.004	0.103	0.085

[8] The average ore grade for the 880 Development at Jabiluka was 1.15% U_3O_8 SONTER, M. 2000. Jabiluka In-Mine Radiation Studies Report. Jabiru, NT.

9.3 Predicted Member of the Public Dose

In order to quantify the potential risk to members of the public from ventilation emissions of radon and dust, ERA commissioned an ambient air quality assessment (Quinn, 2012). The principal emission sources input into the model were:

- Underground blasting;
- Underground diesel trucks; and
- Radon emissions from mineralised rock faces.

The modelling was conducted over the period of the cross cut, when radiation emissions could be expected. It assumed that 100 % of all emissions associated with the activities are emitted by the ventilation system to atmosphere. The air study assessment included the following three computer models (AUSPLUME, CALPUFF and CSIRO TAPM).

The results of the modelling are provided in Figure 9.3 and Figure 9.4 for Radon concentrations and dust deposition respectively. This shows that the ventilation stack sourced radon concentrations are very low, ranging from 0.03 to 0.002 Bq/m^3 in areas likely to be inhabited by members of the public. This is well below the natural background concentrations historically reported in the region that are in the order of 10's of Bq/m^3 (Akber et al., 1991, Bollhöfer et al., 2011).

The pathway for exposure of non-human biota will be predominately via dust deposition. Converting the modelling results in mg/m^2 over a 45 day period to a uranium concentration in Magela Riparian zone soils gave approximately $1.5e^{-6}$ Bq/kg Uranium[9]. This is a very low incremental concentration when compared to worldwide average natural background uranium concentrations found in soils of 32 Bq/kg (UNSCEAR, 2010). Based on this, the risk to non-human biota is expected to be negligible.

Exposure to gamma radiation is not a pathway for members of the public since gamma dose rate decreases by the square of the distance from the source. Gamma dose rates in the nearest occupied areas will not be detectable above background levels.

From this it has been concluded that the radiation risk to the environment and members of the public from the Ranger 3 Deeps exploration decline project is negligible and, as such, no specific management or monitoring on top of that currently undertaken as part of Ranger Operations RMP has been proposed.

[9] Soil concentration calculated assuming a mixing depth of 10cm and a soil density of $1.3g/cm^3$.

