Eneabba Rare Earth Refinery Radiation Management and Waste Management Plan

	NAME	DESIGNATION	SIGNATURE	DATE
ENDORSED BY:		ENEABBA SITE REGISTERED MANAGER		

ILUKA

Document Control

REVISION	DETAILS OF REVIEW OR CHANGES	DATE CREATED	APPROVAL FROM REGULATOR/S
0	Original Document 1 – Eneabba Monazite processing Operations – Radiation Management Plan	2011	DMIRS and RCWA provided feedback – no approval
0	Original Document 2 – Transport and Shipping of Zircon Sands - Radiation Management Plan	2011	DMIRS and RCWA provided feedback – no approval
1	Original documents combined (Phase 1), details updated in accordance with current regulations. Submitted to DMIRS & RCWA for review.	June 2019	Feedback provided
1.2	Updated to address DMIRS and RCWA feedback on revision 1 (Phase 1). Submitted to DMIRS and RCWA for approval.	November 2019	Feedback Provided
1.3	Minor wording updates to clarify operational aspects in response to DMIRS comments (Phase 1)	December 2019	Approval from DMIRS and RCWA
1.4	Phase 1 RMP updated to include Plant 2.	November 2020	DRAFT provided to RCWA & DMIRS for review
1.5	Phase 1 RMP updated to include Plant 2.	November 2020	Comments provided by DMIRS & RCWA.
1.6	Updated Phase 1 and 2 RMP including Regulator comments	December 2020	Approval from DMIRS
1.7	Updated Phase 2 RMP to include Phase 3 (Eneabba Rare Earth Refinery – ERER)	September 2021	

This document has been prepared by Iluka Resources Limited to support a referral to the West Australian Environmental Protection Authority (EPA) for the Eneabba Phase 3 Project - Eneabba Rare Earth Refinery (ERER) to determine whether approvals under Part IV of the Environmental Protection Act 1986 (EP Act) are required.

This document is not intended to and must not be used for any other purpose. This document per current revision is not intended to be considered for approval by the Western Australian Department of Mines Industry Regulation and Safety (DMIRS) and Radiological Council of Western Australia (RCWA) as official Radiation Management Plan (RMP) or Radiation Waste Management Plan (RWMP) for ERER. This RMP and RWMP has been prepared based on available information on ERER processes, design, and management practices as at September 2021, and a future final version will be submitted to DMIRS and RCWA for approval at a later date.

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1. SCOPE

1.1. SUMMARY OVERVIEW

This Radiation Management Plan (RMP) and Radiation Waste Management Plan (RWMP) is specifically for the Iluka Resources Limited (Iluka) Eneabba Rare Earth Refinery (ERER), Phase 3. Some aspects of Eneabba Phase 1 (EP1) and Phase 2 (EP2) will be covered as background information and for inter-connectivity to ERER. This document is a combined RMP and RWMP (collectively referred to as the RMP) for the project and is intended for use during the construction, commissioning and initial operation of ERER. It will undergo review periodically to ensure that it remains relevant.

ERER aims to process rare earth oxides and carbonates for market. The feed stocks are known to contain elevated concentrations of naturally occurring uranium and thorium which will be routed to the bulk waste stream in a largely diluted form, to be disposed of within existing mining voids. Iluka proposes to upgrade the existing mineral processing facilities at Eneabba and construct and operate the ERER, which will process monazite product (~90% monazite) from Eneabba (EP2 Product) and other sources. ERER will be located at the Iluka Eneabba mine site in Western Australia adjacent to the current EP1 and EP2 processing plants. ERER is expected to have a throughput of 55,000 tonnes per annum (tpa). The plant will utilise roasting, leaching and purification processes followed by solvent extraction and product finishing to produce 17,000 tpa of individual rare earth oxides and carbonates. Products will be transported as bags via road from Eneabba to the port of Fremantle for export.

This RMP outlines the plans, systems and methods that will be used by Iluka to identify, assess, control and report radiation hazards and risks to ensure that workers, contractors, the public, and the environment are protected from the harmful effects of radiation that may arise due to the Project and ensure that the exposure to radiation is As Low As Reasonably Achievable (ALARA).

The key documents that address the potential radiological impacts that have been referred to in this RMP are as follows:

- The Eneabba RMP (2021) is the overarching document for the Eneabba site which also includes the Radioactive Waste Management Plan.
- The Eneabba RMP (2021) - the mining of the Mineral Sands by-product stored in the Eneabba Monazite Pit (EMP) during EP1, and up-grading to a 90% monazite purity (EP2) for transportation and shipment from the Geraldton Port.
- A separate RMP is also in place and approved for the Narngulu processing site, including ship loading at the Geraldton Port (approved in 2021). Once the ERER is successfully completed, the transport of monazite product for sale will not be required, as monazite will be further processed at the Eneabba site.

The current RMP is not designed to replace the Eneabba RMP (2021), but rather to be an addition to it, applicable only when the ERER becomes operational.

A number of assessment reports have been concluded and indicate that the radiological impacts of ERER could be managed and are able to be maintained *As Low As Reasonably Achievable*, through effective design controls and administrative processes. To re-enforce this, Iluka currently manages a number of sand mining and mineral processing operations and maintains a high understanding of the measures required for the control of radiation exposure to people and the environment.

This RMP has been compiled to meet the requirements of the Radiation Safety Act, 1975 (RSA); Western Australian *Mines Safety and Inspection Act 1994* (MSIA) and Part 16.7 of the *Mines Safety and Inspection Regulations 1995*. The format of this RMP follows the Western Australian Department of Mines, Industry Regulation and Safety's (DMIRS) guideline: *Managing naturally occurring radioactive material (NORM) in mining and mineral processing NORM 2.2 – Preparation of a radiation management plan – mining and processing* (DMIRS 2010a).

This RMP also addresses the requirements of conditions set as part of the Site Radiation Registration and Licences provided by the Western Australian Government (Radiological Council (RCWA)), in particular:

- The Australian Radiation Protection and Nuclear Safety Agency's (ARPANSA) *Code of Practice and Safety Guide for Radiation Protection and Radioactive Waste Management in Mining and*

Mineral Processing (ARPANSA 2005); specifically sections 2.7 and 2.8 of the Code of Practice, and sections 3.8 and 3.9 of the Safety Guide;

- The *Radiation Safety (Transport of Radioactive Substances) Regulations 2002 (where applicable)*;
- The Radiation Safety regulations – in relation to fixed radiation gauges; and
- Effective Dose Equivalent is less than the maximum levels provided in Schedule I of the *Radiation Safety Regulations (General)* 1983 and reporting in accordance with regulation 15.
- ARPANSA Radiation Protection Series. *National Directory for Radiation Protection*. (RPS6 *2014*)
- ARPANSA Radiation Protection Series. *Guide for Classification of Radioactive Waste*. (RPS G-4)

1.2. SITE LOCATIONS

The Eneabba mine site is located approximately 280km north of Perth and 150km southeast of Geraldton, Western Australia (Figure 1). The site is located within the Shire of Carnamah.

The processing plant would be situated at Eneabba Mine (WA), brownfield site, and the waste facility would also be present at this location and planned to be established within a previous mining void.

1.3. CONTACT DETAILS

The Eneabba Project (the Project) is owned by Iluka Resources Limited (Iluka). Iluka's head office is located in Perth, Western Australia, with details below:

Level 17, 240 St Georges Terrace
GPO Box U1988
PERTH WA 6845

Ph. +61 8 9360 4700
Fax. +61 9 9360 4777

Iluka's contact details for this Radiation Management Plan are:

Russell Browne
Senior Environmental Specialist – Radiation (RSO)
Iluka Resources Ltd

Ph. +61 0417914951
Email. russell.browne@iluka.com

This RMP has been completed prior to operation of ERER and includes the most detailed information available when this RMP was written.

1.4. TENEMENT AND LAND OWNERSHIP

Processing of monazite rich feed material, to produce rare earth oxides and carbonates will take place at the Eneabba mine, located within State Agreement Tenement AM70/267 granted under the *Mineral Sands (Eneabba) Agreement Act 1975*. ERER and associated activities covers an area of approximately 45 hectares and is located on Vacant Crown Land; Victoria Location 12562 (CT LR03121/98). The Eneabba site is regulated under the radiation registration number RS 53/76 482.

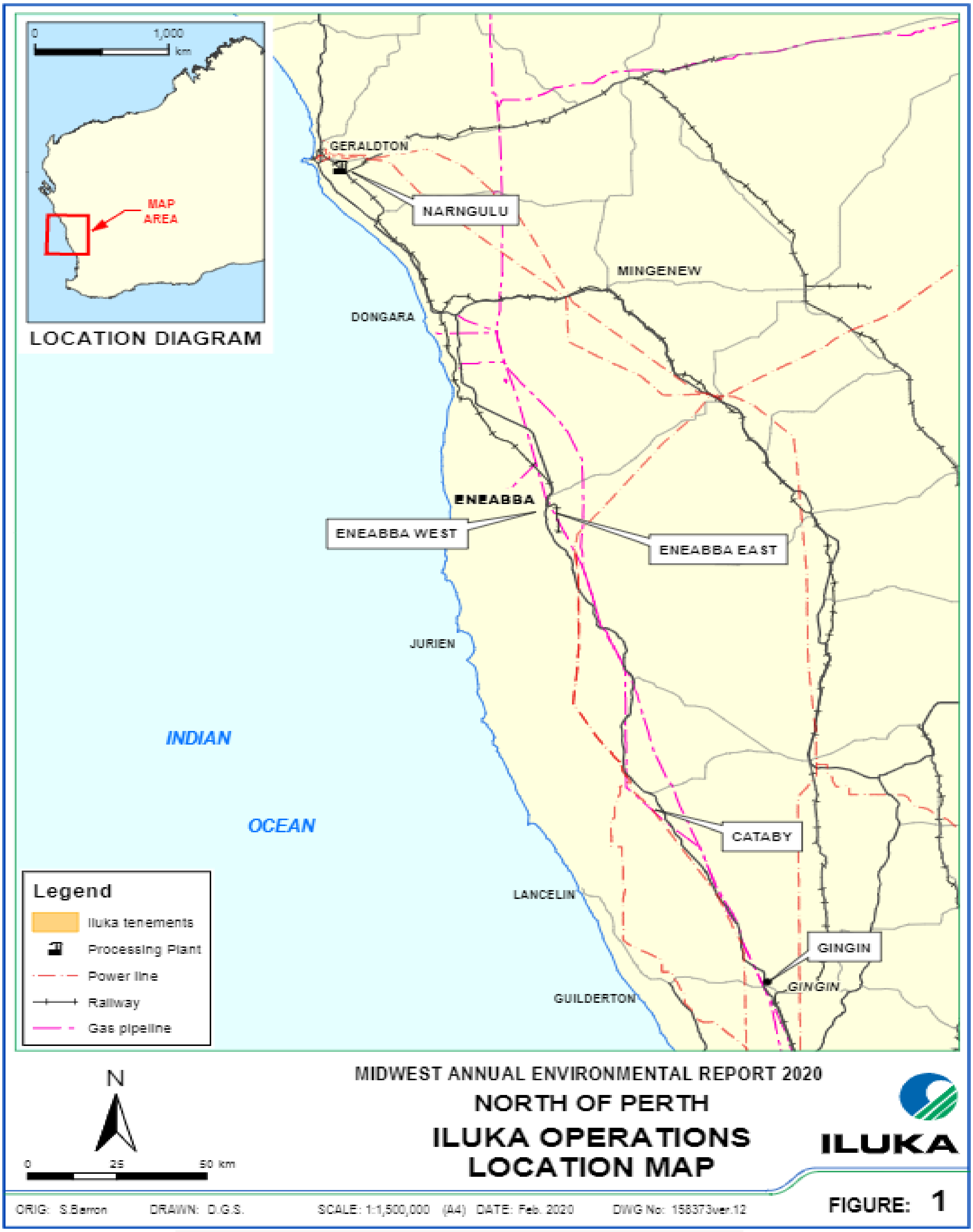

Figure 1: Eneabba Project site location

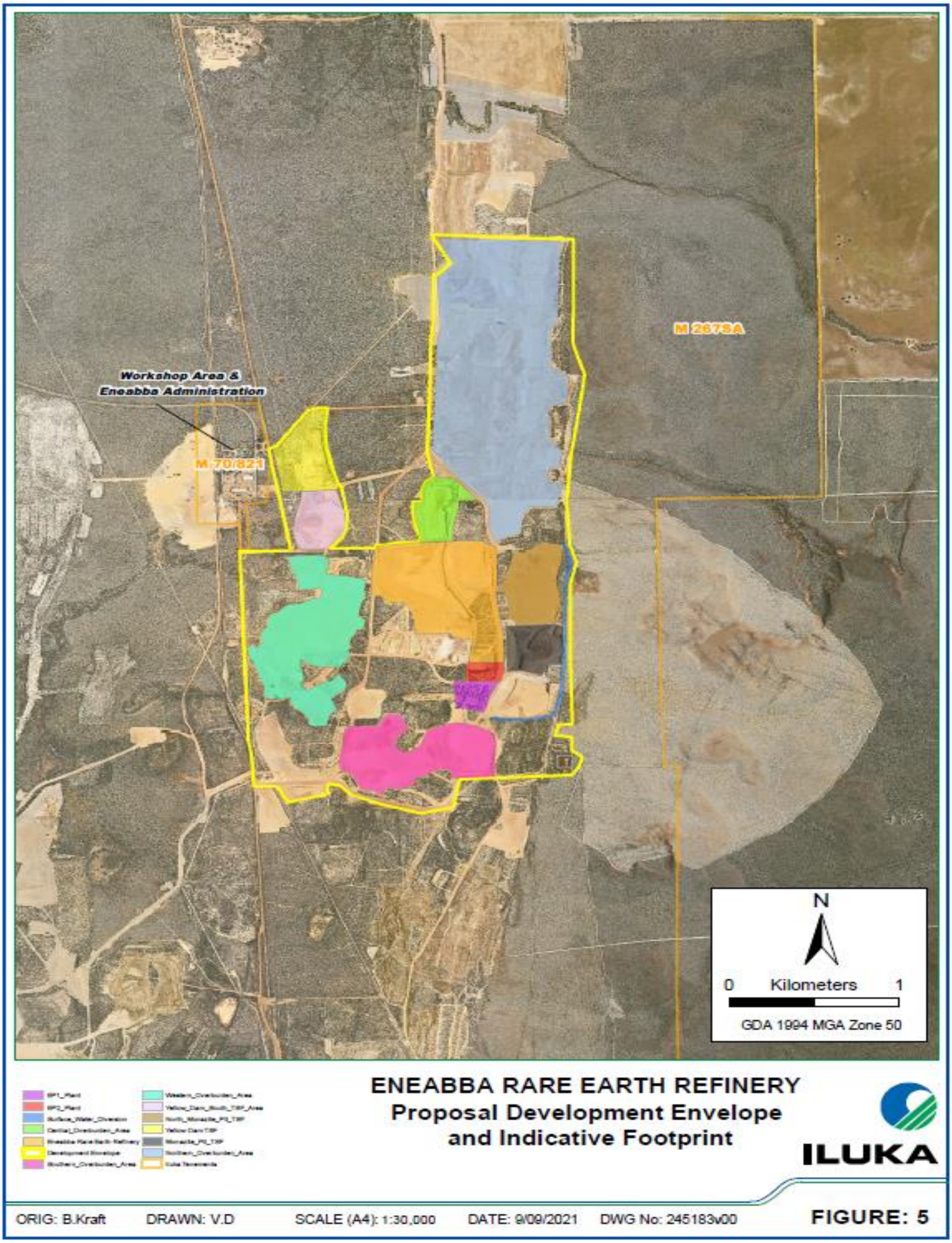

Figure 2: Eneabba Project location detail

2. BACKGROUND

Approach to Radiation Protection

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

- The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), which provides a consolidated overview of the effects of radiation by regularly reviewing research and publishing the summaries. UNSCEAR provides the scientific basis for radiation protection.
- The International Commission on Radiological Protection (ICRP) is recognised as the pre-eminent authority for the protection of people, animals, and the environment from the harmful effects of ionising radiation. Its recommendations form the basis of radiological protection policy, regulations, guidelines and practice worldwide.
- The International Atomic Energy Agency (IAEA) develops and publishes industry standards and guides and provides advice on basic safety precautions when dealing with radiation for both operators and regulators. The IAEA develops operating standards.

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

The basis of radiation protection regulation is outlined in ICRP Publication 103, in which the ICRP first recommended the *system of dose limitation*. This is recognised as the internationally accepted approach to radiation protection and is universally adopted as the basis of legislative systems for the control of radiation. It is made up of three key elements as follows:

- Justification – this means that a practice involving exposure to radiation should only be adopted if the benefits of the practice outweigh the risks associated with the radiation exposure.
- Optimisation – this means that the mechanisms for radiation protection have been optimised so that doses are *As Low As Reasonably Achievable*, taking into account economic and social factors. This is also known as the *ALARA* principle.
- Limitation – this means that individuals should not receive radiation doses greater than the prescribed dose limits.

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

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

Radiation Workers:

- Maximum effective dose of 20 mSv per year averaged over 5 years.
- Maximum effective dose of 50 mSv in any one year or part thereof.

Members of the public:

- Maximum effective dose of 1 mSv per year (averaged over 5 years).
- Maximum effective dose of 5 mSv per year in one year.

3. DESCRIPTION OF PROJECT

Monazite mineral is a by-product of mineral sands separation. Monazite rich streams produced at Mineral Separation Plants (MSP's) were previously sold as products but this practice ended in the early 1990's. The Eneabba Monazite Pit (EMP) has subsequently been used for the storage of by-product material ever since and contains approximately one million tonnes of material, inclusive of ca 827kt (kilo tonnes) of Heavy Minerals. This storage is required to allow the ongoing operation of the Iluka Narngulu MSP. Iluka's intention has been to store and then monetise the by-product at an appropriate time as determined by market conditions. Approvals are in place for long-term storage of the by-product at the EMP but exclude permanent disposal (NB: Iluka has not requested disposal of the by-product material at this site be approved).

3.1. CURRENT ENEABBA PHASE 1, EP1

The functional duty of the existing plant is to remove coarse gravel, rocks and grit (oversize), as well as slimes (clay and fine silt), then dewater the sands for export as Mineral Sand Concentrate (MSC). The operation is predominantly fed by material recovered from the EMP, or to reduce rehandling and consequently radiation exposure, some by-product material from Narngulu slated for storage within the EMP may also be placed directly onto the ROM pad for processing. The material produced in EP1 will be pumped to EP2 for further processing.

3.2. ENEABBA PHASE 2, EP2

EP2 will recover up to 95% of the monazite from EP1 through flotation, leaving the remaining heavy minerals and low value sand for further separation and upgrading through the gravity circuit.

Additional mineral resource feed stocks with low monazite content (e.g. the South Secondary Concentrator Middlings (SSC mids) containing heavy minerals with an assemblage of ilmenite, zircon, rutile and around 0.1% monazite), may be upgraded through the EP2 plant into HMC. HMC material produced from the spiral circuit in EP2 will be processed at an MSP at either Capel or Narngulu.

3.3. ENEABBA RARE EARTH REFINERY (ENEABBA PHASE 3, ERER)

The ERER is still in the development phase, once completed, the refinery will upgrade the rare earth mineral concentrate stream (EP2 monazite product) into individual rare earth oxides. ERER processing will comprise concentrate milling, sulphation, leaching, residue washing, impurity removal, separation through solvent extraction, drying / calcining then bagging (Figure 3). The final rare earth products will comprise dysprosium (Dy) oxide, terbium (Tb) oxide, samarium- europium-gadolinium (SEG) carbonate, Heavy Rare Earth Elements and Yttrium (HREY) carbonate, praseodymium (Pr) oxide, neodymium (Nd) oxide, neodymium-praseodymium (NdPr) oxide, lanthanum (La) oxide and cerium (Ce) carbonate. A by-product will be ammonium nitrate.

It is anticipated that the ERER plant will receive the rare earth mineral concentrate stream from EP2 along with material from third party feed sources, and in the future, rare earth mineral concentrate from Iluka's Wimmera project in Victoria. However, during the initial operational period, only EP2 monazite concentrate will be processed. Third party feed materials are of lower uranium and thorium activity concentrations than that of EP2 Monazite concentrate.

Future revisions of this RMP will incorporate feed blends as relevant to the operational period to which the RMP applies.

Following upgrading of monazite to 20% monazite in EP1, then to ~90% monazite in EP2, the process flowchart will be as shown in Figure 3 for the ERER.

