HASTINGS
Technology Metals Limited

APPENDIX 5-7

Radiation Waste Management Plan

10 December, 2016

Radiation Waste Management Plan

Revision 0

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Executive Summary

Hastings Technology Metals Limited (Hastings) Yangibana Rare Earths Project (the Project) is targeting rare earth elements in ferrocarbonatite veins in four deposits. An open cut mining method will separate waste rock and ore. The ore will undergo processing: Beneficiation and Hydrometallurgy. Tailings from the process plant will be directed to Tailings Storage Facilities (TSFs). Three separate tailings streams will be produced from the processing plant, disposed of in distinct TSFs. Two of the tailings streams contain radionuclides at concentrations of approximately 7 Bq/g and 24 Bq/g and will be disposed in TSF 2 and TSF 3, respectively. The design specification for each TSF will differ due to varying chemical and radionuclide composition, and taking account of the surrounding environment.

The objective of this RWMP, as stated in the Mining Code (ARPANSA 2005) is to:

"*...ensure that there is no unacceptable health risk to people, both now and in the future, and no long-term unacceptable detriment to the environment from the waste so managed, and without imposing undue burdens on future generations*."

Nearest sensitive environmental receptors include:

- Lyons River and Frasers Creek (significant cultural heritage values, and associated aquifers downstream from the TSFs);
- Pastoral bores (closest one is 2 – 3 km from TSF 2 and 3); and
- Employees at the Project site.

The risks associated with the radioactive waste, namely tailings to be deposited in TSF 2 and 3, include:

- Seepage of leachable heavy metals and contaminants;
- Dust generation at ROM pad, processing plant and TSFs;
- Contaminated surface water; and
- Long-term TSF integrity following decommissioning and closure.

A description of the proposed system for waste management during design, construction, operation and closure of the Project is provided, a program for monitoring and contingency planning should risk mitigation fail, and reporting are also described. Periodic review of the adequacy and effectiveness of the RWMP takes account of potential improvements consistent with best practicable technology.

This RWMP will be further developed throughout each phase of the Project, and will also be reviewed whenever there is a significant change in the operation of the TSFs or process plant that may impact engineering considerations for the TSF design and implementation of the design criteria.

1 Introduction

1.1 Overview

Hastings Technology Metals Limited (Hastings) is proposing to develop the Yangibana Rare Earths Project (the Project), which is situated approximately 270 km north-east of Carnarvon and approximately 100 km north-east of Gascoyne Junction, in the upper Gascoyne region of Western Australia (Figure 1). Hastings is targeting rare earth elements in ferrocarbonatite veins in four deposits. An on-going exploration program across Yangibana tenements may discover other feasible deposits to mine. An open cut mining method will separate waste rock and ore. Waste rock landforms will be situated next to each pit. The ore will undergo processing: Beneficiation and Hydrometallurgy. Tailings from the process plant will be directed to Tailings Storage Facilities.