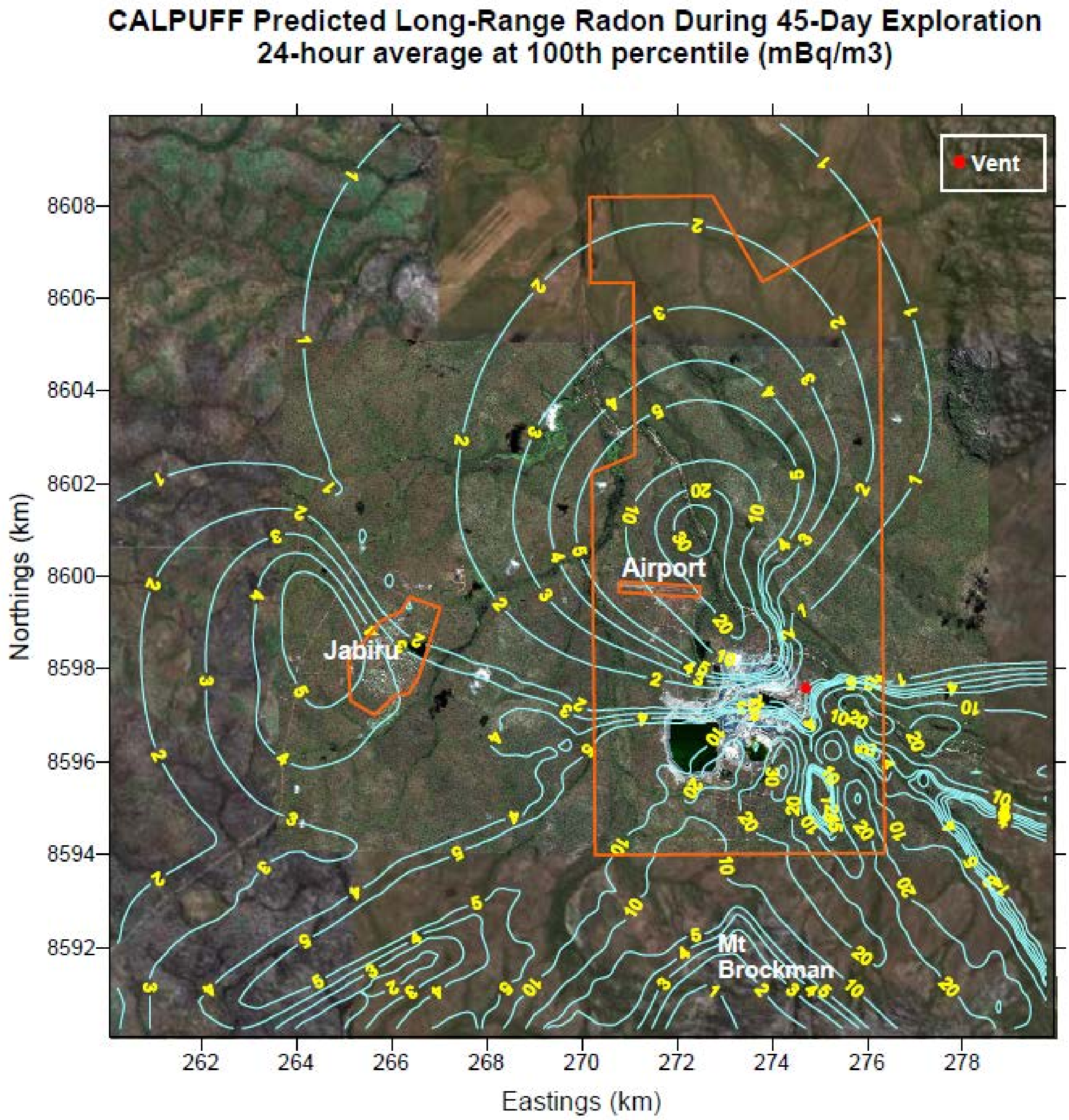

Figure 9.3 - Air quality model results for radon

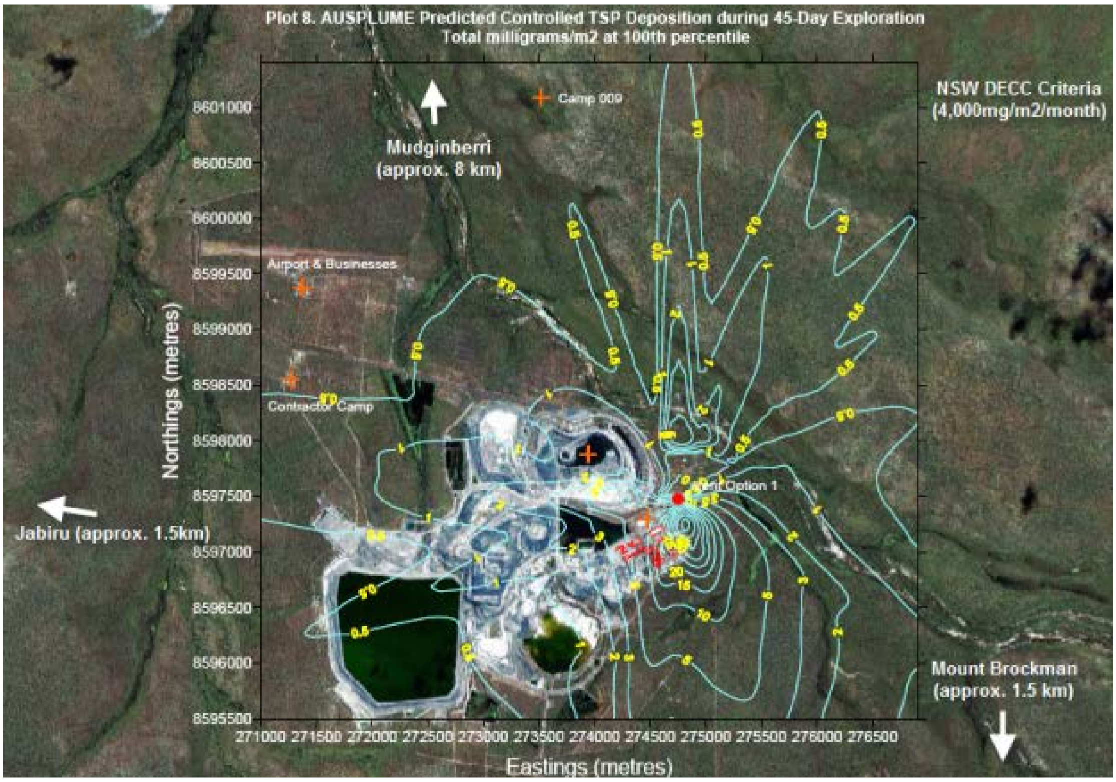

Figure 9.4 - Air quality model results for dust deposition

10 Education and Training

10.1 Inductions

As part to the general Ranger mine site working conditions (refer Ranger main operations RMP), all persons must attend a Radiation Induction within 30 days of commencement of work. This induction must be refreshed annually.

As part of this induction, all workers are provided with a copy of the “Radiation Workers Handbook” which contains general information on radioactivity and radiation theory, radiation doses and risk comparisons, legislation, and mining and processing involving radioactive ores. This document is available in electronic format on ERA’s intranet system.

In addition to this induction, all designated workers on the Ranger 3 Deeps exploration decline project will be required to attend a short talk on commencement and every 12 months. This will be presented by the Radiation team and cover the radiation risks associated with underground mining and how these will be managed and monitored on the Ranger 3 Deeps project.