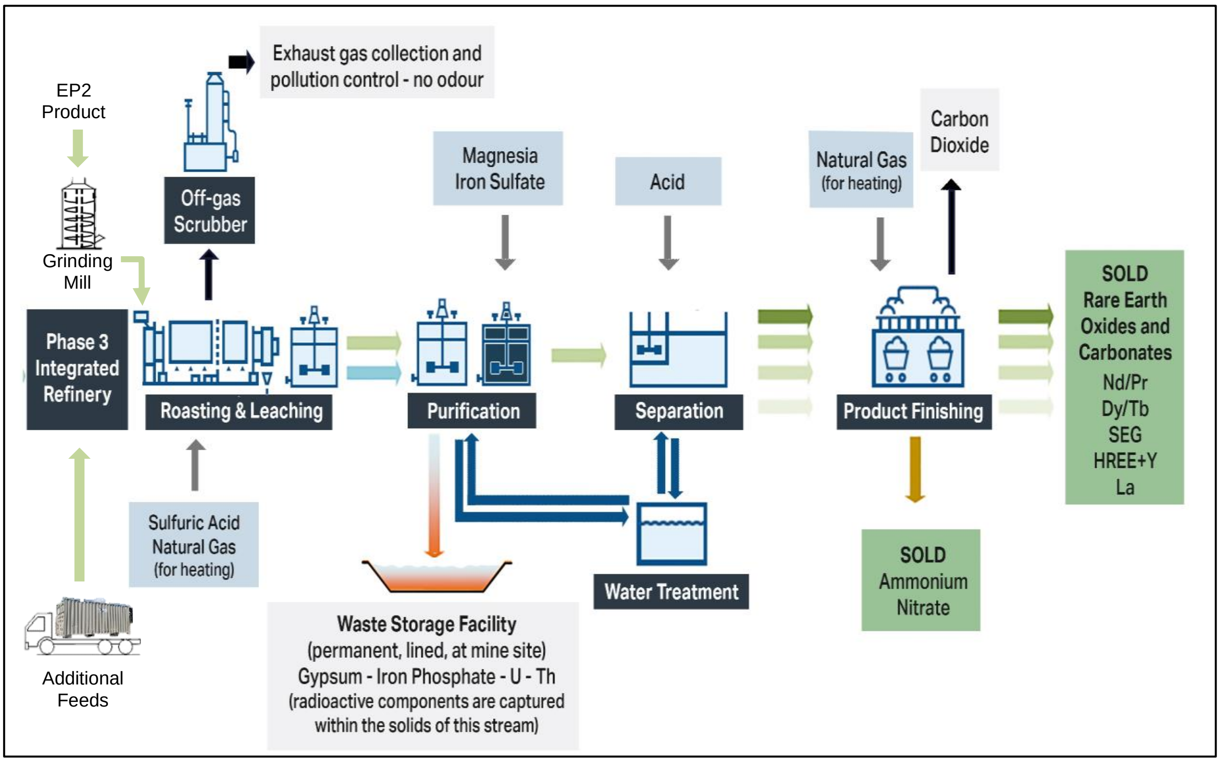

Figure 3: ERER Process Flow Summary Diagram

Processing of the monazite concentrate through ERER will involve:

- ***Feed:*** Concentrate from the EP2 plant will be directly fed (pumped) into the wet grinding mill containing sulphuric acid. Third party concentrate will be fed via rotating/tipping containers into a hopper, which is hooded and drafted to eliminate fugitive dust, and combined with EP2 concentrate and then gravity fed into the kiln;
- ***Sulphation baking (Roast):*** The combined sulphuric acid and concentrate will be heated (calcined) to 270°C in the kiln to form soluble rare earth sulphate.;
- ***Leach:*** The calcine is quench leached / leached with water to dissolve rare earth elements (and other) from the solids into a liquid phase. It is recognised that scale formation could potentially occur within the leaching circuit and would require management;
- ***Off Gas Management:*** Roasting Kiln Off Gas and Acid Recovery Treatment System - consisting of a Venturi Scrubber, Entrainment Separator, Quench Vessel, Spray Tower Scrubber, Wet Electrostatic Precipitator, Fibre Bed Mist Eliminator and acid recovery tanks, with discharge via stack. The off-gas scrubbing effluent from the sulphation roast is anticipated to contain radon and decay products. It is not anticipated that direct volatilisation of lead and polonium would occur during the roast as the roasting temperature is at 270 °C;
- ***Purification:*** Impurities are precipitated and removed from the solution by neutralisation with magnesia and ferric sulphate. The precipitate is the main solid waste stream, consisting of sulphates (mainly calcium) and phosphates (mainly iron). Most of the radionuclides will be rejected to solid residue (bulk waste) during the purification process;
- ***Ion exchange (IX):*** as final purification of the rare earth element solution prior to rare earth separation within the solvent extraction (SX) circuit. The IX circuit will reject the remaining uranium to solid residue. Actinium-227 is expected to still be contained within the rare earth solution as chemically it behaves similar to rare earths. Actinium would be rejected to the sulphate waste stream from the SX circuit;
- ***Solvent Extraction (SX):*** Individual Rare Earth Elements are separated, changed from sulphate to nitrate, by the addition of nitric acid and ammonia, using solvent extraction (SX) technology (kerosene as the solvent);
- ***Product finishing:*** Separated Rare Earth Element products are precipitated as carbonates (stripped from organic phase) from each stream, and in the case of the high value products, these are heated and converted into oxides through drying / calcination;

- ***Calcination Off Gas Management:*** Baghouse filter systems to remove entrained particulates in calciner circuit, including:
    - o Dedicated system installed for each process train.
    - o Multi-compartment bag house filter to capture fine particulates.
- ***Magnesia recovery*** for re-use in purification: The magnesia recovery circuit will receive: off-gas scrubbing effluent from the roasting kiln (could contain radon and decay products); softening clarifier underflow; sulphate waste (non-radioactive, bar some actinium) from rare earth SX; IX effluent; and brine (non-radioactive) from water purification;
- ***Product Bagging*** of rare earth products (oxides and carbonates): The samarium-europium-gadolinium (SEG) carbonate would be the only rare earth product containing natural radioactivity, mainly due to the presence of the Sm-147 isotope. Natural samarium contains three radioactive isotopes: Sm-147; Sm-148; and Sm-149, all of which are primarily alpha emitters and thereby only considered an internal hazard due to inhalation or ingestion risks. Bagging of this product would therefore require appropriate ventilation (dust control); potential automation of bagging process (if practicable); and appropriate PPE requirements. The SEG Carbonate is classified as being radioactive, but not Class 7 under the transport regulations.;
- ***Water Purification:*** Water recovery purification (softening; acidification; ultrafiltration; reverse osmosis (RO); and
- ***Waste Management:*** Bulk residue (waste) washing, neutralisation and disposal.

Test-work has been undertaken by ANSTO (Report C1731 - Waste Treatment for Eneabba Project 30th April 2021 ANSTO Minerals), including radionuclide deportment studies with key radionuclide related conclusions as follows:

- A proportion of the uranium, thorium, lead and polonium will dissolve in the leach;
- All or nearly all of the thorium, lead and polonium will re-precipitated in the FeP purification step;
- Uranium deportment was complex with approximately 23% reporting to purification solids and 18% to aluminium precipitation solids, with uranium reporting to uranium ion exchange;
- Radium extraction was very low and the small amount that dissolved then re-precipitated in the purification circuit; and
- Actinium is expected to follow the light rare earths and report to the solvent extraction plant.

The ANSTO test-work simulated the processing and refining, based on material from Eneabba Monazite pit as feed. In addition, to simulate external feed stocks, material from another Iluka deposit (Wimmera) was used.

3.3.1. Radiological Characteristics of ERER

There are key radiological considerations for ERER due to the monazite feedstock. The monazite feed contains approximately 80 to 90% monazite with natural thorium concentrations of approximately 6.2% Th (250Bq/g Th232 head of chain) and approximately 0.25% natural uranium (31Bq/g). These concentrations are significantly above the natural background radiation levels and exceed the criteria for being defined as radioactive.

The ANSTO deportment study work is summarised in Table 1. In addition to process materials, it is anticipated that scale might form during thermal processing in the sulphation bake / roast circuit (from radon / thoron decay) and within the acid leaching circuit, the formation and extent of which is yet to be characterised.

Scales are expected to be removed during maintenance (depending upon removability; specific activity; and total activity); captured, neutralised, and routed to the solid waste disposal facility. An operational procedure will be developed for scale removal.

If scales are however classified as low level waste (LLW) or intermediate level waste (ILW), removed scales or contaminated items will be separately stored for future disposal.

Table 1: Radionuclide Concentration in ERER Process Streams

ANSTO ID	Eneabba Ore (Feed)	Washed Leach Residue	Quench Leach Filtrate (PLS)	Phosphate Precip Filter Cake	Phosphate Precip Barren Liquor	Aluminium Precipitate (undil)	Al Precipitation Barren Liquor	Neutralised Waste		
								Solids	Liquor	Evaporite
Production Date	-									
Sample Weight (g) or Volume (mL)	29.33	17.21	450	12.13	420	16.21	450			
Detector	25	26	18	27	18	24	22			
Units	Bq/g	Bq/g	Bq/L	Bq/g	Bq/L	Bq/g	Bq/L			
Th-232 Decay Chain										
Th-232 (a)	230 ± 23	440 ± 44	8540 ± 850	44 ± 4	190 ± 20	110 ± 11	< 4	37	0.002	0.08
Ra-228 (b)	230 ± 23	1080 ± 110	220 ± 22	1.1 ± 0.1	2.3 ± 0.3	1.7 ± 0.2	< 0.20	33	0.055	2.7
Th-228 (b)	230 ± 23	440 ± 44	10000 ± 1000	54 ± 5	76 ± 8	96 ± 10	3.9 ± 0.4	37	0.002	0.083
U-238 Decay Chain										
U-238 (a)	31 ± 3	6.1 ± 0.6	1970 ± 200	2.9 ± 0.3	1120 ± 110	250 ± 25	440 ± 40	2.4	<0.002	<0.12
Th-230 (b)	31 ± 3 (f)	100 ± 10	2500 ± 250	19 ± 2	< 15	21 ± 2	< 12	4.9 **	<0.003	<0.15
Ra-226 (b)	30 ± 3	130 ± 13	16 ± 2	0.084 ± 0.008	< 0.18	0.07 ± 0.01	< 0.15	3.4	0.0047	0.23
Pb-210 (b)	29 ± 3	91 ± 3	240 ± 24	1.7 ± 0.5	< 2.4	< 1.5	< 2.1	4.5 **	<0.0003	<0.02
Po-210 (c)	32 ± 3	60 ± 5	430 ± 54	5.0 ± 0.7	4.3 ± 0.6	nr	2.6 ± 0.6	4.6	-	-
Po-210 Count Date	01-Feb-21	01-Feb-21	27-Jan-21	01-Feb-21	27-Jan-21		01-Feb-21			
U-235 Decay Chain										
U-235 (d)	1.4 ± 0.1	0.28 ± 0.03	110 ± 11 (b)	0.14 ± 0.01	34 ± 3 (b)	9.5 ± 0.9 (b)	19 ± 2 (b)	0.11	<0.0004	<0.018
Pa-231 (b)	2.8 ± 0.3	16 ± 2	< 0.16	< 0.36	< 1.7	< 0.38	< 1.0	<0.81	<0.001	<0.051
Ac-227 (b)	1.5 ± 0.2	na	na	na	na	na	45 ± 5	<0.29	<0.0002	<0.008
Th-227 (b)	1.5 ± 0.2	(g)	96 ± 10	0.13 ± 0.03	36 ± 4	2.1 ± 0.4	45 ± 5	<0.29	<0.0002	<0.008
K-40 (b)	< 0.29	2.5 ± 0.3	< 5.8	< 0.12	< 2.2	< 0.14	< 2.4	<0.3	<0.001	<0.04
Total Contained Activity (e)	2741	6845	91258	472	5531	1845	2010	407	0.2	7.4

3.3.2. Radiological Characteristics of Waste

The solid waste steams have been classified in accordance with ARPANSA RPS G-4: Guide for Classification of Radioactive Waste; and ARPANSA RPS 6: National Directory for Radiation Protection, as based on IAEA General Safety Guide GSG-1: Classification of Radioactive Waste; and General Safety Requirements GSR Part 3: Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards. Table 2 provides a summary of the waste characteristics and Table 3 provides a summary of the waste classifications.

Table 2- Eneabba EP3 Solid Waste Stream Estimated Radionuclide Concentrations

	Bulk Waste Solid	**Alpha Scale NSR**	**Radium Scale**
Unit	Bq/g	Bq/g	Bq/g
U-238	2.4	0.37	0.12
Th-230	4.9	1.2	9.2
Ra-226	3.4	2.3	150
Pb-210	4.5	180	51
Po-210	4.6	205	
U-235	0.11	0.017	0.53
Pa-231	0.81	0.13	1.4
Ac-227	0.29		
Th-227	0.29	0.085	2.7
Th-232	37	0.4	25
Ra-228	33	5.4	380

Th-228	37	5.5	480
K-40	0.3	0.055	0.68
Total	407	630	5220

Table 3 - Eneabba ERER Waste Classification

ERER Bulk Waste Solid	Alpha Scale NSR	Gamma Scale NSR
VLLW (Category C)	LLW (based on Pb-210 & Po-210 concentrations)	ILW (based on Th-228 concentration)

3.3.3. Scales Characterisation

In 2017, ANSTO conducted preliminary radionuclide characterisation of potential scales from Narngulu Synthetic Rutile plant high temperature section and acid leach section (REF: Characterisation of Scales, ANSTO May 2017).
Three samples were analysed and indicated that thermal related scales consisted primarily of Po-210 and Pb-210 of the order of 200Bq/g. Acid leach scales predominantly consisting of radium (Ra -226 and Ra-228) with concentrations of approximately 100 to 150 and 380 to 530 Bq/g respectively.

It is anticipated that scale might form in ERER during thermal processing in the sulphation bake / roast circuit (from radon / thoron decay) and within the acid leaching circuit, the formation and extent of which is yet to be characterised.

3.3.4. Airborne Emissions

An assessment of potential radionuclide emissions from the Wimmera Project was undertaken by ANSTO in 2019, under a crude upper estimate made that roasting would increase the radon (Rn-222) emanation coefficient by a factor of 4. The ANSTO report ignores radon-220 due to its short half-life.

Radon emanation and decay within the off-gas system is scoped to be evaluated in the upcoming ANSTO test program for ERER.

3.3.5. Transport of Radioactive Material

The only product from ERER expected to be classified radioactive is the samarium-europium-gadolinium (SEG) carbonate. This product is however not classified as radioactive under the ARPANSA Code of Practice for the Safe Transport of Radioactive Materials (2019), based on Bq/g activity concentration limit. The SEG carbonate contains natural radioactivity, mainly due to the presence of the Sm-147 isotope. Natural samarium contains three radioactive isotopes: Sm-147; Sm-148; and Sm-149, all of which are primarily alpha emitters and thereby only considered an internal hazard due to inhalation or ingestion risks. Bagging of this product would therefore require appropriate ventilation (dust control); potential automation of bagging process (if practicable); and appropriate PPE requirements. Transport requirements (if any) are still under investigation, but the most conservative outcome would be to classify as Excepted Consignment: no external labelling required, with safety mark “RADIOACTIVE” visible upon opening the package. The radiation level at any point on the external surface of the package must not exceed 5 µ Sv/h. As this product is an alpha emitter, it is not expected to have any gamma dose on the outside of the package. Primary packaging labelled similar to UN2912; LSA-1 (based on A2); Radioactive 1 is therefore considered the most conservative outcome.

3.3.6. Expected duration of operations

The ERER has a potential mine life for the EMP of approximately ten (10) years, however additional feed material for the ERER will be imported to the site for processing. The life of the ERER is expected to be around 20 years but could extend further depending on the availability of feed and other market conditions.

The RMP will be reviewed and updated every two (2) years, and during these updates, additional detail will be provided in relation to different feed sources and any other changes expected during the following 2 year period.

ERER construction is anticipated to commence in mid to late 2022. It is expected that commissioning of the ERER would occur in 2023 or 2024.

3.4. ENVIRONMENTAL IMPACT ASSESSMENT

3.4.1. Onsite Environmental Impacts

The Eneabba site operates under prescribed premises licence L5646/1994/10 issued under Part V of the *Environmental Protection Act 1986*. The activities proposed as a result of this project are not considered significantly different from those approved under existing Licence L5646/1994/10. A Works Approval will be submitted for assessment and approval to enable the construction of the infrastructure required to allow for processing of Monazite through ERER at Eneabba.

Key environmental factors identified include radon emissions, dust emissions, groundwater management, surface water management, surface/soil contamination and waste disposal. Failure to control dust and surface water run-off has the potential to result in elevated gamma radiation levels in areas surrounding the waste disposal facilities, and process infrastructure. Management controls and monitoring are proposed to ensure these impacts are minimised, a summary of the environmental commitments is provided in section 7 (Dust Control), (Contamination Control) and (Environmental Monitoring) (including Table 13).

Environmental impacts are usually determined by considering impacts to plants and animals (also referred to as non-human biota (NHB)).

The assessment method (endorsed by ARPANSA) is by using the ERICA assessment software (http://www.erica-tool.com/) which uses changes in the radionuclide concentration of media (such as soil and water) as a result of emissions from the operation, to determine a dose rate and radiological risk quotient. The method for determining the change in media concentration is via modelled dust deposition results, or direct exposure of NHB to e.g. waste materials contained within TSFs.

Assessments of impacts to NHB from bulk ERER waste material have been conducted and reported in section 12.4 of this RMP.

Solid waste will be combined, collected and disposed of as a slurry into purpose-built waste disposal facilities. The waste cells will be flooded during active operation to prevent fine gypsum dust from distributing into the surrounding environment. Active waste cells will be fenced off to prevent unauthorised human access as well as prevent access of terrestrial fauna to the extent possible, both to mitigate radiological exposure, as well as to reduce the risk of drowning. Diversion drains and bunds are included within the refinery and waste facility designed to capture contaminated water runoff and separate from un-contaminated surface water.

Engineering and Cost Study Development Phase – ERER Solid Waste Disposal Pond Design, Wood, September 2021: Waste cells will be prepared with a low permeability clay liner for use as a HDPE liner foundation; providing puncture resistance; and a low permeability barrier should the liner system rupture or leak. The primary HDPE liner will be overlain by primary geofabric; geogrid / flownet leakage detection; secondary geofabric; and secondary HDPE. A collection sump will be located at the basin of the pit, directly next to the downstream toe. The sump will be filled with clean sand and wrapped in geofabric. A HDPE riser pipe will be installed in the collection sump, to allow a water monitoring sensor to be lowered to the bottom of the collection sump to determine if there is any leakage water. The operator will take regular readings throughout the operational life and beyond. If water is found in the leakage detection system, it will be removed as soon as possible to avoid the risk of leakage through the second HDPE liner.

Historic mining voids within the disturbance footprint will be used for these waste facilities, including Yellow Dam; former Yellow Dam South; former North Monazite Pit; and the Monazite Pit. The solid waste produced from the ERER will contain gypsum, iron phosphate, aluminium and low levels of Naturally Occurring Radioactive Material (NORM), specifically Uranium (~200 to 350 ppm) and Thorium (~6,000 to 9,200 ppm). The refinery will produce up to 180 kilotonnes per annum (ktpa) of solid residue. Daily samples of this tails stream will be collected to make a weekly composite for analysis.

Upon closure of the waste cell, surface water infiltration will be reduced to avoid movement of water through tailings. The capping landform design will have shallow slope lengths and where possible long planar slopes will be avoided. The overall closure capping thickness above the tailings will be around 4m at the outer edges of the facility and mounded to a thickness of around 9 m in the northern end of the deposit to tie into the existing topography and maintain water flow away from the deposit.

Management of potential exposure to the NORM within the tailings is a closure design objective. An intrusion prevention layer will be considered to prevent human, fauna, and flora intrusion into the tailings materials. If selected, this layer will be constructed to form a physical barrier and may include rubble, large rocks, bitumen, cement, concrete or other equivalent materials.

3.4.2. Offsite Environmental Impacts

There are not likely to be any offsite impacts in relation to the operation of the ERER. The refinery and waste facilities are all located within the Eneabba disturbance footprint and rare earth products being transported off-site to Fremantle Port are not considered to be radioactive, with the exception of SEG Carbonate. It is recognised that natural samarium is an alpha emitter (as part of the samarium - europium-gadolinium (SEG) carbonate product). Bagging of this product would therefore require appropriate ventilation (dust control); potential automation of bagging process (if practicable); and subject to appropriate PPE requirements.

Emissions from point sources (stacks) will be minimised through the use of a sophisticated waste gas scrubbing system. Sensitive receptors are greater than 5 km from emission sources and modelling has shown air quality guidelines will be met at these locations.

The waste cells will be flooded during active operation, and drained of water upon reaching capacity to allow for consolidation and rehabilitation. High level gypsum facilities at other sites indicated crust formations by wetting / drying cycles, thereby naturally reducing dust liberation (as relevant to the rehabilitation phase when these facilities will be dried for consolidation). Crust formation does however reduce water infiltration as well once formed. Active dust suppression measures will be incorporated as required during the rehabilitation phase.

Diversion of surface water around operational areas is a planned measure to prevent localised flooding and minimise potential for contamination. Wetlands are not present within the Development Envelope.

The waste facility will be double HDPE bottom lined on top of a clay layer and incorporate leak detection. The final landform will be water shedding and the cover design incorporates multiple geotextile layers; a LLDPE geomembrane (liner); as well as a drainage and potentially an intrusion prevention layer. Residual Radiation (RESRAD) modelling has indicated that a leak in the liner would not result in any potential plume of groundwater contamination to influence Eneabba town (at 5.5 km away), even if the liner is constantly leaking. Section 12.4 of this RMP details RESRAD scenario modelling outcomes.

3.5. REQUIREMENT FOR RADIATION MANAGEMENT PLAN

This RMP follows the structure outlined in the NORM Guidelines and its contents is consistent with the existing Iluka Western Australian RMPs.