10.2 Training of Competent Persons

The Senior Radiation Advisor should have the following or suitably equivalent qualifications to ensure that the radiation protection requirements are met:

- Degree in Science or Engineering,
- Vocational Graduate Certificate in Radiation Safety (PSP80212)[10];

Radiation Technicians should have the following or suitably equivalent qualifications:

- Radiation Technician Safety Skill Set (PSP12)[9].

[10] The Government Skills Australia Vocational Graduate Certificate in Radiation Safety (PSP80212) and Radiation Technician Safety Skill Set (PSP12) are not currently offered by any Registered Training Organisations. Until these courses are offered they should have attended alternative relevant radiation training courses. Once it is offered they should by working towards obtaining the qualification either through course attendance or recognition of prior learning (RPL).

11 Reporting and Record Keeping

11.1 Document control and confidentiality

Management and control of all radiation related records and documents will be undertaken according to ERA Major Project document control procedure (*61800-0000-WP-DC-0005*).

All radiation dose records shall be classified the same as health records in these documents and shall be securely stored to protect confidentiality.

The radiation team, and other persons that have access to radiation dose information, must not directly or indirectly disclose that information to another person. Confidentiality Agreements must be signed by all personnel with access to the radiation dose records. These are available through the Ranger main operations Radiation Safety Officer (RSO).

All radiation related records will be managed according to the requirements of the NOHSC National Standard for limiting occupational exposure to ionizing radiation (ARPANSA and NOHSC, 2002). Records of doses assessed, details of monitoring results and dose calculation methods will be kept during the working life of the employee and afterwards for not less than 30 years after the last dose assessment and at least until the employee reaches, or would have reached, the age of 75 years. At the completion of ERA operations then all records of doses will be passed to the DME.

11.2 Quarterly and annual reporting

All radiation monitoring results and dose assessment records will be summarised quarterly and provided to the Ranger main operations Radiation & Hygiene Team for inclusion in their quarterly and annual reports to stakeholders.

11.3 Designated worker doses

The personal radiation dose record for each designated worker will contain the following information:

- employee ID number;
- full name, gender and date of birth;
- start date and termination date if relevant;
- designation as radiation worker and relevant dates;
- details of previous exposure records;
- workgroup and history of any workgroup changes; and
- annual effective dose from each pathway and total for the year.

The annual radiation dose received by each designated worker will be reported to that worker annually or at any other time as requested by that worker.

Each individual dose record, calculated on a quarterly basis, will be uploaded into the Australian National Radiation Dose Register (ANRDR) within 6 weeks of the end of the quarter. These ANRDR records are then available to the worker on request.

The ANRDR transfer will be undertaken by the Ranger main operations Radiation & Hygiene Team along with the other Ranger dose records. Within 3 days of transferring of dose records into the ANRDR, the Ranger main operations Radiation Safety Officer (RSO) will send a letter to the Chief Health Officer of the Northern Territory Department of Health (DoH) informing them of the transfer.

If requested by the DoH radiation dose records will be provided to the regulator and other persons as directed. This will be undertaken via the Ranger main operations RSO.

11.4 Exceedance of dose limits

In the unusual instance that a worker receives a radiation dose in excess of the dose limit outlined in Section 4.3, then the Senior Radiation Advisor will, immediately on becoming aware of the exceedance, verbally inform the Ranger main operations RSO, who will in turn verbally inform the Chief Health Officer of DoH and provide written advice within 7 days.

The Senior Radiation Advisor will confidentially inform the worker involved of the exceedance and provide details of any possible health consequences and continuation in their normal work role.

The Senior Radiation Advisor will conduct an investigation into the reasons for the exceedance and, based on the outcomes of this investigation, make recommendations to management about what action should be taken to reduce the likelihood of possible future exceedances.

11.5 Optimisation of Protection

The optimisation process, outlined in section 4.2, for keeping radiation doses to workers ALARA will involve regular monitoring and review of radiation controls and the selection of the most appropriate control by considering the net exposure reduction versus the economic and societal factors.

Records will be kept of any update or change to radiation controls and where applicable of any cost-benefit analysis used to select the best set of controls for keeping doses to individuals ALARA.

12 Incidents and Emergency Management

Given the relatively simple nature of the Ranger 3 Deep Exploration Decline, the potential for an emergency is relatively small. However any underground operation has inherent risks and scenarios which should be considered during the planning, design and operation of the mine. From the radiation perspective, the major potential risks are associated with failure of the ventilation system or prevention of egress of the workforce. These scenarios could result from relatively minor occurrences, such as a power failure for the ventilation fans, through to catastrophic risks such as an underground fire or tunnel failure.

In the event of a simple ventilation failure, workers will be required to shut down safely and exit the mine. The potential radiological exposure in this scenario is minor due to the short duration in which workers could be exposed to elevated RDP concentrations. If corrective actions are required, such as repairs to a ventilation component underground, all work would be undertaken only after formal consideration of potential radiological exposure and would likely include the use of appropriate respiratory protection equipment.