3.5.1. Sources of Radiation

The main source of radiation is the presence of the mineral monazite which contains naturally occurring radioactive elements thorium (Th-232) and uranium (U-238 and U-235). The monazite content within the EMP varies from between 20% and 40%. Monazite (Ce,La,Pr,Nd,Th,Y)PO_4 is a heavy mineral commonly associated with traditional mineral assemblage sources from the Eneabba Mineral Sands Province located in the Mid-West of Western Australia. Monazite naturally occurs mainly as four different mineral varieties depending on the relative elemental composition. The monazite sources from Eneabba are generally dominated by Cerium (Ce) and contains lower (in decreasing order) proportions of Lanthanum (La), Praseodymium (Pr), Neodynium (Nd), Thorium (Th) and minor amounts of Yttrium (Y).

Monazite will be concentrated to ~90% through EP1 and EP2, prior to further processing, with natural thorium concentrations of approximately 6.2% Th (250 Bq/g Th-232 head of chain) and approximately 0.25% natural uranium (31 Bq/g). These concentrations are significantly above the natural background radiation levels and exceed the criteria for being defined as radioactive.

The monazite concentrate from EP2 (along with other rare earth feed sources) will be processed through the ERER, and this will result in varying deportment of radionuclides to the off-gas system, leach liquors, potential scales, precipitates, and bulk leach residue (solid waste) per sections 3.3.1; 3.3.2; and 3.3.4 of this RMP. The solid waste produced from the ERER will contain gypsum, iron phosphate, and aluminium and overall dilution in the levels of NORM: Uranium (~200 to 350 ppm) and Thorium (~6,000 to 9,200 ppm).

Processing of rare earths can also change potential exposure levels from individual radionuclides from the natural radioactivity decay chains such as radium, rubidium, samarium, actinium, polonium and radon. These individual radioactive components (and others not listed) will be assessed prior to, and during commissioning and the early operation of the ERER.

Another source of radiation at the site is the density gauges used as density measurement instruments during processing. These density gauges consist of a strong radioactive source, in an enclosed container located on one side of a pipe, with a radiation detector on the other side. The density of the material inside the pipe is estimated by the degree of penetration of the radiation beam through the material. Radiation density gauges is anticipated to be used in various parts of the ERER processing plant, however, their location and size are yet to be finalised. The controls for density gauges for ERER would be identical to the controls used in earlier stages.

The details of the sources currently in use on site are provided in the Eneabba site radiation gauge register. As new gauges arrive on site, they will be added to the register, RCWA will be informed as required in relation to any new gauges prior to their arrival on site.

XRF devices, such as a hand-held XRF for in-pit grade control, benchtop XRF for quality control, and laboratory XRF for product analysis will also be used at the site as par to the ERER.

3.5.2. Legislative Framework

A RMP is required for the Eneabba site due to the presence of thorium and uranium within the HMC, by-product, monazite concentrates (EP1 and EP2); monazite intermediates; ERER processing streams and waste. Due to the elevated level of radiation associated with these materials, it is expected that workers (both employees and contractors) on the Eneabba site may be exposed to levels of radiation above 1 mSv/y arising from Iluka's operations. Accordingly, Part 16 of the *Mines Safety and Inspection Regulations 1995*: *Division 2 – Mining and processing of radioactive material* applies to all aspects of this project.

The aim of this RMP is to:

- Provide additional detail in relation to the processes and potential radiation doses related specifically to the ERER Project;

- Satisfy regulatory bodies (DMIRS and RCWA) that radiation exposure associated with these operations will be manageable and acceptable;
- Satisfy the requirements of the *Mines Safety and Inspection Act (1994)* and Regulations (1995);
- Satisfy the requirements of the *Radiation Safety Act (1975)* and associated Regulations;
- Meet the objectives of the *Code of Practice and Safety Guide for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing RPS 9* (ARPANSA 2005);
- Meet the requirements for production, handling and storage of radioactive waste material at the site in accordance with RPS-6: ARPANSA *National Directory for Radiation Protection, 2014. Radiation Protection Series No. 6*.

The overall objective of the RMP is to provide details on radiation risks posed by the ERER Project and how these risks will be controlled. The RMP will be used by site personnel as a guide to protect workers, contractors, members of the public and the environment from the potential harmful effects of radiation arising from this Project.

4. WORKFORCE

ERER will require an increase in workforce noting that the exiting workforce had been significantly reduced in recent years as works at Eneabba were predominantly confined to rehabilitation activities. The overall Eneabba workforce is estimated to be 300 people with about 250 people required specifically for the operation (four shifts) of the Proposal and up to 500 people for construction.

The intent is to manage the workforce in a manner similar to EP2, which is through classification of workers / work areas into similar exposure groups (SEG's). It is anticipated that an overlap of operational phases (EP1, EP2 and ERER) as well as work areas would be assigned to individual workers as outlined in Table 4. The anticipated workforce is outlined as follows.

Construction:
Approximately 500 construction workers. Note that no radiation exposure (above current site background) to construction workers is expected, however, monitoring will be conducted to verify this.

Operations:
The operation is expected to run four shifts, with approximately 60 workers per shift. There will also be a permanent day shift (for administration, technical services and other services) of approximately 50.

For this RMP, it is assumed that there will be four SEGs as follows.

- Feed stock handling and roasting
- Wet processing
- Waste management
- Services and administration

Further detailed assessment of radiation exposure levels is provided in Section 1212.

Table 4: Operations Workforce Stratification Eneabba Operational Based Roles

Work Categories (“Similar Exposure Groups” (SEG’s))	Work Areas and Tasks		Shift Pattern and Description	
	Principal Work Areas	Regular Tasks	Fortnightly Shift Pattern	Description
Shift Plant Operators (per shift	EP1, EP2, ERER (feed, roast, wet process), Tailings areas, Control room & associated operational works at the site.	Operations, monitoring & checking of process equipment, grade control. Could include EP1, EP2 and ERER locations over a year.	7 days on, 7 off. 5 weeks leave per year.	Working 12-hour shifts, with a 15-minute break & ½ hour meal break. Total hours per year = 2100
Senior Shift Plant Operators/Leading hand	Control room, EP1, EP2 and ERER (feed, roast, wet process), Tailings areas, & associated operational works at the site.	Management of process, ensuring sections of the plant are operating correctly. May include helping in the field at EP1, EP2 and ERER locations over a year.	7 days on, 7 off. 5 weeks leave per year.	Working 12-hour shifts, with a 15-minute break & ½ hour meal break. Total hours per year = 2100
Production Superintendent	Office and Control rooms.	Overall management and accountability for Eneabba EP1, EP2 and ERER Operations	7 days on, 7 off. 5 weeks leave per year.	Working 12-hour shifts, with a 15-minute break & ½ hour meal break. Total hours per year = 2100
Electrical and Mechanical workers (plant based,2 electrician & 2 mechanical)	EP1, EP2, ERER, Tailings areas, Control room & associated operational works at the site. Significant time will be spent in workshops away from operational areas.	Repair plant & equipment, preventative & planned maintenance, plant & equipment inspections.	7 days on, 7 off.7 nights on, 7 off.	Working 12-hour shifts, a 15-minute break & ½ hour lunch break. Total hours per year = 2100
Process Support workers Process technicians, Process Engineers, Chemists,	EP1, EP2, ERER (feed, roast, wet process), Tailings areas, Control room & associated operational works at the site. Significant time will be spent in laboratory and offices away from operational areas.	Trouble shooting for process, testing and sample collection for assessment.	7 days on, 7 off. 5 weeks leave per year.	Working 12-hour shifts, a 15-minute break & ½ hour lunch break. Total hours per year = 2100
Warehouse - coordinator, stores supervisors and storemen.	Warehouse at Eneabba Admin or at ERER store.	providing spare equipment, consumables and general stores.	5 days on, 2 days off, 4 days on, 3 days off. All day shift.	Working 9-hour shifts, a 15-minute break & ½ hour lunch break Total hours per year = 2000
Laboratory workers	Laboratory and non-operational areas.	Analysis of samples in the lab.	7 days on, 7 off. 5 weeks leave per year.	Working 12-hour shifts, a 15-minute break & ½ hour lunch break. Total hours per year = 2100

Work Categories ("Similar Exposure Groups" (SEG's))	Work Areas and Tasks		Shift Pattern and Description	
	Principal Work Areas	Regular Tasks	Fortnightly Shift Pattern	Description
Health Safety/Environmental, Radiation Specialist.	EP1, EP2, ERER (feed, roast, wet process), Tailings areas, Control room & associated operational works at the site. Significant time will be spent in laboratory and offices away from operational areas.	Monitoring and collection of samples (Environmental and occupational) then data assessment or management.	5 days on, 2 days off, 4 days on, 3 days off. All day shift.	Working 9-hour shifts, a 15-minute break & ½ hour lunch break. Total hours per year = 2000
Total Workforce	**Total workforce of around 250 direct plant staff (four shifts of around 60 workers per shift)**			

The ERER is a significant operation and will need to have a significant administrative supporting structure at the site. It is expected that these workers would not spend any more than a few hours per week at the operational areas of the site.

Table 5: Operations Support Workforce (Support Services Not Operational based)

Work Categories SEG's	Work Areas and Tasks		Shift Pattern and Description	
	Principal Work Areas	Regular Tasks	Fortnightly Shift Pattern	Description
Commercial services workers - HR, Clerical, accounting, shipping & transport coordinator	Mostly in office & administrative areas.	Officed based work, occasional plant visit.	5 days on, 2 days off, 4 days on, 3 days off. All day shift.	Working 9-hour shifts, a 15-minute break & ½ hour lunch break. Total hours per year = 2000
Engineering support - engineers, maintenance planning	Mostly in office & administrative areas.	90% office based, some supervision/inspections done in the ERER.	5 days on, 2 days off, 4 days on, 3 days off. All day shift.	Working 9-hour shifts, a 15-minute break & ½ hour lunch break. Total hours per year = 2000
Management - Operations, production, engineering, technical, laboratory and commercial managers.	Mostly in office & administrative areas.	90% office based, some supervision/inspections done in the ERER.	5 days on, 2 days off, 4 days on, 3 days off. All day shift.	Working 9-hour shifts, a 15-minute break & ½ hour lunch break. Total hours per year = 2000
Total Workforce	**Total workforce of around 50 non- operational staff**			

5. CRITICAL GROUPS

A Critical Group is defined in DMIRS (2010a) as:

> *"a group of members of the public comprising individuals who are relatively homogeneous with regard to age, diet and those behavioural characteristics that affect the doses received and who receive the highest radiation doses from a particular practice."*

For the purposes of this RMP, the Critical Group is considered to be the residents of the Eneabba town. It is expected the critical group will not be exposed to radiation levels above 1mSv/y (above the natural background level), due to the ERER project.

The location of the critical group (Eneabba town) is shown on Figure 1, the town is located around 8km to the north west of the ERER processing plant and around 5.5km from the initial tailings facility (Yellow Dam). The number of people in this group is ~ 150 (2016 census data). Details relating to calculation of potential doses have been provided in Section 12 of this RMP. Table 6 provides a summary of the Critical Groups total radiation exposure due to this Project.

Table 6 Eneabba Critical group radiation exposure estimate 2021

Components of the total dose	**Current Eneabba Critical Group (2021)**	**Dose related to the Eneabba Critical group**
Dose from Gamma radiation	0.16 mSv/year	Based on the current average background gamma readings from samples collected around the town.
Dose from airborne dust (Including background)	0.005 mSv/year	Based on Hi-vol dust samples collected in the Eneabba town background.
Dose from drinking water (including background)	0 mSv/year	Based on gross alpha beta samples collected from drinking water in the town.
Total dose for the critical group (Internal + external)	**0.17 mSv/year**	**No expected additional dose for the Eneabba critical group due to this project.**

Eneabba residents are expected to be exposed to natural background gamma radiation levels of around 0.13µSv/hr. If this hourly dose rate is applied over a year the annual dose received by the Eneabba residents over a year (8,760 hours in a year) would be around 1.14mSv/y.

6. SOURCES AND PATHWAYS OF RADIATION EXPOSURE

6.1. TYPES OF RADIATION

The three main types of radiation associated with mining and processing of mineral sands are alpha (α), beta (β) and gamma (γ) radiation.

α radiation is considered to be a hazard if the source is taken into the body. In mining and processing, this material can enter the body as dust (*inhalation*). Depending upon the dust particle size and solubility of the radionuclides, the dose received from the inhalation can vary. The dose from dust inhalation is generally due to the longer lived radionuclides in the dusts which can continue to emit radiation until cleared from the body. For predictive modelling, conservative default values are used when making dose assessments. During operations, dust inhalation can be measured, through monitoring. The radionuclide characteristics of the dust can also be measured, or a knowledge of the process that generated the dust can be used to determine the characteristics. The ICRP has recently published new dose factors for inhalation of radionuclides.

Dust inhalation is usually controlled through:

- Limiting the source of dust generation (e.g. wet processing; spillage management prior to drying out and forming dust; dust suppression on stockpiles etc.);
- Good ventilation (dust extraction; open operations etc); and
- PPE (dust masks; respirators)

Small amounts of alpha radiation may also be taken in through the mouth (*ingestion*); however most of this material will be excreted from the body within a few days. Ingestion of radionuclides can occur when radioactive contamination is, for example, transferred from dirty hands to food. The ingestion pathway is generally a low exposure pathway and not usually considered in worker dose assessment, unless an incident occurs where there is exposure. For the public, the ingestion pathway is considered and occurs when radioactive emissions from the Project deposit in the environment and are taken up into the food chain. The ingestion dose pathways can be predicted from air quality modelling before an operation commences and can be monitored during operations through deposition monitoring.

Worker ingestion dose is usually controlled through Good hygiene practices (washing hands prior to eating, drinking or smoking)

Other sources of α radiation within the body are the decay products of *radon* and *thoron*, which are radioactive gases in the decay chains of uranium and thorium. Each of these radon isotopes decays to produce short lived decay products which can be inhaled and deliver an immediate dose in the lungs. The doses that arise from the inhalation of the isotopes of radon are treated differently from the doses received through inhalation of radionuclides in dusts. This is because the radon isotope decay products are short lived, while the radionuclides in dust are long lived.

β-radiation mainly affects eyes, skin and the tissue that lies immediately underneath the skin. Beta radiation can be shielded with e.g. aluminium.

γ-radiation sources can cause radiation damage without residing within the body i.e. gamma radiation is an external hazard. A person located near any radioactive material, which emits γ-radiation, will be a subject to a certain radiation dose. For example, someone working near a radiation density gauge or within approximately 2m of a HMC stockpile is likely to experience an elevated gamma radiation dose. Gamma radiation levels can be predicted, based on empirical relationships between the different radionuclide concentrations and gamma radiation levels. Gamma radiation levels and exposures are also readily measurable. The IAEA recommend 16µSv/h per % natural thorium and 65µSv/h per % natural uranium at 1m from a medium size source. These figures can be used to estimate dose rates from the Project materials.

Gamma radiation is usually controlled through:

- limiting time of exposure,
- separating the source of material from people, and
- shielding where necessary.

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6.2. EXPOSURE PATHWAYS – CRITICAL GROUPS

Possible radiation exposure pathways for the Critical Groups are outlined in Table 7. These exposure pathways include potential exposure from ERER processes. Members of the public are not expected to receive radiation dose levels above the established background limit of 1mSv/y as a consequence of the ERER during processing at Eneabba or during transportation of the rare earth products.

Table 7: Possible Exposure Pathways for Critical Group (Eneabba town)

EXPOSURE PATHWAYS	RELEVANT	COMMENT
External radiation exposure (γ-radiation)	Yes	Considered applicable only to potential for contamination from light / ancillary vehicles entering the town from site. Gamma surveys will be carried out every year to assess changes to gamma levels around the Eneabba town site. Considered negligible from direct exposure to material processing on site due to process materials being contained (fenced and access controlled) at a distance in excess of 5 km from town (note that gamma dose rate decreases as the inverse of distance and at a reasonable distance this decreases to the inverse square of distance as the source approaches a point source).
Inhalation of resuspended dust (α-radiation)	Yes	Emissions form the project may impact on nearby residents. Due to the use of grinding and roasting to treat ERER feed, fine dust could be mobilised in very small amounts. It has to be noted that EP2 product will be pumped directly into the grinding mill and grinding would be conducted as a wet process. The inclusion of waste gas treatment systems for roasting; distance from the processing plants; planned waste management practices (below water during operational phase); and other controls to ensure dust is contained and controlled on site will mitigate the impact. Alpha counting of High-Volume dust filters collected close to the town will be conducted regularly to assess if any changes have occurred.
Ingestion of drinking water (α- and β-radiation)	Yes	Groundwater contamination is considered a low risk due to very low leachability of NORM. The disruption of secular equilibrium during ERER operation could lead to increased mobility of radionuclides. The ERER waste will be stored in a double lined facility with leak detection, underlain by an impermeable clay layer; the direction of groundwater flow away from the Critical Groups groundwater catchment area and the distance from the mine site would lead to dissipation of any radionuclides, even if a leak in the liner would occur.
Incidental ingestion of dust and soil (α- and β-radiation)	No	Not considered applicable to the Critical Group. Low levels of naturally occurring uranium and thorium are present in the soil, but the mining process does not constitute an increased dose contribution.
Surface contamination (β-radiation)	No	Not considered applicable to the Critical Group. Gamma surveys of Critical Group will indicate if this pathway should be further assessed.
Inhalation of radon and decay products (α-radiation)	No	The inclusion of waste gas treatment systems for roasting; distance from the processing plants; the open cut nature of Eneabba mining operations (including ERER) would disperse any gases, so work at the site would not lead to a dose above background in the Eneabba town.
Ingestion of home grown/local produce (meat, milk & fish)	No	Not considered applicable to the current Critical Group as food produced around the area would not be exposed to the uptake of radiation which could lead to any additional dose above background.

6.3. EXPOSURE PATHWAYS – PROJECT WORKFORCE

Possible radiation exposure pathways and their relevance to Eneabba workers are identified in Table 8. Relevant pathways of radiation exposure are considered in the dose assessment for the Eneabba workforce.

Table 8: Possible Exposure Pathways for Eneabba Workforce

EXPOSURE PATHWAYS	RELEVANT	COMMENT
External radiation exposure (γ-radiation or X-ray radiation)	Yes	Workers will be exposed to increased gamma radiation levels due to processing of EP2 product; as well as waste management in ERER.
Inhalation of resuspended dust (α-radiation)	Yes	Possibility of wind spread of dried out spillages in ERER processing or from dust generation during the rehabilitation phase of the ERER waste facility after the water is drained.
Ingestion of drinking water (α- and β-radiation)	No	Drinking water is not to be sourced from local groundwater sources at the site.
Incidental ingestion of dust and soil (α- and β-radiation)	Yes	Ingestion of soil; EP2 monazite product; ERER processing streams or wastes, is not considered to be high risk for employees as direct contact with materials will be minimised as far as practicable: pumping of feed and water in pipeline; enclosed processing (grinding; roast; leach; purification etc) Further ongoing assessment will be made to ensure controls are in place and followed by workers
Surface contamination (α- and β-radiation)	Yes	Due to the need to monitor and maintain equipment involved with processing of radioactive minerals surface contamination is considered as a low exposure risk for workers. The potential formation of alpha scales (radon decay products) in thermal processing; and gamma scales in leaching processes will be evaluated during operations and managed accordingly. Controls have been implemented and regular monitoring will be ongoing.
Inhalation of radon and decay products (α-radiation)	Yes	With monazite present in-process, decay products will be present in work areas, regular monitoring will be carried out to assess exposure.
Ingestion of home grown/local produce (meat, milk & fish)	No	Not considered relevant in this situation to this Project workforce.

7. CONTROL OF RADIATION EXPOSURE

Iluka's management of radiation sources and exposure risks follows the accepted hierarchy of control measures:

- Eliminate the hazard.
- Substitute a work process for one in which exposure levels are decreased.
- Engineering control to prevent or reduce contact between the hazard and people (e.g. shielding, ventilation, isolation).
- Apply administrative controls such as signage, time restrictions, work procedures and training.
- Personal Protective Equipment (PPE).

In eliminating and reducing radiation hazards, Iluka believes that due regard should be given to best practicable technology. This takes into account:

- Prevailing circumstances and conditions;
- Current state of technological knowledge;
- Regulatory exposure limits;
- Safety and safe working conditions and whether these are being compromised by introducing the control; and
- Social and economic factors, and consequences.

The goal of Iluka's hierarchy of control measures is to reduce the risks of radiation exposure to workers, the general public and the environment to ALARA.

Iluka has completed a detailed radiation design assessment and a summary is shown in Table 9.

- ***Ion exchange (IX):*** as final purification of the rare earth element solution prior to rare earth separation within the solvent extraction (SX) circuit. The IX circuit will reject the remaining uranium to solid residue. Actinium-227 is expected to still be contained within the rare earth solution as chemically it behaves similar to rare earths. Actinium would be rejected to the sulphate waste stream from the SX circuit;
- ***Solvent Extraction (SX):*** Individual Rare Earth Elements are separated, changed from sulphate to nitrate, by the addition of nitric acid and ammonia, using solvent extraction (SX) technology (kerosene as the solvent);
- ***Product finishing:*** Separated Rare Earth Element products are precipitated as carbonates (stripped from organic phase) from each stream, and in the case of the high value products, these are heated and converted into oxides through drying / calcination;
- ***Calcination Off Gas Management:*** Baghouse filter systems to remove entrained particulates in calciner circuit, including:
    - Dedicated system installed for each process train.
    - Multi-compartment bag house filter to capture fine particulates.
- ***Magnesia recovery*** for re-use in purification: The magnesia recovery circuit will receive: off-gas scrubbing effluent from the roasting kiln (could contain radon and decay products); softening clarifier underflow; sulphate waste (non-radioactive, bar some actinium) from rare earth SX; IX effluent; and brine (non-radioactive) from water purification;
- ***Product Bagging*** of rare earth products (oxides and carbonates): The samarium-europium-gadolinium (SEG) carbonate would be the only rare earth product containing natural radioactivity, mainly due to the presence of the Sm-147 isotope. Natural samarium contains three radioactive isotopes: Sm-147; Sm-148; and Sm-149, all of which are primarily alpha emitters and thereby only considered an internal hazard due to inhalation or ingestion risks. Bagging of this product would therefore require appropriate ventilation (dust control); potential automation of bagging process (if practicable); and appropriate PPE requirements. Packaging will adhere to requirements of the Transport Regulations and the International Maritime Dangerous Goods (IMDG) Code;

Table 9: Radiation Controls

Area of Plant	**Controls**	
	Admin	**Engineering**

Concentrate Delivery into ERER (Feed)	• Admin
	• Worker Training
	• Shielding
	• Controlled access
	• Rotating Shifts
		• Automatic material transfer (pumping EP2 concentrate into ERER grinding mill; 3rd Party concentrate fed via rotating / tipping containers into hopper (hooded and drafted to eliminate fugitive dust), combined with EP2 concentrate and gravity fed into kiln)
		• Design to enhance:
		  • Distancing (separation of workers from direct contact processing materials: automatic material transfer between processing units)
		  • Physical barriers (ERER process enclosed. Pipes, sumps, and processing equipment engineered to be leak-proof as far as practicable; with an enhanced level of process automation minimising physical handling of materials)
		  • Spillage control (Plant floor areas sealed (concrete / bitumised base sloped towards sumps) and bunded.
		  • Wash down (Sump pumps will return spillage to feed, and sufficient hoses for water washdown)
		  • Dust extraction as required

Concentrate Milling	• As above	• As above • Wet grinding process
Sulphation Roast	• Access control • Scale management and disposal • Confined space monitoring gasses, alpha, gamma • Maintenance procedures • Independent stack testing	• Wash down • Contaminated equipment control • Stack emission dust scrubbing
Leaching	• Generally in liquid/wet form – low inhalation risk • Scale management and disposal • Spillage control	• Wash down and concrete sloped sumps • Contaminated equipment control • Perimeter windrow around facility • Physical barriers (Pipes, sumps, and processing equipment engineered to be leak-proof as far as practicable; with an enhanced level of process automation minimising physical handling of materials (acids as well as radioactive))
Wash	• Spillage management • Sump design	• Wash down and concrete sloped sumps • Perimeter windrow around facility
Impurity Removal	As above	
Product Packaging	SEG Carbonate product does not trigger Transport Regulations, but is an alpha emitter with inhalation risks	• Bagging of products require appropriate ventilation (dust control); potential automation of bagging process (if practicable)
Waste (Residues)	• Controlled access • Rotating Shifts	• Bunded pipelines and contained piper joins • Fencing TSF to limit access • Double bottom liner to prevent seepage • Final encapsulation is 4 to 9 m • Considered intrusion prevention layer in cover

7.1. GAMMA RADIATION EXPOSURE CONTROL

The most significant exposure pathway for workers on the ERER Project is exposure to gamma radiation from the monazite product from EP2 and some of the intermediate process streams. ERER processing waste would also give rise to significant gamma exposure. The following steps have been included as exposure reduction methods:

- Shielding: processing equipment containing higher level materials must have some form of shielding (potentially additional pipe / wall thickness);
- Sealed surfaces; bunding; and spillage management: spillage can be cleaned up quickly in order to prevent it from building up and becoming a gamma hazard;
- A perimeter windrow around the infrastructure area to contain surface-water run-off from entering adjacent native vegetation areas;
- Physical barriers (enclosed processing: Pipes, sumps, and processing equipment engineered to be leak-proof as far as practicable; with an enhanced level of process automation minimising physical handling of materials within the feed, leach, and purification circuits (acids as well as radioactive));
- Classification of areas as restricted, controlled, supervised, and uncontrolled;
- Physical separation between radiation areas and non-radiation areas;
- Fencing and Access control of designated areas (e.g. active waste cells will be fenced to prevent unauthorised access (people and wildlife), both to mitigate radiological exposure, as well as to reduce the risk of drowning); Also designated areas for contaminated equipment (including scales);
- Scales management and disposal;
- Radiation awareness training;
- Maintenance procedures include the identification of potential radioactive scales, protective measures are required (time; distance; shielding; PPE) during maintenance works involving any radioactive scale. The presence of scales and radon gas build-up within confined spaces will be evaluated during operations, as per existing procedures. The site RSO will work directly with the maintenance managers and workers to ensure removal of scales is conducted to result in the lowest possible exposure for workers;
- Clean / Dirty Change House;
- Area and personal gamma monitoring; record keeping; and reporting (including for pregnant workers);
- Rotating Shifts

7.2. DUST CONTROL

Exposure of workers at the site to monazite; processing materials and waste through dust is considered to be relatively high risk and the implemented controls have been selected to ensure the likelihood of dust exposure is minimised. Control measures focus on either containing the monazite inside pipes, vessels, sumps, tanks or, where there is a potential for the monazite to be released, allowing fast and effective recovery of spilled material back into the containment areas and process.

The following controls will be implemented for this Project to reduce dust emissions:

- Wet processing systems have been utilised to minimise exposure to inhalable forms;
- Sealed surfaces; bunding; and spillage management: spillage can be cleaned up quickly in order to prevent it from drying out and becoming a dust hazard;
- A perimeter windrow around the infrastructure area to contain surface-water run-off from entering adjacent native vegetation areas;
- Automatic material transfer (pumping EP2 concentrate into ERER grinding mill; 3rd Party concentrate fed via rotating / tipping containers into hopper (hooded and drafted to eliminate fugitive dust), combined with EP2 concentrate and gravity fed into kiln);
- Off-gas scrubbers (roasting circuit); baghouse (product calcining); dust extraction (3rd party feed arrangement; product bagging);
- Maintenance procedures will include the potential presence of alpha scales in roaster and off-gas system; monitoring for alpha surface contamination and radon gas will be required prior to

maintenance inside enclosed operational equipment; protective measures will be required during maintenance works, procedures will be developed to capture these hazards;
- Designated storage area for contaminated equipment with alpha scales and / or scales removed from equipment (so access is controlled);
- Solids within ERER waste cells will be maintained below water surface to minimise dust formation. Dust suppression will be required after cell drainage (upon reaching capacity) as well as during the process of rehabilitation / capping;

Basic controls will also be in place to ensure movement of environmental dust from operational areas is minimised including; visual dust inspections carried out throughout the shift by plant operators, plant supervisors and earthmoving equipment operators.

Monitoring of personnel using personal dust pumps as well as monitoring of environmental dust levels using the High-Volume dust sampler and depositional dust gauges will be carried out to assess the effectiveness of the dust control systems.

7.2.1. Personal Dust Protection Equipment

Personal dust exposure will have an additional layer of control in relation to PPE and designated sections of ERER will be classified as mandatory dust mask areas and signage will be installed to this effect. Workers will need to be fit tested to ensure the dust mask they are wearing is protecting them from any dust exposure and, if required, powered air purifying respirator (PAPR) helmets will be available for workers.

Although the use of PAPR will be discouraged (disposable dust masks are preferable), if this equipment is required it must be maintained, cleaned regularly and controlled by the wearer. Each person would be required to look after their own PAPR, clean it regularly and maintain it in good working order. PAPR will be stored in the workers locker when not in use. PAPR will be issued by the Eneabba Production Superintendent and regularly checked by the site RSO/Deputy RSO to ensure it is being maintained.

7.3. CONTAMINATION CONTROL

The operational area of ERER (feed; grinding; roast; leach; CCD wash; purification; IX; and waste) will by default at a minimum be classified as a supervised area due to the radioactive content of the materials being handled.

The layout has been designed to isolate these areas by enabling access to be controlled through a change house system. Workers will only be able to access these operational areas after they change clothes at the access point. This system will ensure potentially contaminated clothing (radiation and chemicals) is controlled and remains at the change house/s where it can be washed. Showers and lockers are available so that workers can wash contamination off. For ERER, contamination from chemical management will be an additional requirement over and above radiation contamination. Separate clothing will be required inside the processing area, including boots. This change house system and separate clothing will ensure any contamination is restricted.

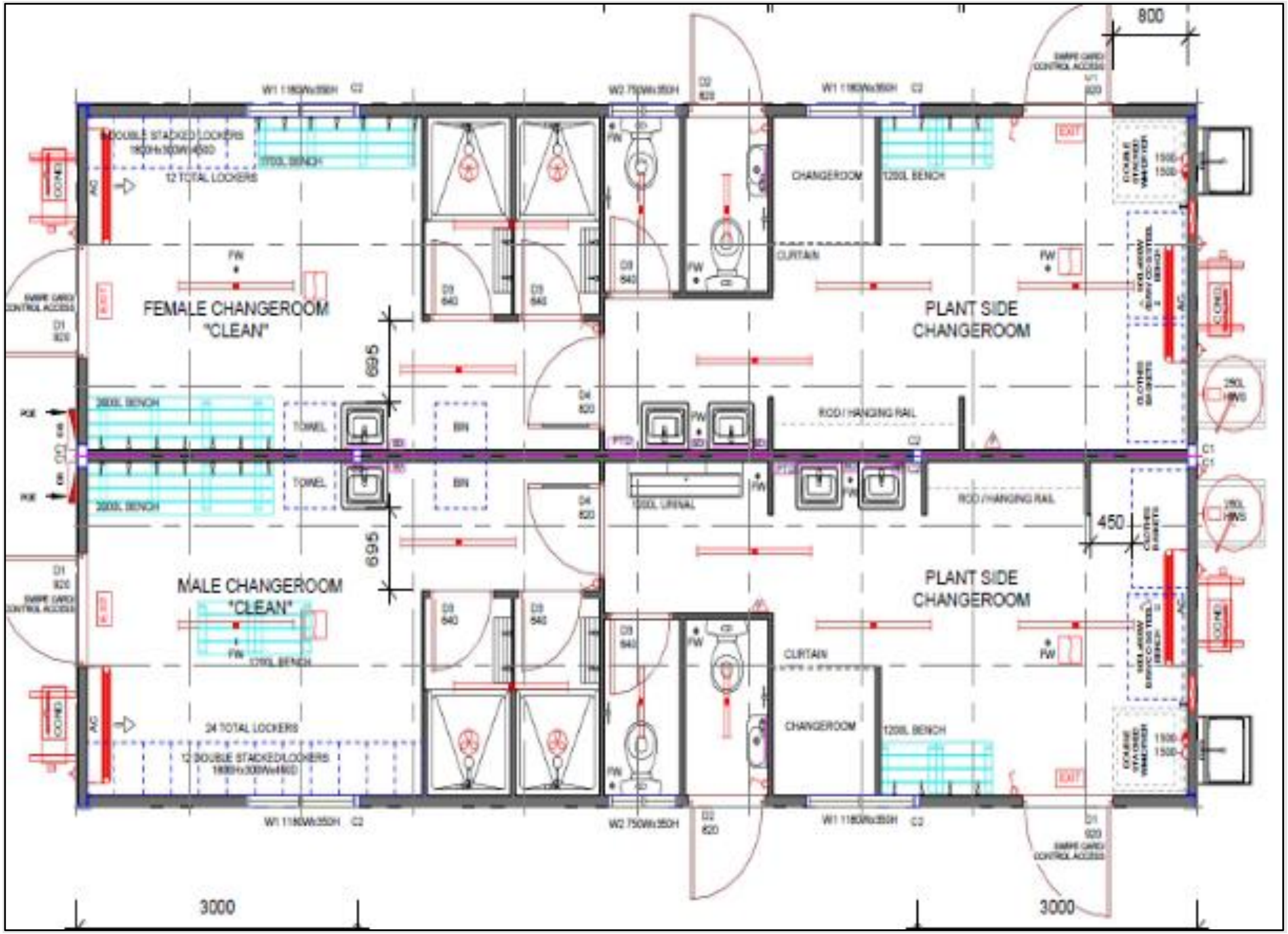


Figure 4: Change-House designed for entry into EP2 Monazite processing area (similar change house for ERER)

Additional contamination controls also include:

- Pumping slurries in appropriately designed pipelines to reduce the pressure and minimise leaks and blockages;
- Earthen bunding of major pipelines to contain potential spillages from pipe bursts (including regular inspections of the pipelines will occur);
- Instrumentation control of slurry lines to enable the detection of leaks and blockages and avoid spillage from pipes;
- Regular testing by the RSO/Deputy RSO of work areas and packaging facilities for surface contamination; and
- The ERER waste will be stored in a double lined facility with leak detection, underlain by an impermeable clay layer; the direction of groundwater flow away from the Critical Groups groundwater catchment area and the distance from the mine site would lead to dissipation of any radionuclides, even if a leak in the liner would occur.

7.3.1. Control of potentially contaminated waste

Redundant processing or transport equipment that may be contaminated with radioactive material will be tested to ensure it is less than the release level of 0.4 Bq/cm^2 averaged over 300 cm^2 (for surface α-radiation). Equipment exceeding this limit will not be released from site. If equipment is found to be above the release level, it will be high-pressure washed, dried and re-tested. As per the current site standard, a Materials Clearance Advice form will be issued by the site RSO (or Deputy RSO) to the site personnel requesting the release of the material. If high-pressure washed equipment still exceeds the release level, it will be retained on site and disposed of appropriately.

7.4. FIXED RADIATION GAUGES

Fixed radiation gauges will be used at the ERER for the purpose of density measurement. These gauges contain a radiation source and can therefore present an occupational radiation exposure risk to those who work in the vicinity. The quantity and location of gauges is not defined yet for ERER. The gauges will be stored in a radiation gauges store when they arrive on site and will then be installed in the plant at their designated location prior to commissioning.

Regulations provided under the *Radiation Safety Act (1975)* apply to these radiation gauges and details on how these gauges will be controlled, maintained and signposted have been provided in the Eneabba RMP (2021). Fixed radiation gauges must be isolated (by an approved RSO or nominated delegate) if work is to be carried out close to them (the guideline followed is within 1 metre for more than 1 hour). Gauge installation locations should be selected away from general movement areas or areas where spillages could influence them.

Any damage that occurs to a radiation gauge must be reported to the RSO immediately and access to the area restricted until a safety assessment can be made. *Standard Job Procedure 1 – Radiation Emergency Procedure* (SJP MW RMP 01) documents the procedures to be followed in the event of an emergency relating to damage caused to a fixed gauge. Awareness training of this requirement is provided to workers. Fixed radiation gauges are disposed of when they have exceeded their useful life. This will be controlled at the site by the designated RSO for fixed gauges.

7.5. OTHER RADIATION SOURCES

Other radiation sources planned to be used on site for processing operations include:

- Desktop XRF located in the sample room for process and grade control at Eneabba.

The RSO for XRF devices is anticipated to initially will be the Narngulu Senior Chemist, who is the current RSO for XRF devices at Narngulu. The same controls in place at the Narngulu laboratory will be implemented at ERER. This will include training to be provided for the use of this equipment and secure storage of the XRF devices.

Once relevant operational procedures have been established a site based RSO for XRF will be nominated and RCWA will be notified of the relevant changes.

7.6. EXPOSURE MINIMISATION CONTROLS

Employees are trained and supervised to understand the risks posed by radiation and take precautions to reduce their personal radiation exposure, and ensure others are not exposed to elevated radiation doses from processing and waste materials. Iluka will undertake investigative monitoring to identify areas where additional controls are necessary, then ongoing review of monitoring data, Management Plans, company HSEC Standards, and Standard Job Procedures / Safe Work Instructions.

Radiation training and induction will be required and provided for:

C1. Workers at the Eneabba site (Plant operations SEGs); and
C2. Iluka or contract workers who may need to attend the Eneabba site to complete maintenance or project works at the Eneabba ERER plant.

Examples of specific exposure reduction techniques detailed in the training will include:

- Personnel should minimise the amount of time spent in proximity to processing materials or wastes;
- Explanation of the Change House and entry / exit requirements while in operation (including chemical control);
- ERER processing streams and waste dust generation should be minimised and PPE worn to prevent exposure to dust.;
- Additional washing facilities will be provided for workers at the site, which will include washing machines and dryers for cleaning clothes which may contain ERER materials, and a shower facility where workers can wash off any loose mineral; and,
- A high standard of personal hygiene should be maintained to reduce exposure to ERER process materials or wastes.

Exposure for ERER workers will be regularly monitored, reviewing the real-time (EPD Trudose) gamma data. Tasks involving exposure to the high activity materials, will be shared between a workforce via task rotation practices. The Operators will spend a limited amount of time in areas with high radiation levels. Initial dose estimates for these workers are based on the current operation of EP1, measured exposure levels and predicted exposure levels based on pilot plant samples of the 90% monazite product. With rotating rosters, 24-hour operations and 4 dedicated production shifts, each worker is not anticipated to be at the Eneabba site for more than 2,184 hours per year.

The exposure of these workers will be continuously monitored, summarised at the end of each block. Internal trigger levels are set at 5 and 10 mSv/y and, if they are projected to reach or exceed such levels, they will be further rotated to keep the doses as low as is reasonably practical.

The ERER has been designed to optimise automation and controls have been based on the modelled and projected exposure levels using measurements taken during the pilot scale production of monazite. However, if the exposure levels measured during commissioning are above those modelled and predicted, further controls will be considered during and after commissioning. These controls could be in the form of additional shielding or further rotation of workers to reduce the amount of time spent conducting higher dose tasks.

The details of the exposure minimisation techniques described in this section will be specifically discussed, along with other relevant details, during the radiation awareness training.

8. INSTITUTIONAL CONTROLS

8.1. RESPONSIBILITIES AND ACCOUNTABILITY OF PERSONNEL

The key accountabilities for radiation management are outlined in Table 10. The Eneabba Production Superintendent is the key role in ensuring controls are in place for this Project. This role will have a detailed knowledge of the operation of ERER, and transport aspects, and will have a thorough understanding of the radiation related risks associated with operations. The Eneabba Production

Superintendent will also ensure the RSO is engaged as required and that the commitments in this RMP are upheld.

Table 10: Key actions and responsibilities for radiation management for this Project

Parameter	Action	Timing	Responsibility
Induction & Training	Radiation Awareness Training for relevant employees, contractors and associated work groups will include information described in Section 8 of this RMP.	Induction, & as required.	Eneabba Production Superintendent, RSO, Deputy RSO, Eneabba RM (Registered Manager), Transport Coordinator, Midwest Port Authority (MWPA) management.
Monitoring	Ensure that the nominated radiation monitoring is carried out and results are reported to appropriate employees, contractors or associated work groups, management and government departments accordingly.	Ongoing	RSO, Deputy RSO, RSO Fixed Gauges, Eneabba Production Superintendent, Production Coordinators.
Radiation Exposure	Ensure no workers under the age of 16 are employed to work on site.	Ongoing	Eneabba Production Superintendent, Production Coordinators, Eneabba RM, Human Resources, Transport Coordinator, MWPA management.
	Ensure that appropriate resources are available for controlling radiation exposure at the sites (including dust masks / respirators and disposable overalls to be available).	Ongoing	Eneabba RM, Narngulu RM & Eneabba Production Superintendent.
	Ensure that all nominated safe working practices are followed to minimise radiation exposure.	Ongoing	All employees, contractors and associated workgroups
	Ensure Operations personnel exposure is limited to 20 mSv/yr from this Project. Use of internal trigger levels of 5 and 10mSv; workers will be informed if they have received this level of dose and additional controls will be implemented to reduce further exposure.	Annual	Eneabba Production Superintendent and RSO.
	Effective Dose Equivalent is reported in accordance with the *Radiation Safety Regulations (General) 1983*, Regulation 15. Radiation levels measured using Optically Stimulated Luminescence (OSL) devices (or similar), An email will be sent to report such occurrences to RCWA and DMIRS officers.	3 Monthly or more frequently if excessive exposure is received	RSO
Radiation Fixed Gauges	Control all activity related to gauges (as detailed in the Midwest Mining and Rehabilitation Operations RMP) including; Gauge isolations, annual wipe tests and gauge inspections.	As required	RSO Fixed Gauges, Eneabba Production Superintendent.
XRF Devices	Ensure workers using these devices are trained and understand the risk and hazards associated with them. Ensure controls are in place and maintained.	Prior to use	RSO for XRF, Eneabba Production Superintendent.