In the event of an emergency which impacts ventilation and prevents egress workers will be required to enter emergency refuge stations. All refuge stations will include provision of clean air stations and emergency equipment to minimise impacts on the workforce whilst the emergency is rectified. In this emergency scenario, radiation will be a comparatively minor risk in comparison with other risks. As such, any emergency response will concentrate on the primary risks but will take potential radiological aspects into account.

Specific details of how radiation incidents and emergencies will be managed are provided in the following sections.

12.1 Radiation Incidents

A radiation incident is defined by the NT Radiation Protection Act (Northern Territory of Australia, 2012b) as an incident adversely affecting, or likely to adversely affect, the health or safety of any person because of the emission of radiation.

Radiation incidents will all be managed and reported according to the *Incident Recording and Investigation Procedure (91800-0000-WP-HE-0053)*

All radiation related incidents must be reported to the Senior Radiation Advisor. If required they will:

- conduct an investigation into the incident;
- calculate doses to workers;
- determine if the incident requires further reporting to stakeholders and regulatory authorities;
- provide advice to management on appropriate mitigating actions;

- council workers regarding radiation matters relating to the incident; and
- record all details of the incident along with corrective actions taken as required by paragraph 14.1 of the National Standard (ARPANSA and NOHSC, 2002).

The Senior Radiation Advisor will advise the Ranger main operations RSO and the General Manger of any reporting requirements under the Act.

12.2 Emergency response and management

Initial response to an incident will be undertaken in a manner consistent with the ERA Major Projects *Initial Emergency Response Procedure (61800-0000-WP-HE-0070)*.

All emergency situations will be initially managed by the site Emergency Response Team (ERT). If required, the ERA Business Recovery and Resilience Plan will be activated along with the Business Resilience Team (BRT).

For radiation related incidents, the Senior Radiation Advisor will provide advice to the ERT Incident Controller and the BRT to ensure that radiological exposures to workers and members of the public are minimised.

13 Implementation of Plan

13.1 Radiation Personnel

The Ranger 3 Deeps exploration decline project will employ adequate numbers of staff, contractors and consultants to ensure that this RMP is properly implemented and that senior management has access to appropriate radiation advice to ensure it meets all the requirement of the Code (ARPANSA, 2005).

Radiation protection staff will have the qualification and experience outlined in Section 10.2.

Radiation protection staff will also have access to continued training and professional development to ensure they remain up to date with the latest radiation development and regulations.

13.2 Monitoring Equipment

Radiation monitoring equipment will be purchased or hired in sufficient numbers to ensure all monitoring detailed under Section 8 is completed. Only monitoring equipment that meets stringent requirements for the task will be used on the project.

All monitoring equipment will be maintained and calibrated at regular intervals, to ensure compliance with all monitoring requirements, refer Section 14.

13.3 Integration into Operation

This RMP forms part of the overall ERA Major Project Health, Safety and Environment Management System (HSE MS) making it fully integrated into the daily HSE MS processes on the project.

The HSE MS is based on the Rio Tinto group-wide HSE management process and is certified to the standards ISO14001:2004 (Australian/New Zealand Standard, 2004) Environmental management systems and AS4801:2001 Occupational health and safety management systems (Australian/New Zealand Standard, 2001).

14 Quality Assurance

To have confidence in the validity of monitoring results and the subsequent worker dose estimates, the site will adopt good quality management principals. These will include:

- regular calibration of equipment;
- regular background measurements when relevant;
- competency of the person undertaking the monitoring (refer Section 10.2);
- clear labelling and chain of custody of samples collected;
- prompt recording of results in a secure form (refer Section 11.1); and
- backing up of documentation (refer Section 11.1)

The quality management system adopted is consistent with the Australian Standard for quality management systems (Australian/New Zealand Standard, 2008).

All equipment used for radiation monitoring will be calibrated to a known standard at the frequency recommended by the manufacturer and at least annually. This calibration can be conducted either by an external provider, or conducted in house if in possession of a known standard or certificated calibration source.

All standards or sources will be calibrated or certificated at least every 5 years or sooner if recommended by the manufacture or regulator. Any reduction in activity due to radioactive decay will be allowed for prior to the use of the standard or source. For radionuclides with very long half-lives; for example ^{230}Th or ^{36}Cl, this decay will be negligible and adjustment will not be necessary.

In addition to regular calibration, weekly, or prior to use for less used equipment, calibration checks should be performed. These checks are to demonstrate consistency in measurements conducted or indicate when an instrument may have fallen out of calibration. The checks do not need to be performed against calibrated standards or sources, rather any radioactive material that can be used to demonstrate consistency from week to week.

Alpha/Beta monitoring equipment will be checked for background at least weekly. This information will be used to determine if the instrument has become contaminated or as an early indication of potential failure. If the background needs to be subtracted from the measurement being conducted (e.g. alpha sample counter) then the background check will be performed daily or prior to the equipment being used. If the instrument is portable, then the background will be checked at the monitoring location (not in the laboratory or office) as there could be significant differences.