Parameter	Action	Timing	Responsibility
Dust Control	Provide adequate resources to control dust during processing and transport of monazite product at the site and during ship loading activities.	Ongoing	Eneabba Production Superintendent, Eneabba RM and Transport Coordinator.
	Provide adequate resources to control dust at ERER waste facility during rehabilitation phase	Ongoing	Eneabba Production Superintendent, Eneabba RM and Production Coordinators
	Workers to be clean shaven (or facial hair appropriate) if a dust mask / respirator is worn to reduce dust exposure (dust mask seal should not be impeded by facial hair). PAPRs to be used if required.	Workers	Eneabba Production Superintendent, Production Coordinators, Eneabba RM and individual workers.
Waste Management	Ensure all scrap steel and other waste to be sent off-site for recycling has been appropriately screened for radiation.	As required	Production Coordinators, Maintenance Coordinators, RSO.
	Random surface alpha contamination checks of site rubbish bins.	Weekly during production	RSO or Deputy RSO.
	Record volumes and location of waste materials in the appropriate manner to ensure accurate tracking and reporting can occur.	Annually	Site Environmental Specialist, Deputy RSO/EHS Technician, Production Coordinators.
Contamination Control	Ensure surface contamination checks are carried out as described in Section 6, and where equipment is to be released from the site or from the Project (i.e. sea containers).	Weekly and as required	Individual workers, Production Coordinators, Maintenance Coordinators, RSO, Deputy RSO, Transport Coordinator.
	Ensure personnel entering the Monazite processing areas (flotation, filtration and bagging areas) or ERER (roast, leach, purification areas) use the change house and ensure potentially contaminated clothing is controlled through this process.	During operation of the Monazite processing plant.	Individual workers, RSO, Production Coordinators, Deputy RSO, Eneabba Production Superintendent.
Transport of Radioactive Materials	Ensure controls are in place as required under Transport Code for radioactive material (ARPANSA, 2019) for ERER materials >1Bq/g or >10Bq/g.	If required	Transport Coordinator RSO, Deputy RSO.
Rehabilitation	Ensure radiation monitoring of rehabilitation areas is undertaken prior to completion to ensure activity levels are acceptable for closure.	Post mining	Eneabba RM, WA Rehabilitation Manager.

8.2. COMMITMENT

Radiation is one of a number of hazards within the workplace. Iluka is committed to providing a workplace that is, as far as reasonably achievable, safe and healthy for employees, visitors, and without risk to the environment in accordance with the Iluka HSEC Policy. In order to achieve this commitment, Iluka has adopted the following international accepted best practice principles so that all exposures shall be kept ALARA, with economic and social factors being taken into account.

The major factors in the ALARA process include:

- Identifying and quantifying the sources of radiation;
- Defining possible workers for whom radiation protection would reduce exposure or dose;
- Quantifying the economic factors (cost of systems, operations, maintenance);

- Quantifying exposures and doses to individuals and to populations in the vicinity of the mine; and
- Understanding and controlling any radioactive waste material associated with the processes at the site, in a way that does not have a significant impact on the environment.

8.3. DESIGNATION OF CONTROLLED, SUPERVISED AND RESTRICTED AREAS

To ensure the ALARA principles are maintained, Iluka has classified the ERER operational activities as restricted areas. This is based on the potential annual radiation exposure in excess of the natural background, in accordance with the DMIRS' *Guideline NORM 6 Reporting Requirements* (DMIRS 2010c). Area classification limits are shown in Table 11.

Areas around the ERER which are not "restricted" may be designated as "controlled areas", and this may include the pipeline corridors, and other areas outside the direct operation of the plants but still within the project area. Signage will be placed near these areas to designate the area. Controls will be in place to ensure entry is limited. Once the plant is in operation a map will be provided (in the first monthly occupational dose report) outlining these areas.

Table 11: Area classification based on potential annual exposure

Classification	Potential Dose above Background (mSv/year)
Supervised Area	>1
Controlled Area	>5
Restricted Area	>15

Supervised and Controlled Areas: Access is limited to those persons required to work in these areas. Persons needing to enter the area shall be provided appropriate training about the radiation hazards and safeguards in the area.

Restricted Areas: These areas have a significantly elevated radiation level and access should be controlled. Only personnel with a good understanding of radiation exposure risks associated with the area will be able to enter. The designated site RSO will need to be involved in controlling radiation exposure for tasks carried out in these restricted areas. In some cases, monitoring equipment (such as electronic gamma meters or dust pumps) will need to be worn during the work so that a dose assessment can be carried out.

For restricted areas, an Access Permit , refers to a "*Permit to Work*" (PTW) form (the name of this form varies over time, but the intent remains the same), which has been provided in Appendix 5. The PTW allows work to be carried out in a controlled manner under the guidance of Iluka personnel. This process is standard at Eneabba and will be extended to also cover the ERER work areas at Eneabba. The Iluka coordinator in control of a work area will be required to authorise permits. This PTW is only required in restricted radiation areas if the works are going to be carried out by personnel who don't normally work in these area (e.g. ERER operator would not be required to complete a PTW). The PTW allows the Iluka personnel in control of the area to ensure personnel working in the restricted area for an extended period (greater than 3 hours) have had training and understand the risks associated with tasks inside the radiation restricted area and may be required to wear radiation monitoring equipment (such as a dust pump) during the work.

To assess the risk associated with external gamma radiation exposure in specific areas, the results from area gamma radiation surveys will be used to determine the degree of exposure. These surveys will be carried out using the RS125 gamma survey meter (calibrated to traceable standard), or similar calibrated gamma meter.

8.4. OPERATING PROCEDURES

Operating procedures will be developed for routine and non-routine tasks following an assessment of risks within the work area. These procedures will take the form of SWIs, which each functional unit at the mine develops specifically for their discipline and work area. An SWI involving radiation risks is to be reviewed by the RSO/RSO Fixed Gauges to ensure appropriate controls are in place. Standard Job Procedures (Appendix attached to both the Eneabba Rehabilitation Operations and Narngulu RMPs) will also be in place for routine tasks involving radiation management or monitoring.

8.5. SIGNAGE

Supervised, Controlled and Restricted radiation designated areas will be demarcated consistently with other Iluka sites in the Midwest, using the standard signage shown in Figure 5. Radiation hazard warning signs will also be placed on all fixed radiation gauges on site when they are placed in the field.

Figure 5: Signage used on site to communicate restricted area designations

8.6. PREVENTATIVE MAINTENANCE AND INSPECTIONS

All radiation gauges will be audited and wipe tests will be performed annually to ensure ALARA principles are maintained.

To ensure the nominated radiation controls are being adhered to by the personnel working on this Project, checklists will be developed in consultation with the Project workers, to ensure the controls nominated in this document are followed (i.e. as described in Section 6):

> ERER Processing Checklist: Restricted area is in place, workers are aware of radiation and the controls relevant to them, monitoring equipment is being used and the wearer understands the information being collected, measures are in place to clean up spillage and personal hygiene requirements are adhered to.

8.7. HOUSEKEEPING AND PERSONAL HYGIENE AND PPE RULES

General housekeeping procedures will be discussed during the site induction and more specifically in the radiation awareness training. It is an expectation at Iluka's operations that personnel (employees and contractors) will wash their hands to remove any mineral prior to eating or entering clean areas such as the control room. Facilities will be provided for this, such as basins, washing machines and dryers, along with showers at the change house and control room site.

If clothes are covered with mineral (monazite product or otherwise), workers will be required to brush down their clothes prior to leaving the work area, then remove and wash them at the change house. Loose process material shall be removed and remain in the mineral processing areas. Workers will be required to complete a full visual check of their clothing, boots and equipment before leaving the monazite processing areas. Separate clothing (potentially a different colour or a different design compared to standard Iluka clothing, and/or disposable coveralls) will be provided at the Eneabba site for employees to wear. This process will be assessed during commissioning of the ERER to allow it to be practical. The entry process for areas which contain elevated levels of monazite (EP2 and ERER feed areas) will be controlled through the change house. Disposable overalls are not mandatory, however they will be available if required.

All workers at the Eneabba operational areas will be expected to remove any residual mineral from their clothing and boots prior to leaving these areas. Tracking of monazite product or other materials into control rooms and other clean areas will be minimised through the change house and associated decontamination procedures. Disposable PPE (gloves, dust masks, and coveralls) and other disposable consumables will be visually checked and, if found to contain monazite product, will be washed before being placed in the rubbish bin. Most of the rubbish created on site will be free from mineral contamination and can be disposed of in local landfill sites. Any PPE contaminated with monazite will be stored in a separate labelled bin at the change house and disposed of inside the monazite pit or appropriate waste facility on site. There is not expected to be any significant amount of this type of waste produced at the site. Random checks of the bins will be carried out for surface contamination by the RSO or Deputy RSO.

Due to the ambient conditions at the Eneabba site during summer, heat stress needs to be considered in the risk assessment process associated with tasks workers will complete. Drinking water will be made available through a fountain in the change house for workers to maintain hydration while in the monazite areas. Prior to drinking in the controlled areas workers are expected to wash their hands before touching the cup or water bottle. This high level of hygiene is to ensure contamination is minimised and workers don't inadvertently ingest radioactive materials. This will be discussed in detail in the radiation awareness training.

Dust masks (P2) will be compulsory in designated sections of ERER to minimise potential dust exposure. Workers must have clean shaven faces around where the seal of the dust mask would sit, or use PAPR units, and be fit tested for the correct dust mask. Dust masks will be selected, used and maintained in accordance with manufacturers recommendations and AS1716. Personal dust monitoring results from EP1 operations indicate that dust exposure is minimal and that the dust to which workers are exposed has radiation levels that are generally below detection levels. PAPR units are available on site for workers that may not gain a correct fit with a dust mask or for short term workers (such as maintenance workers on shutdowns) who may have reasons not to remove facial hair (i.e. cultural reasons). Dust mask fit testing (using a porta-count) will be carried out for workers at the Eneabba site.

Smoking at the Eneabba site is prohibited, this includes areas involved in ERER processing, and the associated tailings areas.

The RSO will perform surface contamination checks using an alpha beta radiation detector (Radeye GX, with a Ludlum 44-9 probe, or equivalent) during processing to ensure operators clothing is not contaminated with radioactive materials and that the change house process is effectively eliminating surface contamination. These checks will initially be carried out daily during the start of commissioning then they will become part of the weekly checks during operations.

8.8. JOB ROTATION

Job rotations will be utilised to ensure doses remain below the annual exposure limit for designated radiation workers on this Project. Doses will be closely monitored and assessed. Initially each SEG will be assessed daily for gamma radiation electronically and cumulative dose for each worker should remain below 0.38 mSv/per week (380 μSv).

The dose limit will be 20 mSv/year for all workers in relation to the operation of the ERER. Workers will be continuously monitored and, if modelling projects that doses are likely to exceed this level, the workers will be further rotated to reduce exposure. All workers at the Eneabba Project site will be designated as radiation workers and will be regularly informed of their measured gamma doses from electronic monitoring devices. Data from these devices will be assessed by the RSO. Internal trigger levels of 5 mSv and 10 mSv will be imposed on the Project to ensure that, if personnel do receive this level of exposure, the RSO will inform the employee. The RSO and the worker will complete a task assessment to find the reason for the highest exposure and implement additional controls to reduce the exposure levels, in conjunction with the worker's supervisor.

The RSO shall assess measured radiation doses during commissioning activities and, therefore, may not be indicative of ongoing exposure levels, however the results will allow an assessment of the implemented controls. Further job rotations and engineering or administrative controls may be required based on the initial assessment of exposure.

Iluka will put the following measures in place to ensure the ability to effect job rotations is retained:

- Iluka is planning to employ sufficient processing operators to enable job rotation, holiday coverage and to ensure relevant training can be carried out during operations;
- Employees working on the Project will be required to notify Iluka as soon as they become aware that they have become pregnant. Job rotation away from radiation exposure would be implemented should an ERER plant employee become pregnant. This requirement is included in radiation awareness training;
- Some workers may also work, or participate in training activities, at the Narngulu MSP when they are not at the Eneabba Plant, however their exposure at Narngulu will continue to be monitored and recorded. Iluka will have a system to keep a central record of all employees who work on the Project regardless of which site they may spend some time. Annual radiation doses will need to be controlled for these personnel to ensure they do not receive exposure above the dose limit of 20mSv/year. The RSO for the Eneabba and Narngulu site will be responsible for tracking and controlling these cumulative exposures at the different sites; and
- Contractors who work on the Project during commissioning and operation will be required to bring their record of radiation exposure for the previous 12 months at any site where they would have worked. These exposures will be added to their exposure on the ERER to provide an annual estimate and model a projection.

8.9. EMERGENCY PLANNING

The *Radiation Management Standard Job Procedure Manual* (Appendix 1) details procedures for responding to an emergency relating to a fixed radiation gauge and other radiation related incidents (including truck rollover with radioactive material). Emergency response drills will be conducted as required. Emergency response drills may involve participation with local emergency services personnel.

The most likely emergency incident to occur would be a major spillage of acid treated feed material inside the operational areas. Recovery of this material would involve additional safety risks as well as those related to radiation. Emergency management processes will be put in place prior to the ERER plant becoming operational and will include input and guidance from the site RSO.

9. EMPLOYEE TRAINING

All Eneabba mine site personnel, workers associated with the ERER, transport drivers carting monazite by-product and HMC, and contractors will be provided with both general and specific instruction and training on radiation protection and safety prior to working with the radioactive materials. This awareness training will be delivered by either the RSO or Deputy RSO and the specific types of training represented on Figure 6.

Specific radiation training for workers is mandatory if employees need to enter supervised, controlled or restricted areas; the highest level of training will be provided to workers required to enter ERER processing areas. Training for these personnel will be carried out at least every 2 years, and training records will be stored on the Iluka training database.

Topics to be covered during training include:

- The principles and basic units of measurement used in radiation protection;
- The properties and hazards associated with minerals sand processing, rare earths processing, waste management and transport;
- The purpose and methods of estimating workers radiation dose, including how to use personal gamma monitoring devices and the employee requirements in regards to reporting any damaged monitoring devices to the RSO or Deputy RSO;
- The proper practices to eliminate, limit or control worker radiation doses, including personal hygiene (how to clean PPE/other rubbish before disposal into bins, use of the change house to control contamination and other expected behaviours) and basic dose reduction techniques, such as maintaining distance from monazite product, reducing time near monazite product, and using shielding where appropriate;
- Levels of radiation expected for workers on the Project, including an overview of which areas have the highest potential exposure levels at the site;
- Who to contact on matters of radiation health and safety, or in the event of any radiation related emergency;
- Job rotation for specific SEGs;
- Pregnant employees/contractors to inform their manager/RSO as soon as they realise that they are pregnant, and
- The purpose of warning signs, and permit requirements in restricted areas.

All personnel attending Radiation Awareness training for this project will be required to complete a short assessment to ensure that they have understood the key requirements relating to radiation safety.

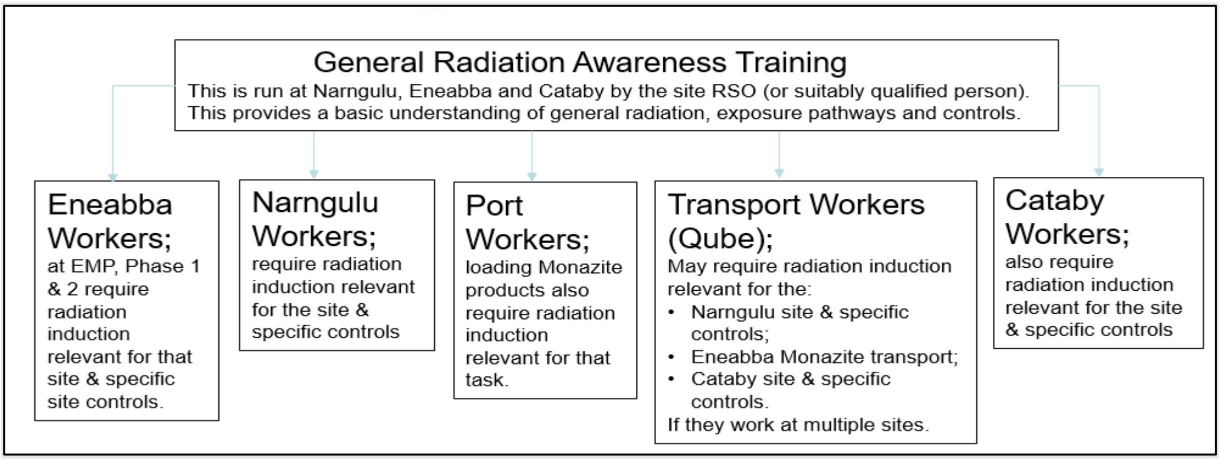


Figure 6: Current Midwest Radiation Training system (process flow) General and specific training

10. RADIATION MONITORING PROGRAM

Radiation monitoring has been described in detail in the Eneabba RMP (2021); this monitoring is also relevant to the ERER Project. Additional monitoring will be carried out during the operation of this Project to evaluate effectiveness of controls.

As part of the ERER operations additional full time Environmental advisors, Environmental technicians, Health and Safety Technicians will be based at the Eneabba site to complete regular personal and environmental monitoring. The Health and Safety team associated with the ERER will include around 13 full time workers.

10.1. PERSONAL RADIATION MONITORING

External gamma radiation exposure is expected to be the single largest contributor to dose related to the ERER Project. OSL badges used to measure gamma radiation will be issued to site based personnel at Eneabba to record quarterly exposure. In addition to this, electronic dosimeters will be worn daily by the Eneabba site workers.

In addition to Gamma exposure, alpha radiation exposure from dust produced will be monitored.

The monitoring program will initially consist of a baseline assessment for the following:

1. Monitoring gamma radiation exposure of all workers in restricted areas, including plant operators and maintainers at Eneabba, (who will be monitored using Electronic Personal Gamma Devices such as Thermo Scientific EPD TruDose or Isotrak DoseGuard monitors). Additionally, longer term workers will also wear personal OSL badges to record gamma radiation exposure;
2. Gamma surveys of work areas;
3. Area monitoring for Radon/Thoron using electronic meter (Sarad EQF3200 or similar meter) and where applicable, measurement of decay products;
4. Personal dust sampling for potentially exposed SEGs Once the monazite is bagged dust exposure is not expected and therefore only Eneabba plant workers will be sampled for dust exposure;
5. personal contamination checks for alpha radiation on clothing; and
6. Random surface contamination measurements of workshop, crib room, change house, rubbish bins and office surfaces.

All monitoring will be conducted in accordance with relevant SJPs.

Table 12: Occupational monitoring program

Monitoring type	Source/Location	Number of samples and Frequency	Parameters
Personal gamma – Monitoring	EPD and OSL badges for all workers in long term SEGs/workgroups (plant operators/maintainers).	Eneabba - EP1, EP2 and ERER operators, supervisors maintenance workers and technical personnel.	Direct readings cumulated during work for each worker. µSv/hr, averaged across the designated SEGs and assessed over a working year.
Area gamma – Monitoring	ERER work and tailings areas .	Sample locations will be where workers spend most time. Approximately 20 locations at each operational area. 6 monthly frequency.	γ-survey – specific points will be selected in plant areas and designated stockpile areas will be monitored. Conversion Gy:Sv = 1:1
	Radiation gauges.	Annually	γ-survey

Monitoring type	Source/Location	Number of samples and Frequency	Parameters
Long lived Alpha Dust	Baseline personal dust sampling - representative from each workgroup.	At least 6 valid samples per Eneabba based SEG within the ERER commissioning period. Reduced frequency based on measured dust levels reviewed in consultation with RCWA and DMIRS following exposure reports.	Flow rate of 2L/min. Alpha radiation counts of samples. Dose conversion for Th-232 and U-238 as per ICRP 37 and NORM V. Also consider Actinium 227 and Samarium 147 and their associated decay chains.
Radon/Thoron	Measurements taken using electronic radon detector. ERER work areas. Waste storage areas, offices and in Eneabba town.	Initial assessment during commissioning then further sampling of all areas 6 monthly to detect significant changes.	Electronic Radon/Thoron detector. Conversion factors as per ICRP publication 137 and in agreement with DMIRS.
Surface Contamination	ERER - workshop, crib room, change house, office surfaces and rubbish bins.	During commissioning and then randomly during subsequent production campaigns.	α-contamination, using alpha meter.
	Eneabba Plant operators clothing.	Daily checks on operators during commissioning with monazite. Then weekly random checks.	α-contamination, using alpha meter.
	'Wipe tests' for radiation gauges	Annual	α-contamination

The calculation method used to convert measured radon and thoron levels, is to individually apply the dose conversion factor (DCF) to the measured Radon (Rn-222) or Thoron (Rn-220) gas, then multiply by the equilibrium factor (F) which allows for the relationship between the Radon and its progeny.

The DCF and F are provided in ICRP (International Commission on Radiation Protection) Publication 137, in table 12.7 (page 315) and provided in section 11.1 as Table 16 - Radon (Rn222 and Rn220) Dose Conversion Factors.

Based on the measured radon levels from existing Eneabba operations, as well as pilot plant production of monazite, exposure levels have been calculated at a "worst case" level of around 0.55μSv/hr. The equilibrium factor F measured on site at EP1 for both Rn and Tn appears to be lower than the default numbers used in ICRP 137. In agreement with DMIRS the ICRP 137 F factors in Table 16 have been used in all dose calculations for EP1. The use of these F factors is supported by the data provided in ICRP 137 table 12.7 (page 315). Where appropriate, radon decay products can be measured as alternative.