If personal air samplers are being used to measure LLAA in dust, then the flow rate will be checked through the actual filter prior to and immediately after monitoring. The average flow rate will then be used in the calculations.

Monitoring logs will be created for each type of sampling to provide a record of the sample number, equipment ID and operator conducting the monitoring. All samples will be clearly labelled with their sample ID.

If samples are to be sent for external analysis then they will be clearly labelled with an ID number and date and be accompanied by a chain of custody form.

15 Review and Assessment

A program of Inspections, Audits and Review will be conducted to insure that the radiation management system is continuously improving.

15.1 Work area inspections

Documented audits and inspections of the workplace will be carried out regularly. They will primarily focus on controlled areas.

Inspections will often be incorporated with area monitoring programs for gamma dose rate and surface contamination. All results will be recorded in a register and a summary routinely presented back to the work areas.

The objective of inspections is the early identification of any potential issues with the radiation protection program and the radiation controls. Any improvements identified will be reported to the area Superintendent or equivalent immediately.

15.2 Audit and Review

An internal audit of the radiation management system and associated plans and procedures will be conducted annually.

An external audit of the system, including a review against all relevant legislation will be conducted every three years. This external audit will prompt the review and updating of the RMP.

As part of the overall site HSE MS the RMP will also be audited regularly by:

- Rio Tinto for its conformance with the Rio Tinto B5 Radiation standard.
- External audits as part of the standards certification process.

At the completion of each audit, the RMP will be updated as required by identified actions.

In addition to the audits, the RMP will be updated following any changes to radiation legislation or regulatory requirement outlined within the RMP.

Following any update of the RMP, it will be re-submitted to the regulatory authorities for approval.

16 Definitions

Term	Description
ALARA	As Low As Reasonably Achievable, economic and societal factors being taken into account
ANRDR	Australian National Radiation Dose Register
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
BR	Breathing rate
BRT	Business Resilience Team
the Code	The code of practice for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing (ARPANSA, 2005)
DCF	Dose conversion factor
DME	Northern Territory Department of Mines and Energy
DoH	Northern Territory Department of Health
EPBC Act	Environmental Protection and Biodiversity Conservation Act
EPD	Electronic Personal Dosimeter
ERA	Energy Resources of Australia Limited
ERT	Emergency Response Team
HSE MS	Health Safety and Environment Management System
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IT	Inhalation time
JHA	Job Hazard Analysis
LLAA	Long Live Alpha Activity
MTC	Minesite Technical Committee
NOHSC	National Occupational Health and Safety Commission
OEL	Occupational exposure limit
PAEC	Potential Alpha Energy Concentration (RDP concentration)
PAS	Personal Air Sampler
PPE	Personal Protective Equipment
RDP	Radon Decay Products
RMP	Radiation Management Plan
RPA	Ranger Project Area
RSO	Radiation Safety Officer (Ranger main operations)

Term	Description
TLD	Thermo luminescent dosimeter
WI	Work Instruction
WL	Working Level
WP	Work Procedure
U_3O_8	Uranium oxide

17 References

AKBER, R., PFITZNER, J. & JOHNSTON, A. 1991. Public Radiation Dose due to Radon Transport from Ranger Uranium Mine. *Internal Report 24.* Jabiru: Supervising Scientist.

ARPANSA 2004. Code of Practice and Safety Guide on Portable Density/Moisture Gauges Containing Radioactive Sources. *Radiation Protection Series No. 5.* Australian Government.

ARPANSA 2005. Code of Practice on Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing. Australian Radiation Protection and Nuclear Safety Agency.

ARPANSA 2007. Code of Practice on the Security of Radioactive Sources. *Radiation Protection Series No. 11.* Victoria: Australian Government.

ARPANSA 2008. Code of Practice on the Safe Transport of Radioactive Material. Australian Government.

ARPANSA 2011. National Directory for Radiation Protection, Republished July 2011, amendments 1-5. Victoria: Commonwealth of Australia.

ARPANSA AND NOHSC 2002. Recommendations for Limiting Exposure to Ionizing Radiation (1995) (Guidance Note [NOHSC:3022(1995)]) and National Standard for Limiting Occupational Exposure to Ionizing Radiation [NOHSC:1013(1995)] Republished March 2002. Comonwealth of Australia.

AUSTRALIAN/NEW ZEALAND STANDARD 2001. AS/NZS 4801 Occupational health and safety management systems - specifications with guidance for use. Standards Australia.

AUSTRALIAN/NEW ZEALAND STANDARD 2004. ISO 14001:2004 Environmental Management Systems-Requirements with guidance for use. Standards Australia.

AUSTRALIAN/NEW ZEALAND STANDARD 2008. AS/NZS ISO 9001:2008 Quality management systems - Requirements. *Incorporating Amendment No. 1.* Standards Australia.

BOLLHÖFER, A., ESPARON, A. & PFITZNER, K. 2011. Pre-mining radiological conditions at Ranger mine. *In:* JONES, D. & WEBB, A. (eds.) *eriss Research Summary 2009-2010, SSR 202.* Darwin: Supervising Scientist Division.