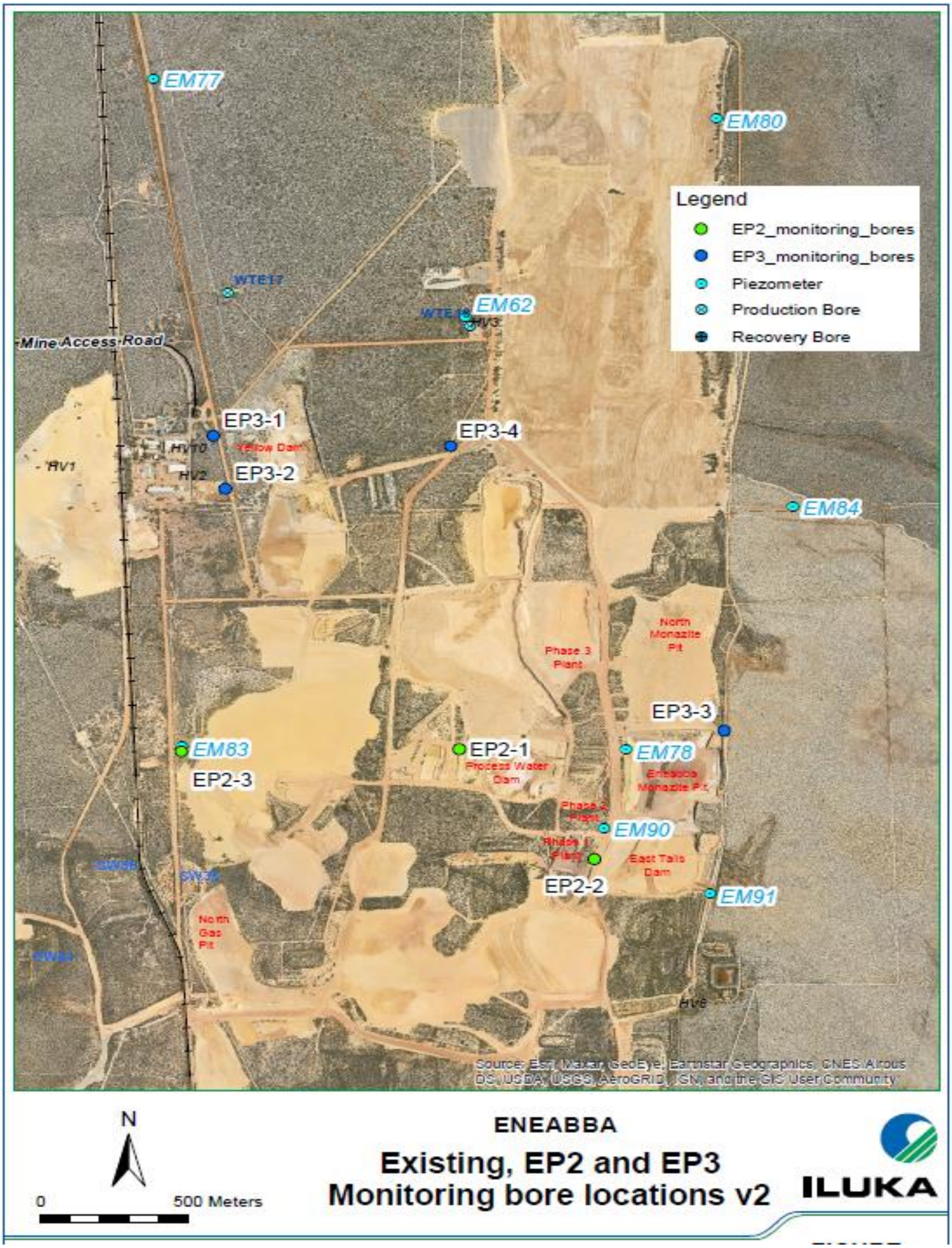
10.2. ENVIRONMENTAL RADIATION MONITORING

Table 13: Environmental Monitoring Program

Monitoring type	Source/Location	Frequency	Parameters
Water Monitoring - Groundwater	Groundwater monitoring at existing locations EM78, EM90 and EM91 adjacent to the EMP will continue as detailed in the Eneabba Rehabilitation Operations RMP. Additional monitoring wells have been installed at the Eneabba site as part of the ERER, including deep and shallow monitoring wells.		
Water Monitoring – Surface water	Surface water from the site.	During and after rainfall events.	Visual assessment to ensure stormwater is contained within the operational footprint with no impact to adjacent native vegetation.

			Assess and maintain earthen windrows around infrastructure area to contain run-off.
Dust Monitoring	Eneabba Fugitive Dust Hi-Vol – locations will be reviewed based on final design. A background location away from the processing area will also be included.	1 sample at each location every 2 months. Frequency to be reviewed based on initial sample results. An additional sample every 2 months at Eneabba town at current monitoring position F.	72-hour sample - alpha radiation.
	Deposition dust monitoring at Eneabba.	Monthly samples at each location.	Analysis of U & Th in the collected dust. Additional locations will be set up near the tailings facility and other ERER operational areas.
Area γ- Monitoring	Baseline sampling at Project site.	Prior to processing commencing.	γ-survey, to provide environmental gamma data in nGy/hr.
	Project area – ERER and waste facility	3 monthly for the first year of operations then review in AERR (6-monthly if results indicate no significant changes).	γ-survey 200m radius around the project area Gamma surveys of immediate operational areas and along pipeline corridors.
Waste	ERER Waste	Daily sample for a weekly composite analysis during production.	Th & U concentration.
	ERER Waste (Tails facility)	Daily visual inspection.	Integrity of tailings, pipeline leaks and freeboard is maintained at no less than 500mm.
	ERER Process waste	On-going as required	Process waste to be checked for surface contamination.
	Rubbish bins from processing areas – contaminated material only.	Weekly.	Record volume of rubbish, disposal location and details contamination checks carried out.
	Eneabba Rubbish bins – non-contaminated material.	Random weekly checks during operation of Plant 2.	Surface contamination checks for alpha radiation and visual inspections for monazite or other mineral.
	Redundant or damaged equipment to be disposed of or repaired offsite	As required	All equipment should be washed and free from mineral. Equipment will be checked for surface contamination as per Surface contamination procedure (SJP MW RMP 09)

Figure 7: Eneabba Groundwater Monitoring Locations



10.3. COMPLIANCE WITH LIMITS

The Registered Manager to ensure that a worker at the mine does not receive a dose of radiation exceeding:

- Effective dose limit in a single year of 50 mSv.
- Effective dose limit over a period of 5 consecutive years of 100 mSv (therefore the derived exposure limit is 20 mSv/year).
- 25 µSv/hr radiation exposure from a radiation gauge.
- Dose constraints of 5 and 10 mSv/year will be applicable

Regulation 16.19 of the *Mines Safety and Inspection Regulations 1995* and the *Radiation Safety Regulations (1983)* requires that the Registered Manager must ensure that a member of the public does not receive a dose of radiation, as a consequence of the mine, exceeding an effective dose limit of 1mSv/year. In all cases, the radiation dose for workers and members of the public should be kept as low as reasonably achievable (ALARA). Investigation levels for all monitored radiation parameters are provided in Table 14.

Table 14: Investigation levels

PARAMETER	GUIDELINE LEVEL (Reportable)	INTERNAL INVESTIGATION LEVEL	COMMENT
1. Area Gamma Dose Rate			
1.1 Site boundary	More than 0.11 µGy/hr above background	200 nGy/hr	Background established at ~129nGy/hr at Eneabba.
1.2 Supervised area	More than 0.50 µGy/hr above background	N/A	Background established at ~129nGy/hr at Eneabba. If gamma surveys indicate area designations have changed update RMP, personnel training and area signage.
1.3 Controlled area	More than 2.50 µGy/hr above background		
1.4 Restricted area	More than 7.50 µGy/hr above background		
2. Personal Exposure (Total Effective Dose Equivalent)			
2.1 Designated Worker	>2.5 mSv/quarter	2 mSv/quarter	Applies to all Eneabba workers. Compared against OSL badge result and dose measured from dust and radon monitoring .
	3/10 dose limit over relevant time period.		Report directly to RCWA & DMIRS officers via email when dose assessment is completed.
2.2 Non-Designated Worker	>0.5mSv/quarter	0.3 mSv/quarter	Based on short term workers using EPD in non-restricted areas at the sites.
	3/10 dose limit over relevant time period.		Report directly to RCWA & DMIRS officers via email when dose assessment is completed.
3. Personal Internal Dose			
3.1 Designated Worker	>2.5 mSv	1 mSv/quarter	Assessed from air sampling.
4. Airborne Radioactivity			
4.1 Total alpha activity on the personal air sample	>4Bq/m^3 for a single personal shift dust sample	3 Bq/m^3 (8-hour shift)	Baseline monitoring indicated dust exposure is minimal and low in radiation.
		2 Bq/m^3 (12-hour shift)	

PARAMETER	GUIDELINE LEVEL (Reportable)	INTERNAL INVESTIGATION LEVEL	COMMENT
4.2 Total alpha activity on the personal air sample	4 consecutive samples >1B q/m^3	2 consecutive samples >1 Bq/m^3	Indicates potential for significant exposure.
4.4 Total Alpha activity on environmental air sample	>1 mBq/m^3 on high volume air sampler	>0.5 mBq/m^3 on high volume air sampler	100µSv/year to member of public continuously exposed (>10 x background levels).
6. Radon in Air			
6.1 Radon in air _ workplaces	>1000 Bq/m^3 (ARPANSA) >5 mSv/year (2000hrs) DMIRS (NORM 6) >250 Bq/m^3 (recent update from DMIRS)	>200 Bq/m^3	Measured levels in and around Eneabba operational areas are well below this level for Rn222 however have been elevated for Rn220.

10.4. SAMPLING EQUIPMENT, AUDITS AND METHODS USED

Standard Job Procedures (SJPs) have been developed for all key monitoring and management tasks relating to radiation protection. These are listed in Appendix 2 and are regularly reviewed. All equipment to be used in radiation monitoring will have a current calibration certificate as appropriate. Calibration certificate records are stored in accordance with Iluka's document management system. Calibration of radiation monitoring survey meters will be carried out by a NATA approved laboratory using traceable standards.

External and internal audits will be conducted periodically to provide independent verification of the status of Iluka's radiation management systems and implementation of controls; this will include regular completion of checklists mentioned in Section 7.6. The aim of internal audits is to ensure commitments made in this RMP are being implemented and that monitoring is conducted in accordance with the relevant procedures in the RMP. Environmental monitoring for radiation is carried out either by the RSO, Deputy RSO or other suitably qualified and trained professionals.

11. RECORDS MANAGEMENT AND REPORTING

11.1. RECORDS MANAGEMENT

Key documents relating to radiation, including this RMP, Annual Environmental Radiation Reports, monitoring results and procedures are managed in Microsoft SharePoint (Teams). This system is backed up daily to ensure all records are retained indefinitely. Hard copy reports will be available on-site.

11.2. EXTERNAL REPORTING

The Eneabba Environmental Radiation Report (EERR) is prepared annually in accordance with requirements of the State Mining Engineer. Environmental monitoring related to this Project will be included with each site report. A separate specific report for this Project will not be provided (unless specifically requested in writing). The environmental report will capture the environmental monitoring data collected at the site.

Occupational monitoring carried out at the Eneabba Mine will be reported in the Eneabba Occupational Radiation Report (EORR) which will be prepared annually and include a summary of personal radiation results obtained between 1st of April to the 31st of March. This report will include occupational radiation monitoring data such as external (OSL badge/electronic gamma monitor) and internal (dust/thoron) monitoring results and dose estimates for workers. The first report will be provided once a sufficient amount of radiation monitoring has been completed on this project.

An additional monthly report will be provided to the RCWA and DMIRS following the first month of processing of monazite through the ERER. This personal exposure report will include the individuals EPD (gamma data) and OSL monthly badge results, measured levels of dust and radon, and will provide a cumulative dose for each worker exposed to radiation during commissioning/production. The first report will be submitted as soon as practicable once OSL badge results have been received (within ~2 weeks of the month ending).

11.3. INTERNAL REPORTING

If a *Notification Level* of radiation exposure is exceeded, a Lost Control notification is distributed as soon as possible to all relevant Iluka personnel. If a formal investigation is required, the incident is investigated by the relevant staff with results communicated and stored in Iluka's *Cintellate* incident management system and UDOCS record management system. Iluka's incident investigation system requires corrective actions to be identified and implemented to prevent reoccurrence.

Internal reporting will include;

- Weekly reporting of personal EPD gamma monitoring;
- Daily review of EPD gamma results by RSO/Deputy RSO (or Production coordinator);
- Monthly reporting of EPD gamma monitoring data for all project employees and contractors;
- Regular reporting of dust exposure levels to both the person wearing the monitor and the SEG;
- Regular reporting of radon measurements at ERER and relevant work groups; and
- Any minor radiation issues or breaches of the controls described in this RMP.

12. DOSE ASSESSMENT

Dose assessment provided in this RMP is based on both monitoring data collected from current operations at the Eneabba site and modelled exposures based on future processes involved in the operation of ERER.

Iluka expects workers will implement the required controls during operations such as adhering to the radiation principles of Time, Distance and Shielding, and radiation safety will be strictly controlled based on practical experience gained during current operations.

Iluka radiation safety personnel will be regularly assessing exposure levels, and will investigate any unusual increases to design and implement immediate changes where necessary and keep radiation as low as reasonably achievable. As such, the expected radiation exposure data is provided with a focus on the average exposure levels over the course of a monitoring year (Arithmetic mean will be used where data is statistically normal, Geometric mean would be used where data is statistically Log-normal).

Although the radiation exposure data is generally based on annual averages, there will be individual exposures in a SEG which are higher than the average. A more detailed assessment of workers annual radiation doses will be completed as the components of the ERER are finalised, and assumptions made in the dose assessment are tested.

12.1. METHODOLOGY FOR EXPOSURE CALCULATIONS

12.1.1. Dust

The internal dose assessment for α-radiation is carried out using the mean (arithmetic or geometric) of multiple samples, which is used with the formula in Table 15 to calculate an annual dose. This calculation is used for estimating dose for both the critical groups and Iluka workforce, occupancy and DCFi vary for each group.

Table 15: Internal Dose Calculation for α-radiation

Individual Internal Dose = (AM_i x HW_i x BR) x DCF_i Where:	
AM_i	Arithmetic mean of gross α-activity concentration for the critical group ***i*** (Bq/m^3)
HW_i	Occupancy Hours per year (hours)
BR	Assumed breathing rate (1.2 m^3/hour);
AM_i x HW_i x BR	Personal intake for the period of assessment for the group i (Bq);
DCF_i	Dose conversion factor in mSv/Bq (different factors used for critical group and workers)
Calculations and assessment methods are taken from *NORM Guideline V Dose Assessment* (DMIRS 2021). DCFi for workers is taken from ICRP Publication 137 and associated OIR data viewer (2019) (workers on project, assumed 5µm^ particle size, DCFi of 0.0158* for Th-232 & U-238). Critical group DCFi has not been updated by ICRP so remains from NORM V Table D.1 (for the Critical Group = 0.0131). (These factors are based on Th to U lab assay of 25:1 for 90% Monazite product). Additional assessment of other prevalent radionuclide decay chains may be required as part of the dose assessment for Radium, samarium or actinium decay chains. ICRP 137 will be used as guidance.	

^Iluka has nominated the default 5µm dust size based on the difficulty measuring AMAD when very low dust levels are present. Expected AMAD based on Narngulu monitoring is likely to be above 10µm. The use of 5µm is expected to be conservative when applied to areas of the plant where dust is likely to be present (EP1 and EP2). ERER is expected to have a lower AMAD due to the feed being pulverised for processing. Dust sizing may be used to establish the actual AMAD or a conservative sizing of 1µm and associated DCF will be used for ERER workers.

12.1.2. Gamma

OSL and EPD will be worn at the same time by workers who spend significant amounts of time at ERER. The OSL badges are seen as the most accurate record of dose, however the results from these are not available until the wearing period (~1 or 3 months) is complete and the results have been returned from an external provider. They are therefore only relevant for longer term workers.

The EPDs, however, allow immediate action to be taken during a shift, or after a short number of shifts, to control and reduce gamma exposure. The wearing and recording of EPD data is open to some inaccuracy if not done correctly, for example a worker who completes a 12-hour shift may wear the EPD for the whole shift but only record the portion of the shift they spent in a processing plant, this would overestimate their dose. On some occasions operators don't remember to clear the EPD, and so the previous shift's dose is added to the current dose. Due to these types of inaccuracies EPDs are used but not relied on in all cases to provided annual dose records. Annual doses from gamma radiation will be provided from OSL badge results wherever they are available.

Exposure to gamma-radiation can also be calculated by surveying each work area, Critical Group areas around the site and near where the Critical Groups reside. These gamma readings are calculated in accordance with Standard Job Procedures, using calibrated radiation meters. Dose is estimated by using the average exposure and time spent in different areas. Radiation meter readings collected in nGy/hr are converted on a 1:1 basis to nSv/hr (ARPANSA, 2019) to calculate external radiation dose in mSv per year. OSL badges can also be used to measure gamma levels in Sv/h, however due to the transient nature of workers when they are at the site this is not seen as the most accurate personal dose assessment method.

Gamma exposure levels for the current operations at Eneabba for Phase 1 are measured and well understood. For regular workers in the EMP, average hourly gamma exposure is 4.81 (±2.04) μSv/hr arithmetic mean (4.34 μSv/hr geometric mean). For Phase 1 operators, supervisors and maintenance workers the average hourly exposure is 1.01 (±0.45) μSv/hr arithmetic mean (0.91 μSv/hr geometric mean). These measured levels have been used in some gamma dose calculations for workers.

12.1.3. Radon

The standard calculation method used to convert measured radon and thoron levels is to individually apply the dose conversion factor (DCF) to the measured Radon or Thoron gas, then multiply by the Equilibrium factor (F) which allows for the relationship between the Radon and its progeny.

The DCF and F are provided in ICRP (International Commission on Radiation Protection) Publication 137, in table 12.7 (page 315) as follows;

Table 16 - Radon (Rn222 and Rn220) Dose Conversion Factors

Radon-222 gas (ICRP 137 DCFi)	3.1×10^{-5} mSv per Bq h m^{-3} (ICRP 137 Table 12.7 (page 315))	F (equilibrium factor) = 0.4 (Default)	Br of $1.2m^{-3}$ is already included in DCF.
Radon-220 (Thoron) gas (ICRP 137 DCFi)	1.0×10^{-4} mSv per Bq h m^{-3} (ICRP 137 Table 12.7 (page 315))	F (equilibrium factor) = 0.005 (mine)	Br of $1.2m^{-3}$ is already included in DCF.

Based on the measured levels collected at Eneabba, the equilibrium factor F for both Rn and Tn appears to be lower than the default numbers used in ICRP 137. In agreement with DMIRS the ICRP 137 F factors above have been used in all dose calculations. The use of these F factors is supported by the data provided in ICRP 137 table 12.7 (page 315), and is expected to be an overestimate compared to actual exposure.

Radon levels measured during EP1 operations have ranged from maximum levels of 14Bq/m3 Rn-222 and 1,089Bq/m3 Rn-220 at the base of the EMP on top of screened by-product, to lower levels such as 3Bq/m3 Rn222 and 11Bq/m3 Rn-220 in the main control room at EP1. Based on the 2020/2021 Annual

Occupational Dose report for Eneabba all workers have been assigned an hourly dose rate from Radon (Rn-222 an Rn-220) of 0.55µSv/hr.

An assessment of the radon build-up in an enclosed spaces around ERER will be carried out to understand the maximum levels that could occur. The results of this assessment will be provided with the first monthly report following the commencement of commissioning.

12.2. DOSE ASSESSMENT OF CRITICAL GROUPS

The current radiation dose for members of the public has been provided in the Eneabba Rehabilitation Operations RMP for the Eneabba Critical Group.

The dose is generally calculated by taking into account both external γ-radiation and internal α-radiation, specifically:

1. inhalation of resuspended dust (α-radiation);
2. external γ-radiation exposure;
3. radon/thoron inhalation, and;
4. ingestion of drinking water (α- and β–radiation where relevant).

Dose calculations in this case are limited to specific pathways of exposure related to this Project. These pathways are summarized in Table 7. These specific pathways will be re-assessed after the first production from ERER. This assessment will be provided as part of each Annual Environmental Radiation Report for Eneabba based on the Eneabba Critical Group gamma surveys for the town of Eneabba.

The following table is a summary of current measured Eneabba Critical Group 1 annual dose related to this Project. Current dose assessment based on gamma readings taken around Eneabba have been provided in the updated Midwest Rehabilitation RMP (2019; page 35, Table 12).

Table 17: Eneabba Critical Group Annual Dose Assessment

Components of the total dose	Current Eneabba Critical Group (2021)	Dose related to this project for the Eneabba Critical group
Dose from Gamma radiation	0.16mSv/year	Based on the average gamma readings from samples collected around the town.
Dose from airborne dust (Including background)	0.005mSv/year	Based on Hivol dust samples collected in the Eneabba town background.
Dose from drinking water (including background)	0mSv/year	Based on gross alpha beta samples collected from drinking water in the town.
Total dose for the critical group (Internal + external)	**0.17mSv/year**	**No expected additional dose for the Eneabba critical group due to this project.**

All surveys are carried out in accordance with gamma survey procedure (SJP MW RMP 10) using a calibrated environmental Gamma meter (RS125) by the site RSO and/or Deputy RSO.

It is expected that there will be no significant increase in the radiation exposure for the Eneabba Critical Group from the operation of the ERER. ERER will employ wet processing, inclusive of waste facilities for the operational period. The current background dose assessed in the Eneabba RMP (2021) indicates total dose for the Eneabba Critical Group is expected to remain below 1 mSv/y.

If any significant increase in radiation is detected during monitoring, immediate action will be taken to assess if this increase has impacted on members of the public, and subsequent action taken to reduce increased exposure to as low as reasonably achievable.

12.3. DOSE ASSESSMENT OF WORKFORCE

This dose estimate for workers provides an estimated Effective Dose Equivalent (EDE), including both internal and external radiation exposure. The EDE is based on dust and radon monitoring results from EP1, and gamma measurements, estimated gamma levels and modelled exposures based on concentrated laboratory samples of Monazite.