BORAK, T. B. 1987. A method for prompt determination of working level using a single measurement of gross alpha activity. *Radiation Protection Dosimetry,* 19**,** 97-102.

DERRINGTON, A. 2013. Ranger Exploration Decline Development Ventillation and Cooling Review. Ozvent Consulting.

ICRP 2007. The 2007 reccomendations of the International Commission on Radiological Protection. ICRP Publication No. 103. *Annals of the ICRP,* 37.

JACOBSEN, N. 2011. Ranger 3 Deeps Exploration Decline Application for Approval: Construction of an exploration decline and completion of phase 1 underground exploration works for the Ranger 3 Deeps. Darwin, NT: Energy Resources of Australia.

NHMRC 1989a. Code of practice for the safe use of industrial radiography equipment. *Radiation Health Series No. 31.* Australian Government.

NHMRC 1989b. Code of Practice for the safe use of sealed radioactive sources in borehole logging. *Radiation Health Series No. 28.* Australian Government.

NORTHERN TERRITORY OF AUSTRALIA 2012a. Mining Management Act. *In:* DEPARTMENT OF MINES AND ENERGY (ed.). Northern Territory of Australia.

NORTHERN TERRITORY OF AUSTRALIA 2012b. Radiation Protection Act. *In:* DEPARTMENT OF HEALTH (ed.). Northern Territory Government.

QUINN, P. 2012. Ranger 3 Deeps Bulk Sample: Air Quality Assessment.

RHC 2011. Statement on Changes to Occupational Dose Limit for Lens of the Eye. *In:* AUSTRALIAN GOVERNMENT RADIATION HEALTH COMMITTEE (ed.). ARPANSA.

SONTER, M. 2000. Jabiluka In-Mine Radiation Studies Report. Jabiru, NT.

SUPERVISING SCIENTIST 2001. Annual Report 2000-2001. Darwin: Australian Government.

UNSCEAR 2010. Sources and Effects of Ionizing Radiation. *UNSCEAR 2008 Report to the General Assembly with Scientific Annexes.* United Nations Scientific Committee on the Effects of Atomic Radiation.

17.1 Rio Tinto Standards and guides

Document number	Document title
STH011	*Rio Tinto HSE Standard: B5 - Radiation*
GNH1102	*Guidance Note: Ionizing Radiation Safety, B5 Radiation*
STE05	*Rio Tinto HSE Standard: E5 Hazardous Material and Contamination Control*
STE07	*Rio Tinto HSE Standard: E7 Non-Mineral Waste Management*
STE08	*Rio Tinto HSE Standard: E8 Mineral Waste Management*

17.2 Other documents (eg procedures, registers, forms, drawings)

Document number	Document title
RAP001	*ERA Ranger Mine Radiation Management Plan*
RAP026	*Transport of Samples and other Material off site*
RAP024	*Consignment of Radioactive Material*
61800-0000-WP-HE-0162	*Controlled Area Procedure*
61800-0000-WP-HE-0141	*Hazard Identification and Risk Management Procedure*
61800-0000-WI-HE-0009	*Pre-task Hazard Assessment (Take 3 and JHA) Work Instruction*
61800-0000-WP-HE-0063	*Permit to Work Procedure*
61800-0000-WP-HE-0143	*Personal Protective Equipment Procedure*
61800-0000-WP-HE-0051	*Radiation Clearance Procedure*
61800-0000-WP-DC-0005	*Document Control Procedure*
61800-0000-WP-HE-0070	*Initial Emergency Response Procedure*
61800-0000-FM-HE-0004	*HSEQ Risk Matrix*
61800-0000-FM-HE-0040	*Permit to Work Form*

Appendix A - Radiation Risk Assessment

Radiation risk assessments at ERA are conducted as outlined in Element 3 of the HSE MS, Hazard Identification and Risk Management.

To facilitate a better assessment of radiation risk, a set of consequence descriptors specific for radiation exposure have been developed. These descriptors along with relevant likelihood descriptors and the ERA risk matrix have been provided below.

The risk assessment was conducted as a workshop on the 4th February 2013 with participants from the Ranger 3 Deeps exploration decline team. The risk assessment was then finalised in early March.

The workshop was facilitated by Sharon Paulka and attended by Catherine Turyn, Samantha Sonter, Glenn Strybosch and Frank Ellison.

The assessment identified 64 radiation risks, most of which were ranked as low. No critical radiation risks were identified. A total of 3 high risks and 12 moderate risks were identified as requiring controls and active management to ensure radiation doses are below the dose constraint and ALARA.

All the high risks were related to the potential for increased gamma dose to workers who will be working in the cross cut outside of equipment cabins and in areas with little or no shotcrete. These workers will need to wear electronic personal dosimeters and have a shift dose constraint applied to minimise their exposure. In addition they will be required to be within cabins or in shotcrete (lower exposure rate) areas during times when they are not actively working.