Assumptions have been made in relation to the occupancy time based on continuous annual production, rotation of Eneabba Plant operators has been included as a radiation exposure control in place for the Project. Further review of operational processes to be carried out once the operation commences. Dose estimates have been based on dust exposure measured on workers at EP1 with current controls in place. A more detailed dose assessment will be provided once the operation of the ERER is further understood. “Worst case scenarios” have not been included as part of this dose assessment.

Estimation of internal radon and thoron gas exposure is based on the measured levels around the EMP, EP1 areas. The highest measured levels during EP1 have been assumed for radon and average exposure levels for dust. The monazite will mostly be contained during processing and this is expected to reduce levels of radon (both Rn-222 and Rn-220). Exposure levels based monitoring trends for radon and dust will be amended following operational monitoring.

Table 18: Total Annual Radiation Dose Assessment for Workforce.

Work Categories	**Expected Annual Hours worked per year**	**External dose (mSv/yr)**	**Internal dose Radon/Thoron (mSv/yr)**	**Internal Dose Dust (mSv/yr)**	**Total Effective Dose (mSv/person per year)**
Shift Plant Operators (per shift)	2100	2.69	0.58	0.65	**3.92**
Senior Shift Plant Operators/Leading hand	2100	2.42	0.58	0.65	**3.65**
Production Superintendent	2100	1.57	0.29	0.65	**2.51**
Electrical and Mechanical workers (plant based,2 electrician & 2 mechanical)	2100	3.16	0.58	0.65	**4.39**
Process Support workers Process technicians, Process Engineers, Chemists,	2100	3.1	0.39	0.65	**4.14**

Warehouse - coordinator, stores supervisors and storemen.	2000	0.64	0.18	0.62	**1.44**
Laboratory workers	2100	1.99	0.29	0.65	**2.93**
Health Safety/Environmental, Radiation Specialist.	2000	1.59	0.28	0.62	**2.49**
Commercial services workers - HR, Clerical, accounting, shipping & transport coordinator	2000	0.64	0.14	0.30	**1.08**
Engineering support - engineers, maintenance planning	2000	1.59	0.14	0.30	**2.03**
Management - Operations, production, engineering, technical, laboratory and commercial managers.	2000	0.64	0.14	0.30	**1.08**

12.4. DOSE ASSESSMENT FROM BULK ERER WASTE

In a separate study, Tier 2 terrestrial and aquatic (fresh water) assessments of the ERER waste disposal facilities have been conducted. To quantify the risk to non-human biota, ERICA (Environmental Risk from Ionising Contamination Assessment) has been used to calculate the effective radiation dose rate to representative fauna and flora. The results of the study is thereby not included in this RMP.

A further study was conducted to evaluate the risk to human health, now and in the future, as a result of exposure to radioactive material within the bulk waste facility containing residue from ERER. The approach was to use the RESidual RADioactivity (RESRAD) model for assessment of the dose or risk associated with residual radioactive material to human receptors. The results of this study is also not included within this RMP.

13. WASTE, TAILINGS AND CONTINGENCY MANAGEMENT

13.1. ERER WASTE

ERER will be located at the Iluka Eneabba mine site adjacent to EP1 and EP2. Multiple potential TSF facility locations were identified for the disposal of the solid residue from ERER (Figure 8), with the Yellow Dam mine void selected as the initial location. An emergency bleed brine evaporation pond will also be required, but will be located within the boundary of the refinery.

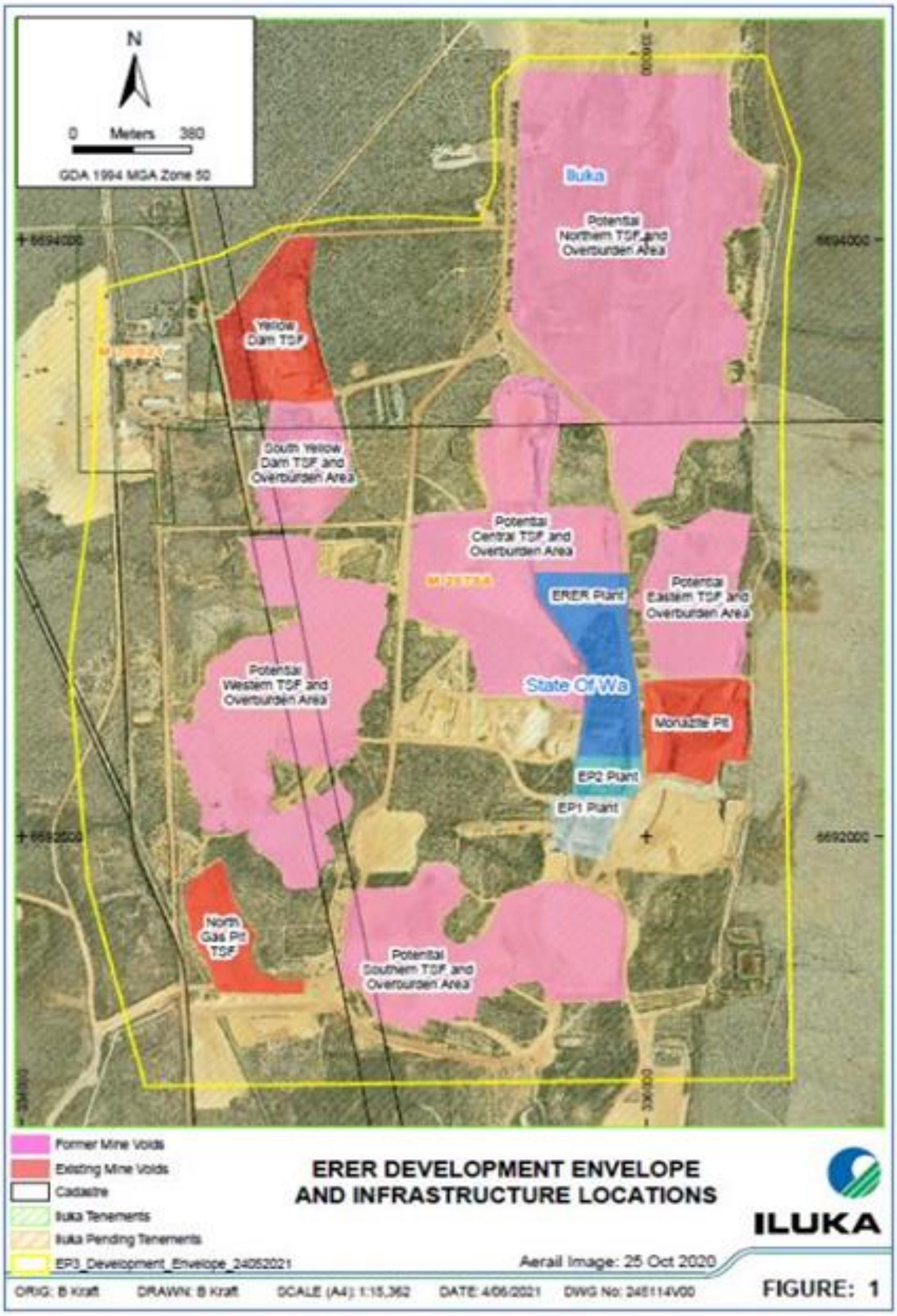


Figure 8 ERER and Potential TSF locations

Solid waste will be combined, collected and disposed of, as a slurry into purpose-built tailings storage facilities (TSFs). Existing disturbed areas within the disturbance footprint will be used for TSFs. Per Figure 8, various TSFs to be constructed over the life of ERER including Yellow Dam; former Yellow Dam South; former North Monazite Pit; and the Monazite Pit. Noting that removal of monazite bearing MSP by product from the Monazite Pit will create the void for the TSF. Additional facilities will be considered in other disturbed areas within the Development Envelope in the event that additional disposal areas are required as a result of significant treatment of 3rd party materials.

The waste cells will be flooded during active operation to prevent fine gypsum dust from distributing into the surrounding environment. High level gypsum facilities at other sites indicated crust formations by wetting / drying cycles, thereby naturally reducing dust liberation. Crust formation does however reduce water infiltration as well once formed.

The solid waste produced by ERER would contain gypsum; iron phosphate; and aluminium. It will also contain Naturally Occurring Radioactive Material (NORM), specifically Uranium (~200 ppm) and Thorium (~6,000 ppm). The refinery will produce up to 180 kilotonnes per annum (ktpa) of solid residue. Eneabba EP2 monazite concentrate as feed to ERER would produce solid waste with an activity concentration of up to 37 Bq/g (single radionuclide high). The addition of third-party feeds into ERER would reduce the expected activity concentration of the solid waste material due to third party feed being lower in activity.

13.2. TSF DESIGN AND OPERATION

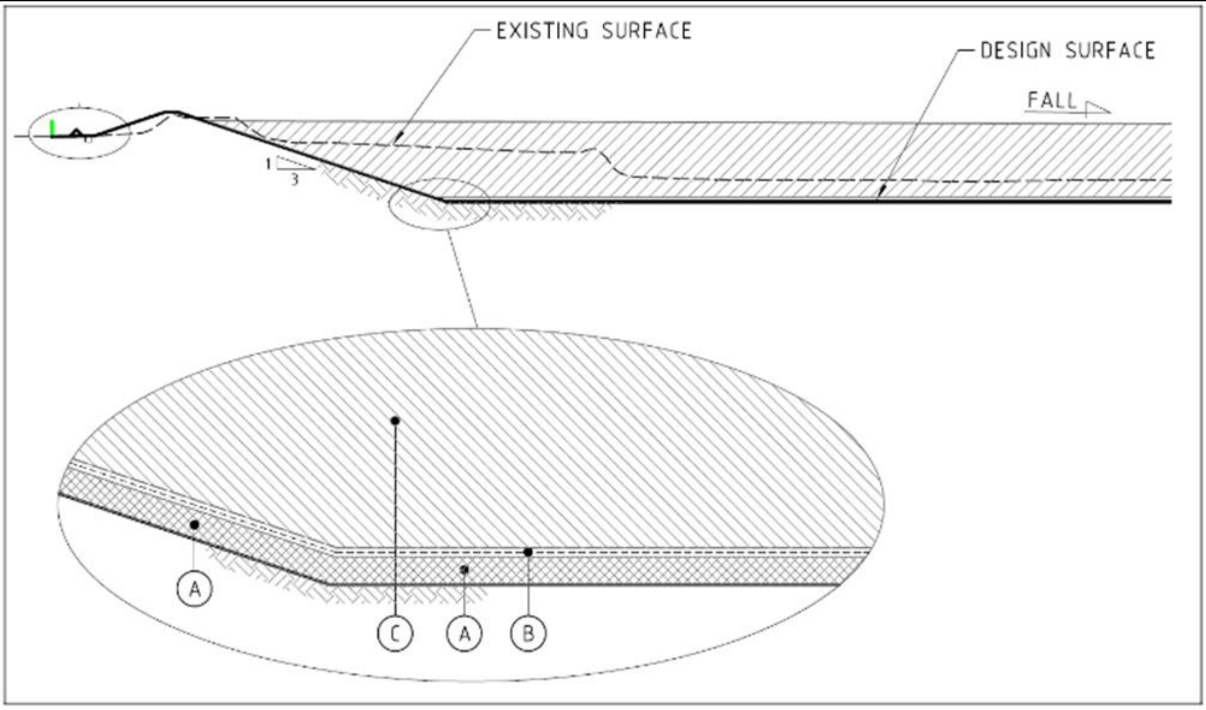
Wood completed a conceptual design for the Yellow Dam TSF (ERER Engineering and Cost Study Development Phase – ERER Solid Waste Disposal Pond Design, Wood, September 2021). The conceptual design report details the basis of design for Yellow Dam, which will be utilised for the remaining TSFs (Yellow Dam South, North Monazite Pit and Monazite Pit).

Waste material will be pumped as a slurry to the TSF at a solids concentration of approximately 24%, measured by weight. The slurry will be deposited into the TSF by multiple spigots and will consolidate to an initial dry density of approximately 0.99 t/m^3. Conceptual diversion drains, and bunds are included within the design.

The containment system within the TSF will comprise the following:

A low permeability clay layer will be used for the base of the facility. This layer is used as a HDPE liner foundation and provides puncture resistance and a low-permeability barrier should the liner system rupture or leak.

The synthetic liner system will consist of HDPE , Geofabric), GeoGrid or Flownet leakage detection, Geofabric and HDPE (Secondary layer). Details of the proposed containment layers are provided in Figure 9.



A description of the layer works depicted above follows:

- A. Clay (Low Permeability) Foundation
- B. Synthetic Liner System (including HDPE)
- C. Tailings Deposit.

Figure 9 Proposed TSF Containment Layers

A leakage detection system will be installed at the basin of the pit to detect any leakage or rupture within the liner(s). A collection sump will be located at the basin of the pit, directly next to the downstream toe. A HDPE riser pipe will be installed in the collection sump, allowing a water monitoring sensor to be lowered to determine if there is any leakage water. The operator will take regular readings throughout the operational life and beyond. If water is found in the leakage detection system, it will be removed as soon as possible to avoid the risk of leakage through the second HDPE liner.

The operator will maintain the tailings beach surface to ensure it remains wet and free from dusting, especially during windy conditions. Liquor from the TSF will be collected from each TSF using floating decant systems and returned to the plant for re-use.

Pipelines will be constructed within existing disturbed areas to transfer tailings and return water to and from the plant. The tailings transfer pipelines will be located within earthen bunds to minimise the extent of any potential leaks. The tailings pipelines will have leak detection systems incorporated into the design.

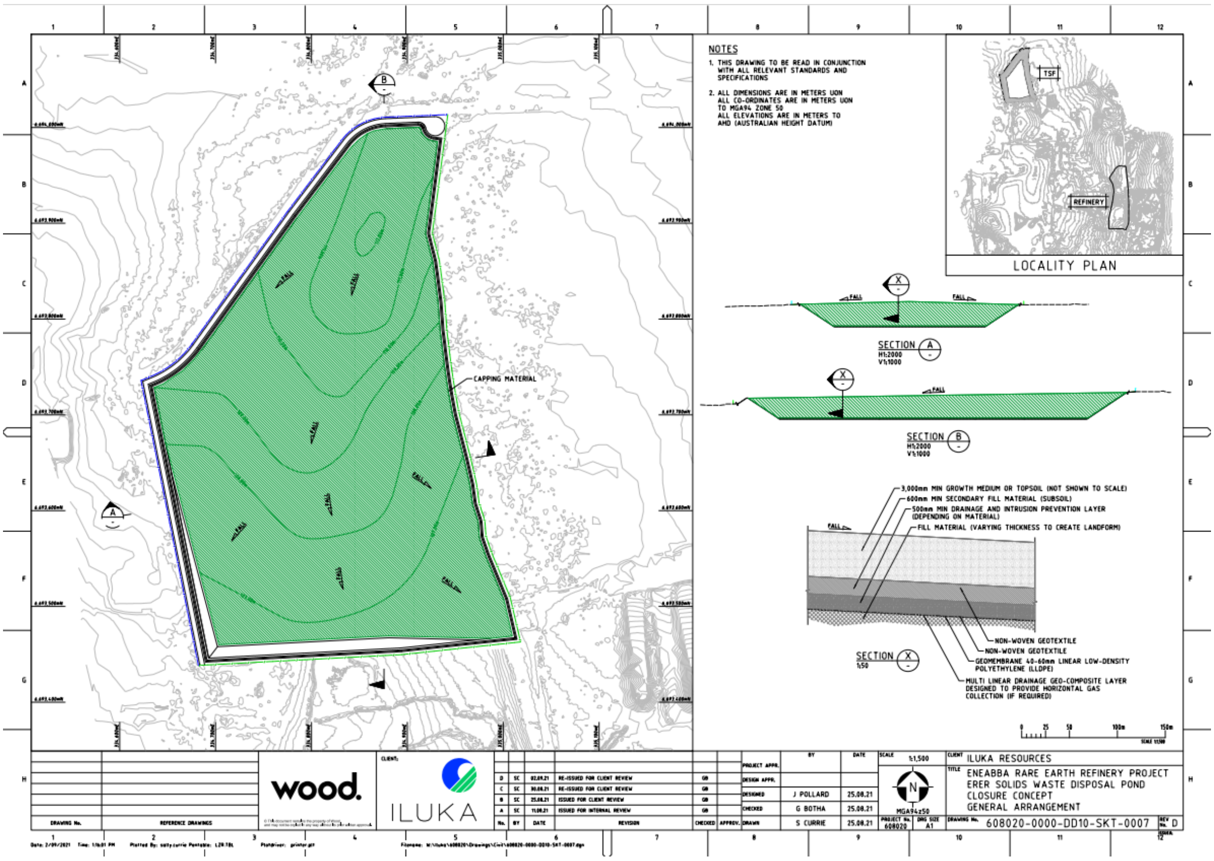
The perimeter of the newly excavated Yellow Pit will be fenced to restrict access to unauthorised personnel or stray animals.

13.2.1. ERER Waste Facility Rehabilitation and Closure

Design goals for the rehabilitation of the waste facility are to create areas that are safe, stable and non-polluting which minimise erosion. Soil profiles will be re-established to be capable of supporting either a self-sustaining ecosystem or an agricultural land use which aligns with the site wide closure plan.

A primary design objective for the closure of the TSF is to minimise surface water infiltration to reduce any movement of water through tailings and ultimately limiting pressure on the containment system. The overall closure capping thickness above the tailings will range between 4m and 9 m. The conceptual closure option is presented in Figure 10.

Management of potential exposure to the Naturally Occurring Radioactive Material (NORM) within the tailings is a closure design objective. The presence of NORM requires a minimum capping thickness of at least 4 m to ensure exposure from gamma radiation to potential occupants on the surface are below annual does rate. An intrusion prevention layer will be considered to prevent human, fauna, and flora intrusion into the waste materials.



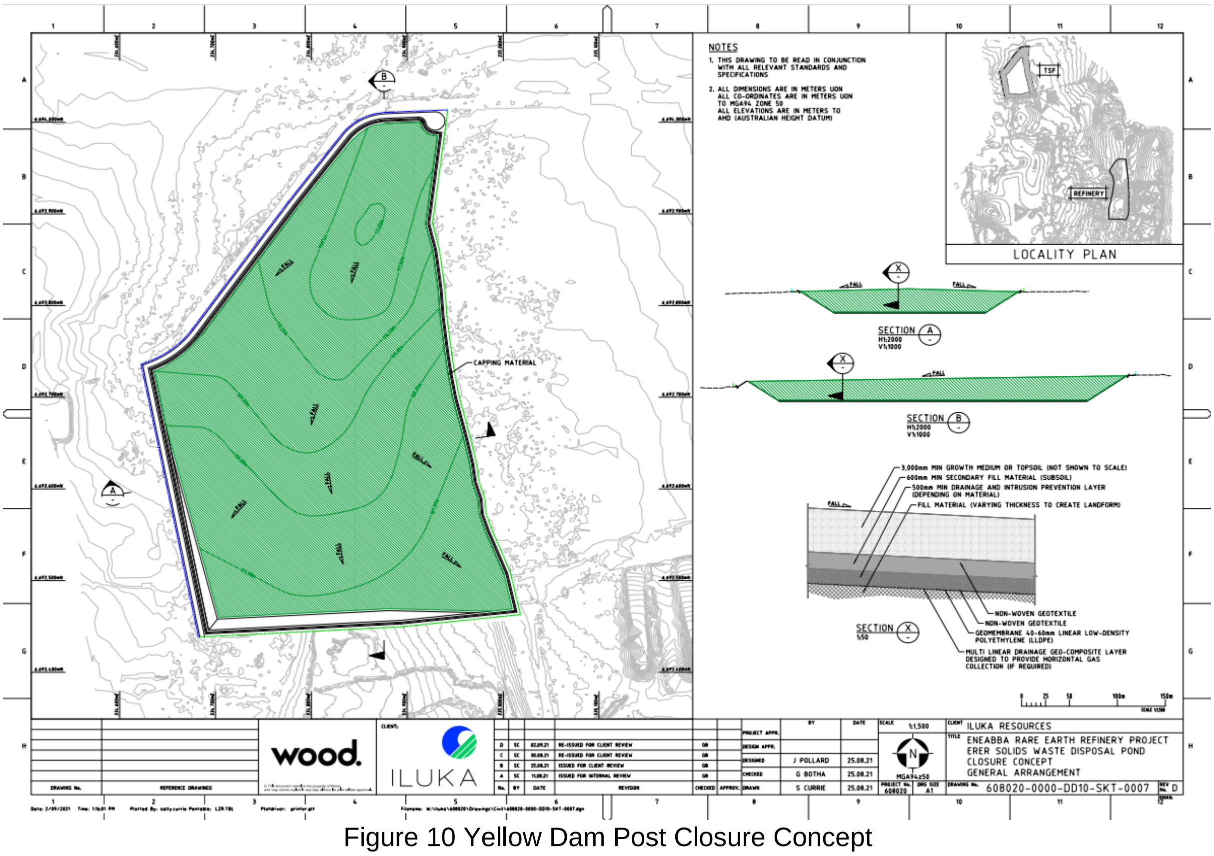


Figure 10 Yellow Dam Post Closure Concept

The conceptual cover closure solution is a growth medium with adequate storage capacity to sustain vegetation, bedding and potential intrusion prevention layers are included, as well as a drainage layer with adequate lateral drainage capacity to limit prolong ponding of water above the geomembrane. The LLDPE geomembrane provides an effective hydraulic barrier to seepage infiltrating the cover and seeping into the underlying tailings.