The moderate risks were predominately associated with the risk of radon decay product (RDP) inhalation underground. RDP concentrations will be monitored and managed daily through the underground ventilation system.

Other moderate risks were associated with:

- gamma dose rate to workers inside of cabins in the cross cut;
- gamma dose to drillers handling uranium core; and
- dust generated during cutting or core.

All of these will be managed as part of the application of optimisation, refer Section 7 Control Measures.

			Radiation Consequence				
			1-Minor	**2-Medium**	**3-Serious**	**4-Major**	**5-Catastrophic**
Likelihood	**Frequency**	**Emissions**	Slight increase in radiation dose with outcomes remaining below dose constraints.	Increase in radiation dose above the dose constraints but still below international limits	Increase in radiation dose to above international limits	Radiation doses above 100 mSv to an individual and likely to significantly increase the risk of cancer to that individual.	Radiation doses to multiple individuals above 100 mSv or acute radiation syndrome to an individual.
A-Almost Certain	Occurs more than twice per year	Frequent (daily) exposure at > 10 x OEL	**Moderate**	**High**	**Critical**	**Critical**	**Critical**
B-Likely	Typically occurs once or twice per year	Frequent (daily) exposure at > OEL	**Moderate**	**High**	**High**	**Critical**	**Critical**
C-Possible	Typically occurs in 1-10 years	Frequent (daily) exposure at > 50% of OEL or Infrequent exposure at > OEL	**Low**	**Moderate**	**High**	**Critical**	**Critical**
D-Unlikely	Typically occurs in 10-100 years	Frequent (daily) exposure at > 10% of OEL or Infrequent exposure at > 50% of OEL	**Low**	**Low**	**Moderate**	**High**	**Critical**
E-Rare	Greater than 100 year event	Frequent (daily) exposure at < 10% of OEL or Infrequent exposure at > 10% of OEL	**Low**	**Low**	**Moderate**	**High**	**High**

Activity/Location	Workgroup	Job/Task	Hazard (Sources)	Risk (Pathways)	Consequence	Likelihood	Risk Ranking	Comments
Exploration decline development	Jumbo Operators and offsiders	• Drilling holes in face for blast • rock bolting • scaling • Charge of face • underground vent workings installation	Dust generated during various activities	Inhalation of LLAA	1-Minor	E-Rare	Low	Exploration decline works is unlikely to intersect uranium mineralisation or radioactive material. RDP modelling showed concentration in decline to be low with normal ventilation.
			Release of radon in groundwater intersecting during drilling	Inhalation of RDP	2-Medium	E-Rare	Low	
			Radioactive contaminated surfaces	Ingestion of radiation	1-Minor	E-Rare	Low	
			Radon emanating from exposed uranium mineralisation	Inhalation of RDP	2-Medium	E-Rare	Low	
			RDP building up during periods of ventilation maintenance	Inhalation of RDP	2-Medium	C-Possible	Moderate	
			Gamma radiation from exposed uranium mineralisation	Gamma exposure	1-Minor	D-Unlikely	Low	
	Bogging and trucking	• Truck Loading • Truck or bogger transport to surface or stockpile cuddy • Truck or bogger dumping	Dust generated during activity	Inhalation of LLAA	1-Minor	E-Rare	Low	
			Radioactive contaminated surfaces	Ingestion of radiation	1-Minor	E-Rare	Low	
			Radon emanating from exposed uranium mineralisation	Inhalation of RDP	2-Medium	E-Rare	Low	
			Gamma radiation from exposed uranium mineralisation	Gamma exposure	1-Minor	D-Unlikely	Low	
	Shotcrete operators	Shotcrete walls and backs	Dust generated during activity	Inhalation of LLAA	1-Minor	E-Rare	Low	
			Radioactive contaminated surfaces	Ingestion of radiation	1-Minor	E-Rare	Low	
			Radon emanating from exposed uranium mineralisation	Inhalation of RDP	2-Medium	E-Rare	Low	
			Gamma radiation from exposed uranium mineralisation	Gamma exposure	1-Minor	D-Unlikely	Low	
Cross cut development	Jumbo Operators and offsiders	• Drilling holes in face for blast • rock bolting • scaling • Charge of face	Dust generated during various activities	Inhalation of LLAA	2-Medium	D-Unlikely	Low	Average grade in the decline will be 0.27% U3O8 that will deliver an unshielded dose of 19uSv/h and modelled radon shows less than 0.5uJ/m3
			Release of radon in groundwater intersecting during drilling	Inhalation of RDP	2-Medium	D-Unlikely	Low	
			Radioactive contaminated surfaces	Ingestion of radiation	1-Minor	D-Unlikely	Low	
			Radon emanating from exposed uranium mineralisation	Inhalation of RDP	2-Medium	C-Possible	Moderate	
			Gamma radiation from exposed uranium mineralisation	Inhalation of RDP	3-Serious	C-Possible	High	
	Bogging and trucking	• Truck Loading • Truck or bogger transport to surface or stockpile cuddy • Truck or bogger dumping	Dust generated during activity	Inhalation of LLAA	2-Medium	D-Unlikely	Low	
			Radioactive contaminated surfaces	Ingestion of radiation	1-Minor	D-Unlikely	Low	
			Radon emanating from exposed uranium mineralisation	Inhalation of RDP	2-Medium	C-Possible	Moderate	
			Gamma radiation from exposed uranium mineralisation	Gamma exposure	3-Serious	D-Unlikely	Moderate	
	Shotcrete operators	Shotcrete walls and backs	Dust generated during activity	Inhalation of LLAA	2-Medium	D-Unlikely	Low	
			Radioactive contaminated surfaces	Ingestion of radiation	1-Minor	D-Unlikely	Low	
			Radon emanating from exposed uranium mineralisation	Inhalation of RDP	2-Medium	C-Possible	Moderate	
			Gamma radiation from exposed uranium mineralisation	Gamma exposure	3-Serious	C-Possible	High	
Exploration drilling	Drillers and offsiders	Drilling into mineral resource	Dust generated during activity	Inhalation of LLAA	1-Minor	E-Rare	Low	
			Release of radon from intersected groundwater	Inhalation of RDP	2-Medium	E-Rare	Low	
			Radioactive contaminated surfaces	Ingestion of radiation	1-Minor	D-Unlikely	Low	
			Radon emanating from core	Inhalation of RDP	2-Medium	C-Possible	Moderate	Core will be the only radioactive material so is ranked higher
			Gamma radiation from exposed uranium mineralisation in cuddy	Gamma exposure	1-Minor	D-Unlikely	Low	
			Gamma radiation from core	Gamma exposure	2-Medium	C-Possible	Moderate	
		• Sampling and handling of mineralised core • Transport of core to surface	Dust generated during activity	Inhalation of LLAA	1-Minor	E-Rare	Low	
			Gamma radiation from core	Gamma exposure	2-Medium	D-Unlikely	Low	
			Radioactive contaminated surfaces	Ingestion of radiation	1-Minor	D-Unlikely	Low	
Core handling on surface	Exploration technicians and geologists	• Handling of core during transport and storage • logging core • Cutting core	Gamma radiation from core	Gamma exposure	2-Medium	D-Unlikely	Low	
			Radioactive contaminated surfaces	Ingestion of radiation	1-Minor	D-Unlikely	Low	
			Dust generated during activity	Inhalation of LLAA	2-Medium	C-Possible	Moderate	