The proposed solution will have the capping layers as described below (from top to bottom) and as per Figure 11:

- Growth medium or topsoil 3 m (minimum)
- Secondary fill material (subsoil layer) 0.6 m (minimum)
- Geotextile (nonwoven polyester)
- Drainage and potential intrusion prevention layer (gravel or fragmented rock) 0.5 m (minimum)
- Geotextile (nonwoven polyester)
- Geomembrane – 40 to 60 mm Linear Low-Density Polyethylene (LLDPE)
- Multi linear drainage geo-composite layer designed to provide horizontal gas collection (if required)
- Additional fill material to create the final landform shape above the tailings. The thickness of this layer will vary.

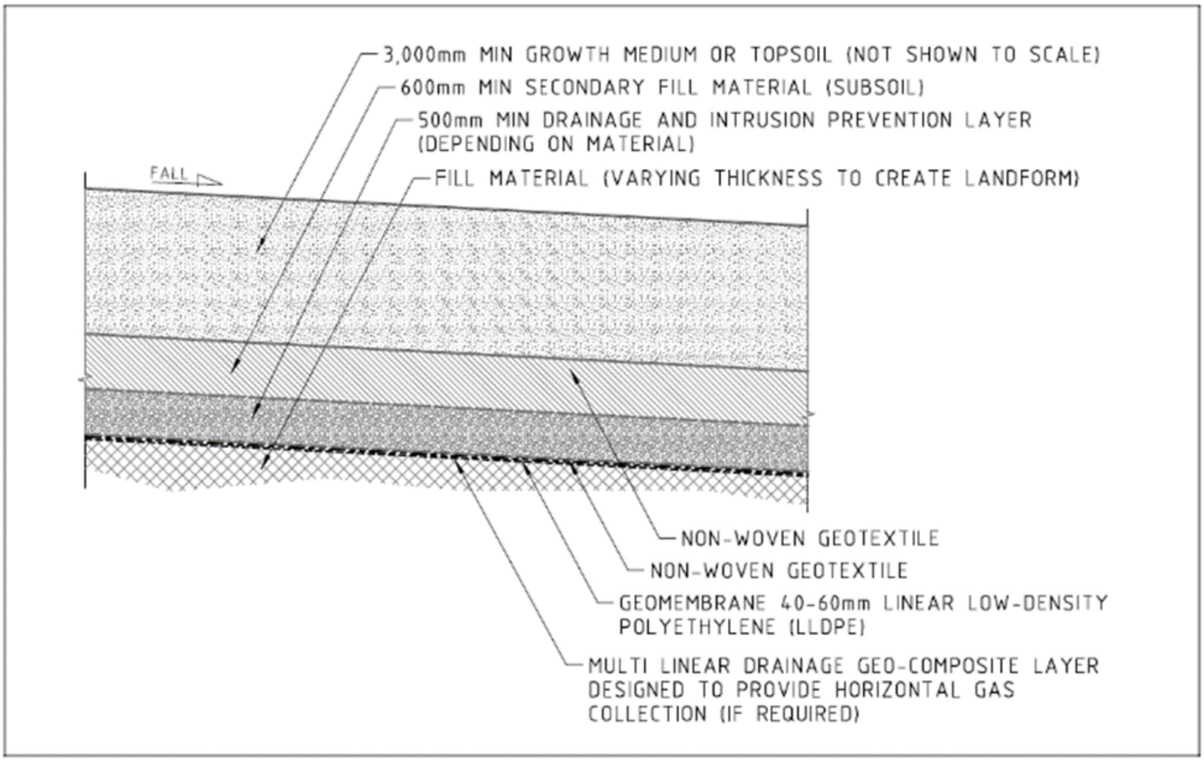


Figure 11 Yellow Dam Conceptual Capping Layers

Once Yellow Dam is in operation, North Monazite Pit will commence construction in accordance with the Yellow Dam basis of design. Yellow Dam South and the Monazite Pit will commence construction following the North Monazite Pit to provide a minimum Proposal life of over 20 years. The materials balance for the proposed waste facilities is summarised in Table 19. Excess material will be stockpiled with the overburden storage areas for reuse in the backfilling of other mine voids within the Eneabba State Agreement lease boundary.

Table 19 Waste Facility Materials Balance

TSF	Surface Area (ha)	Total Material Excavated (m^3)	Capping Material Required (m^3)	Tailings Storage Capacity (t)	TSF Life (yrs)
Yellow Dam North	14.4	975,000	440,000	1,302,650	6.5
North Monazite Pit	16.3	2,435,042	652,000	2,049,088	10.2
Yellow Dam South	10.8	1,515,280	432,000	1,275,108	6.4
Monazite Pit	10.3	0	412,000	1,206,503	6
Total	52	4,925,322	1,936,000	5,833,349	29.1

13.2.2. ERER Liquid Waste Management

Magnesia and ammonia will be recovered through the refinery, with the final liquid waste produced resulting from processing the liquid waste streams from magnesia and ammonia recovery through the reverse osmosis (RO) plant. The brine liquid waste produced as a by-product of the reverse osmosis (RO) plant, will be the only liquid waste produced by the refinery. The waste liquid brine will be recycled to process, but an emergency bleed evaporation pond will be constructed for storage and evaporated in a 2 ha lined evaporation pond, located within the refinery footprint.

13.2.3. Plant 3 Surface Water Management

Surface water management infrastructure will be constructed to divert water away from operations areas, prevent flooding and capture potentially contaminated water that falls within operational areas. This will include drains, diversions and stormwater collection. Surface water management infrastructure will be constructed in accordance with relevant guidelines to ensure effective management of flows.

13.2.4. ERER Scales Management

The extent and characterisation of Alpha scale which could potentially form from thermal processing like the rare earth sulphation bake / roast circuit, is not currently defined. It is not anticipated that lead or polonium would directly volatilise during the roast as the temperatures are not high enough. Secondary formation from decay of radon gas however remains a possibility, the extent of which will be dependent on residence time within the off-gas system, and whether radon emanation would significantly increase during the roasting process. Radon is a radioactive gas which will partially route to the off-gas or scrubber system (extent not currently quantified). Radon's progeny nuclides (lead; polonium and bismuth) have been observed in Iluka Synthetic Rutile (SR) plants at Narngulu and North Capel. The temperatures at which the SR kilns are operated is however high enough to also directly volatilise these nuclides, in addition to decay from radon gas. The presence of alpha scales and radon gas build-up will be evaluated during operations through gas and alpha measurements prior to any maintenance activities, per existing procedures for SR. Dependent on the activity concentrations of such scales, it would either be washed off during maintenance (if removable) and captured in the gas scrubber liquor system, neutralised, and routed to the solid waste residue, or stored for future disposal. Any removal of scales will be conducted in line with site specific procedures.

Potential Gamma scale is expected to form in circuits of acid contact, with specific reference to sulphuric acid. Radium is relatively mobile and would form stable precipitate from solution when in contact with sulphate (SO_4), thereby accumulating in sulphuric acid circuits as scales in vessels, pipes etc. Thorium precipitation can also occur around pH 3, depending on conditions. Gamma scales observed in Narngulu SR Plant acid circuit are dominated by Ra-228 and Th-228. To note: scale characterisation is dependent on the rare earth-bearing feed mineral phase; the amount of thorium and uranium present; and the ratio between thorium and uranium. Monazite feed is dominant in the thorium decay chain with Ra-228 mainly a gamma emitter, thereby accumulating as predominantly a gamma scale. Feed material with a higher component of the uranium decay chain (relative to thorium) could accumulate Ra-226 in a larger proportion, potentially giving rise to an additional alpha scale. The actual formation of such scales within Plant 3 leach section can however only be confirmed once in operation.

13.3. PROCESS WATER

Process water will be recycled where possible for reuse in processing. Water losses inevitably occur due to evaporation, lateral groundwater flow and deep percolation. Groundwater monitoring occurs as part of the Eneabba operation and this will continue during the Project . Results will be reported annually to the DMIRS and RCWA in the Environmental Radiation Report for Iluka's Midwest operations.

Stormwater will also be controlled to ensure process materials are not entrained within stormwater exiting ERER areas.

13.4. MONITORING AND REPORTING

Details relating to radioactive waste management will be reported annually in the Environmental Radiation Report for Iluka's Midwest Operations. Aspects to be reported include the volume of waste generated, radionuclide concentrations (total activity from head of chain in Bq/g) and disposal locations.

13.5. CONTINGENCY PLANNING

As part of the assessment and risk management process, contingencies are in place for significant risks associated with this Project. Some contingencies are included in relevant environmental management plans. For example, the Dust Management Plan (Iluka 2018) describes how accidental releases of dust (which may or may not contain slightly elevated radiation levels) are dealt with at the site.

In the event of any serious incident the Iluka Eneabba Emergency Management Team (EMT) would be activated to deal with the incident. The system used by the EMT is called EMQNET and allows a systematic approach to dealing with emergencies, recording actions and activities carried out during an incident. Incidents can be escalated to include corporate Iluka support (in the event of a significant incident) through the Iluka Crisis Management Team.

RCWA and DMIRS would be informed in the event of any serious incident occurring. Such incidents could include elevated radiation exposure above the levels described in this RMP, a transport incident which involved the spillage of monazite product in a public area, or any other incident deemed a significant radiation incident by the RSO.

13.5.1. Unexpected Site Closure or Reduced Demand for Rare Earths

As part of the contingency planning process Iluka has assessed the unlikely event of an unexpected site closure, or that the demand for product would suddenly cease.

In the event of unexpected site closure the following steps would be taken;

- Processing would cease and all unprocessed material would be returned to storage to ensure potential uncontrolled environmental contamination did not occur;
- ERER areas would be cleaned to remove all material, gamma surveys would be undertaken to ensure the gamma levels at the site were returned to those measured prior to processing;
- Rehabilitation provisioning (money set aside to complete closure of all Iluka sites) or operational funds would be used to cover the cost of this work.

In the event of a complete halt to sale of rare earth products occurring suddenly, an assessment would be carried out in relation to the prospects of resumption of sales by Iluka's Marketing team. If there was no likelihood of further sales, the actions outlined for the unexpected closure of the site would be taken.

In either event (or any significant unexpected event which is contrary to this RMP) the RCWA and DMIRS would be contacted in person by the Iluka RSO and the situation explained. This would include a description of the action Iluka would take. The Iluka Registered Manager for the relevant site would also send an official notification to the State Mining Engineer and the Secretary of the RCWA to detail the issue and action Iluka would take.

14. TRANSPORT

Transport of radioactive substances will be overseen by the RSO or Deputy RSO (Eneabba or Narngulu). Safety requirements for the transport of radioactive substances will be applicable to Transport of radiation gauges.

All transport of radioactive substances will be carried out under the ARPANSA code of practice for *Safe Transport of Radioactive Material* (ARPANSA 2008) and in accordance with license conditions provided under the *Radiation Safety Act* (1975) Section 36, including; radioactive substances to be transported in compliance with the Radiation Safety (Transport of Radioactive substances) Regulations 2002, and radioactive packages to be stored in accordance with regulation 30 of the Radiation Safety (General) Regulations. The samarium-europium-gadolinium-heavies-yttrium (SEGHY) carbonate would be the only rare earth product containing natural radioactivity, mainly due to the presence of the Sm-147 isotope. This Carbonate is classified as being radioactive, but not Class 7 under the transport regulations. None of the other rare earth products (oxides or carbonates) would be subject to the transport regulations.

15. RADIATION SAFETY RESOURCES

15.1. RADIATION PERSONNEL

Radiation Safety Officer (RSO): the project shall have an RSO to cover mining, processing and transport operations. The RSO shall be experienced, qualified and licensed and shall be responsible for:

- Advising the manager on matters relating to the implementation of the radiation management plan for the mine;
- Investigates any defects or malfunctions discovered in plant, equipment or procedure that cause exposure to radiation in excess of dose constraints or limits, or dose rates or contamination levels in excess of authorised limits;
- Prepare working rules for the safe use and operation of prescribed radioactive substances, x-ray equipment and electronic products on site;
- The regulations, or by a condition, restriction or limitation imposed on the registration;
- Ensure that no radioactive substances are used or stored and/or prescribed equipment is installed unless approved by the appropriate regulator;
- Make recommendations to the registrant on the need or otherwise for the medical examination of radiation workers;
- Maintain all records required by the regulations;
- Ensure that all radiation management plan commitments are implemented and monitored;
- Ensure that all reporting and monitoring is implemented as stipulated by this radiation management plan;
- Notify the regulators of an exposure to any person (other than to a patient for medical purposes) which exceeds the limits prescribed in the regulations;
    - Notify the regulators of any abnormal or unplanned radiation exposure as specified in the regulations.

Deputy Radiation Safety Officer (DRSO): the project shall have a dedicated DRSO based at the Eneabba site. The DRSO shall be the onsite monitoring technician and will also complete the training to become a licensed RSO. The DRSO shall be responsible for:

- Daily recording of radiation exposure times and dose meter readings for all workers on the project and compiling into weekly, monthly and annual reports and trends;

- Monitor personnel to determine the amounts and intensities of radiation exposure for each task and work area, investigating any high exposure levels, highlighting to the RSO and the Production Superintendent, and implementing controls;
- Determine intensities and types of radiation in work areas, equipment, or materials, using radiation detectors or other instruments;
- Instruct personnel in radiation safety procedures and demonstrate use of protective clothing and equipment;
- Provide first response to abnormal events or to alarms from radiation monitoring equipment;
- Collect samples of air, water, gases, or solids to determine radioactivity levels of contamination;
- Brief workers on radiation levels in work areas and inform them of their exposure levels.
- Determine or recommend radioactive decontamination procedures, according to the size and nature of equipment and the degree of contamination;
- Prepare reports describing contamination tests, material or equipment decontaminated, or methods used in decontamination processes;
- Set up equipment that automatically detects area radiation deviations and dust levels, as well as testing the detection equipment to ensure its accuracy;

The Senior Chemist at Narngulu will provide additional support as a designated RSO for Irradiating Apparatus and Electronic products such as laboratory XRF equipment.

15.2. RADIATION MONITORING EQUIPMENT

The following equipment will be used for area gamma-surveys and contamination checks:

RS125 GammaSpec meter used for environmental radiation surveys, with integrated GPS.
Radeye GX meter (thermo-fisher) with alpha probe (Ludlum 44-9 for surface contamination) and environmental gamma probe (Ludlum or similar). This meter will be used for environmental surveys in Plant 2 and around site, taking measurements near radiation gauges, and the alpha probe will be used for surface contamination checks.
Isotrak Doseguard or Thermo Fischer EPD TruDose electronic gamma detectors – used for short term personal gamma exposure measurement. The Tru Dose EPD monitors measure energy levels between 16KeV and 10,000KeV. The majority of energy released by the Th-232 (which is the predominant exposure source) is between 20KeV and 1,600KeV, with a small release of energy up to approximately 2,800KeV .
Radon (Rn222 and Rn220) electronic meter (either Durridge Rad7 or SARAD meter). We have access to a Durridge RAD7 and have purchased a SARAD EQF 3200 meter specifically for this project.
OSL badges – provided by Landauer with a minimum detection level of 10μSv.

The following equipment may be used for dust monitoring (equipment from Eneabba or Narngulu may be used for this and other monitoring):

- Ecotech high-volume samplers model No.2000; field calibrated prior to each use (high-volume environmental dust samples at $70m^3$/hour), and
- XR5000 dust pumps used for dust sampling monitoring at 2L/min. These samplers are to be field calibrated prior to each use. SKC 7 hole sample heads, with high efficiency glass fibre filter will be used for dust collection.
- Dust samples will be counted for alpha radiation after a holding period of 7 days using Tennelec alpha spectrometers with alpha pips detectors (active area $1200mm^{2)}$ these will be calibrated with an AM-214 alpha source weekly prior to use.
- If required AMAD will be measured using a Marple Personal Cascade Impactor (series 290).

16. GLOSSARY ABBREVIATIONS AND ACRONYMS

Critical Group: a group of members of the public comprising individuals who are relatively homogeneous with regard to age, diet and those behavioural characteristics that affect the doses received and who receive the highest radiation doses from a particular practice.

Designated employee: an employee who works, or may work, under conditions such that the employee's annual effective dose equivalent might exceed 5 millisievert.

NORM: Naturally Occurring Radioactive Material. Material containing no significant amounts of radionuclide's other than naturally occurring radionuclide's, disturbed or altered from natural settings, or present in technologically enhanced concentrations, above background radiation levels, due to human activities that may result in a relative increase in radiation exposures and risks to the public and the environment.

Notifiable level: A radiation exposure exceeding the Investigation Levels presented in Table 14 of this Radiation Management Plan.

Radioactive Material: Material containing more than 1Bq/g thorium and uranium (head-of-chain). The following extract is NORM Guideline 2.1 "The classification of what is a `radioactive material' varies depending on the legislation used. IAEA Standards], the Transport Regulations, the Contaminated Sites legislation, and the *Radiation Safety Act* (1975), all have different definitions. The Mining Code accepts the same 1Bq/g as the IAEA for head-of-chain uranium or thorium ores or mineral concentrates. For example, in the IAEA Basic Safety Standards 115 it is a material containing greater than 1 Bq/g U-238 and Th-232T while under the *Radiation Safety Act* (1975) it is material containing greater than 30 Bq/g whole U-238 and Th-232 Decay Series.

Radioactive Material for Transport: Material containing more than 10Bq/g thorium and uranium (head-of-chain).

Radiation Safety Officer – Person appointed under MSIR 16.9 and under WA Radiation Safety Regulations (Qualifications, 1980).

Radiation symbols - α - Alpha radiation, β – Beta radiation and γ- Gamma.

Significant Changes – As discussed in section 1 - The following are regarded as "significant changes" or variations and formal notification to the relevant regulatory authority will be provided:

1. any unanticipated circumstances that may lead to a variation in the performance of the approved RMP;
2. variations to operational procedures, changes in equipment in the mine or processing plant, or to the scope or output of the Project that may significantly increase exposure of employees or members of the public;
3. Cessation of operations.

Abbreviations and Acronyms

	Definition
µSv	microsievert (1 Sv = 1000 mSv [millisieverts] = 1,000,000 µSv [microsieverts])
µGy	Micro-gray
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
ANSTO	Australian Nuclear Safety & Technology Organisation
ALARA	As Low As Reasonably Achievable
CCTV	Closed Circuit Television
COP	Code of Practice (2019 ARPANSA Safe Transport of Radioactive Material RPS 2 (rev. 1))
CS Act	Contaminated Sites Act 2003 (WA)
DCFi	Dose Conversion Factors
DMIRS	Department of Mines, Safety and Industry Regulation
DWER	Department of Water and Environmental Regulation
EDE	Effective Dose Equivalent
EMP	Eneabba Monazite Pit

Abbreviations and Acronyms

	Definition
EPD	Electronic Protection Device (Personal electronic gamma monitor)
ERER	Eneabba Rare Earths Refinery
ERICA	Environmental Radiation Modelling tool
FEL	Front End Loader
GIS	Geographic Information System
GLOS	Groundwater License Operating Strategy (set by DWER)
HMC	Heavy Mineral Concentrate
HM	Heavy Mineral
hr	Hour
IAEA	International Atomic Energy Association
ICRP	International Commission on Radiation Protection
JHA	Job Hazard Assessment
Km	Kilometre (1000 metres)
kt	Kilotonne (1000 tonnes)
MSC	Mineral Sands Concentrate (also referred to as By-product in Narngulu RMP)
MSI Act	Mines Safety and Inspection Act 1994
MSIR	Mines Safety and Inspection Regulations 1995
MSP	Mineral Separation Plant (located at Either Narngulu or Capel)
mSv	Millisievert (1 Sv = 1000 mSv [millisieverts] = 1,000,000 μSv [microsieverts])
NORM	Naturally Occurring Radioactive Material
NSR	Narngulu Synthetic Rutile plant
Occupancy	An amount of time spent in a specific location or area (100% = 8760 hours/year)
ppm	parts per million
PTW	Permit To Work (form)
RCWA	Radiological Council of Western Australia
RESRAD	Residual Radiation – radiation modelling program.
RMP	Radiation Management Plan
RWMP	Radioactive Waste Management Plan (usually included as part of RMP)
SC	Sea Container (generally 20 ft long, could be 40ft, half or full height)
SJP	Standard Job Procedure
Sv	Sievert (1 Sv = 1000 mSv [millisieverts] = 1,000,000 μSv [microsieverts])
TML	Transport Moisture Limit
WA	Western Australia
WAPOL	Western Australian Police Force
y	Year

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APPENDIX 1: ILUKA STANDARD JOB PROCEDURE LIST

SJP No.	Standard Job Procedure – Midwest Radiation Management Plan
SJP MW RMP 01	Radiation Emergency Procedure
SJP MW RMP 02	Fixed Gauges Procedure
SJP MW RMP 03	Occupational Dust Monitoring
SJP MW RMP 04	Alpha Counting and Equipment Calibration
SJP MW RMP 05	High Volume Dust Monitoring
SJP MW RMP 06	Groundwater Monitoring
SJP MW RMP 07	Occupational Gamma Monitoring
SJP MW RMP 08	Transport of Radioactive Materials
SJP MW RMP 09	Surface Radiation Contamination Testing
SJP MW RMP 10	Gamma Survey Monitoring (using RS-125 meter)
SJP MW RMP 11	Environmental Radon Monitoring

APPENDIX 2 : PROCESS FLOW DIAGRAM OVERVIEW

ERER flow diagram