Activity/Location	Workgroup	Job/Task	Hazard (Sources)	Risk (Pathways)	Consequence	Likelihood	Risk Ranking	Comments
Stockpiling on surface	Truck Operators	• Transport of cross cut mineralised material to stockpile • Dumping mineralised material on stockpile • Dozing up stockpiles • grading and other road and stockpile maintenance	gamma radiation from uranium mineralisation in stockpile	Gamma exposure	1-Minor	E-Rare	Low	
			Dust generated from hauling and dumping	Inhalation of LLAA	1-Minor	E-Rare	Low	
Maintenance	Surface Maintenance Crew	Maintenance to light and heavy equipment in surface workshop	Radioactive contaminated surfaces	Ingestion of radiation	1-Minor	D-Unlikely	Low	
			Dust Generation from working on dirty equipment	Inhalation of LLAA	2-Medium	C-Possible	Moderate	
	Underground Maintenance Crew	• Breakdown maintenance to underground equipment • Underground electrical work	Dust Generation from working on dirty equipment	Inhalation of LLAA	2-Medium	C-Possible	Moderate	
			Radioactive contaminated surfaces	Ingestion of radiation	1-Minor	C-Possible	Low	
			Working in cross cut with no shotcrete and outside cabins	Gamma exposure	3-Serious	C-Possible	High	This was ranked based on cross cut not decline general
General Surface work	All other workers (non-designated)	General work inside the controlled area on the surface.	Radioactive contaminated surfaces	Ingestion of radiation	1-Minor	E-Rare	Low	
			Dust generated from general wheel traffic	Inhalation of LLAA	1-Minor	E-Rare	Low	

Revision History

Revision number	Revision date	Revised by *	Checked by *	Approved by *	Authorising IDR No.
0	02/04/2013	Sharon Paulka	Imogen Edmunds Colin Chapman Catherine Turyn Peter Anderson	Heath Thorpe	61800-IDR-0208
1	05/06/2013	Sharon Paulka*	Annelize Van Rooyen*	Heath Thorpe*	61800-IDR-0284

* Wet signature supplied

Change Summary

Revision No.	Section	Change
0	All	Updated to new template, changed structure to be consistent with code of practice and B5 standard, added Phase 2 elements. Re-numbered to reflect HSE document rather than Decline document.
1	Various	Updated document to include comments received back from regulators as part of the approval process. Major change was to Table 8.2 the radiation monitoring program. All other changes relatively minor. Included an exclusion for clearance of core transported to Jabiru East