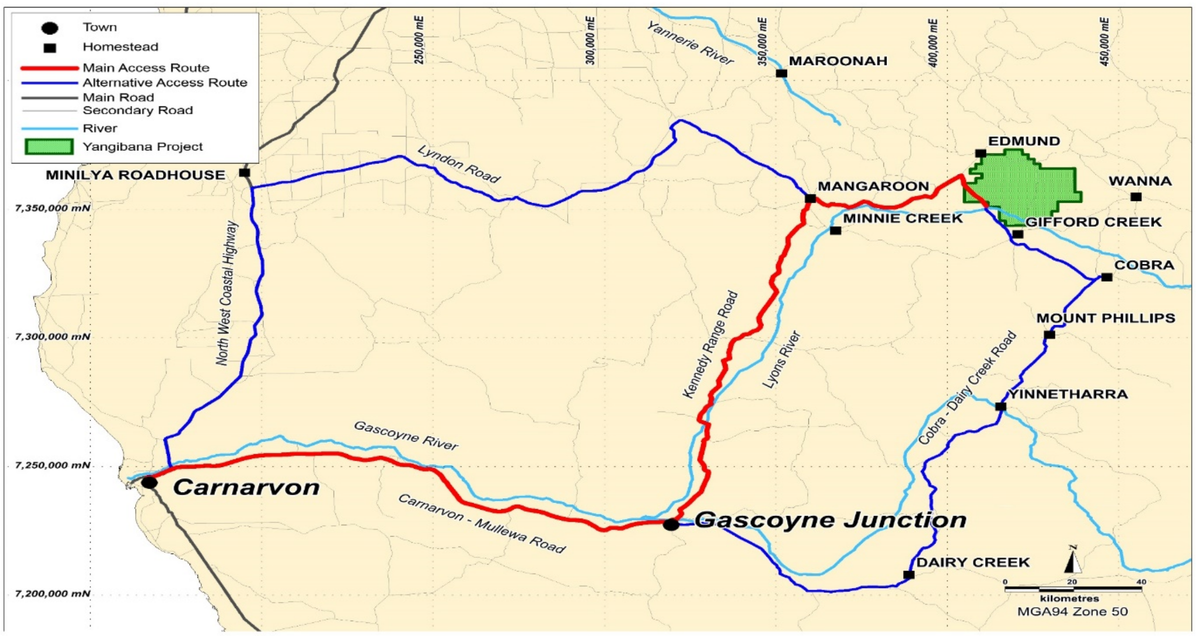

Figure 1 Location of the Yangibana Rare Earths Project

1.2 Scope

The mineralized zone of the target ore body at the Project contains radionuclides. During processing, these radionuclides become concentrated in two of the three tailings waste streams. The radioactive tailings comprise less than 9% of the total tailings. This Radioactive Waste Management Plan (RWMP) describes how radioactive waste, generated from processing streams, will be managed at the Project.

This RWMP meets the requirements set out in the following documents:

- *Code of Practice for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing* (ARPANSA 2005) (the Mining Code); and
- *Managing naturally occurring radioactive material (NORM) in mining and mineral processing guideline. NORM 4.2. Management of radioactive waste* (Department of Mines and Petroleum 2010) (NORM Guideline 4.2).

This RWMP will form a component of the Yangibana Environmental Management System (EMS), which operates on a continual improvement cycle of plan, do, check and act. This RWMP is considered a 'live' document and will be further reviewed during the Detailed Engineering Design phase when the Project will be further refined, and defined in greater detail. Formal approval of this document will be sought from the Department of Mines and Petroleum and Radiological Council prior to the operations phase of the Project.

1.3 Objective

The objective of this RWMP, as stated in the Mining Code (ARPANSA 2005) is to:

"*...ensure that there is no unacceptable health risk to people, both now and in the future, and no long-term unacceptable detriment to the environment from the waste so managed, and without imposing undue burdens on future generations*."

1.4 Key Elements

The key elements of this RWMP (as set out in NORM Guideline 4.2) include:

- An outline of the processes generating waste (Section 3 Background).
- A description of waste including nature of material (chemical, physical and radiological), contaminants, and quantities and rate of production (Section 3 Background).
- A description of the environment into which the waste will be discharged or disposed (climate, terrain, soils, vegetation, hydrology), including the baseline radiological characteristics (Section 3 Background).
- Heritage (social and cultural) and land use (present and potential) (Section 3 Background).
- A description of the proposed system for waste management including the facilities and procedures involved in the handling, treatment, storage and disposal of radioactive waste (Section 4 Management).
- Predictions of environmental concentrations of radionuclides and radiation doses to the public from the proposed waste management practice, including demonstration that the statutory radiation protection requirements will be met both now and in the future (Section 4 Management).

- A program for monitoring the concentration of radionuclides in the environment and assessment of radiation doses to members of the public arising from the waste management practices (Section 5 Monitoring).
- Contingency plans for dealing with accidental releases and the circumstances which might lead to uncontrolled releases of radioactive waste in the environment (Section 6 Contingency Planning).
- Contingency plan to cover cases of early shutdown or temporary suspension of operations (Section 6 Contingency Planning).
- A schedule for reporting on the waste disposal operation and results of monitoring and assessments (Section 7 Reporting).
- A plan for the decommissioning of the operation and associated waste management facilities, and for the rehabilitation of the site (Section 4 Management).
- A system of periodic assessment and review of the adequacy and effectiveness of the RWMP to take account of potential improvements consistent with best practicable technology (Section 8 Review).

1.5 Supporting Documentation

Documentation that should be read in conjunction with and complement this RWMP include:

- Baseline Radiation Report (Radiation Professionals, 2016a);
- Radiation Waste Characterisation Report (Radiation Professionals,2016b);
- Construction and Operations Radiation Management Plans (Hastings Technology Metals Limited, 2016a and b);
- Cultural Heritage Management Plan (Hastings Technology Metals 2016c);
- Mine Closure Plan (Ecoscape 2016b);
- Vegetation and Flora Assessment Report (Ecoscape 2016c);
- Subterranean Fauna Assessment Reports (Ecoscape 2016d);
- Soils Assessment (Landloch 2016a);
- Waste rock characterisation (Landloch 2016b and Trajectory and Graham Campbell and Associates 2016);
- Air Quality Assessment Report (Pacific Environment 2016);
- Conceptual Hydrogeological Assessment (Global Groundwater 2016); and
- Surface Water Assessment Report (JDA 2016).

1.6 Relevant Legislation

Assessment of environmental legislation relevant to the Project highlighted a number of approvals required prior to commencement of proposed activities. Legislation relevant to one or more phases of the Project includes:

- *Aboriginal Heritage Act 1972*;
- *Contaminated Sites Act 2003*:
- *Dangerous Goods Safety Act 2004*;
- *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act);
- *Health Act 1911*;
- *Mines Safety and Inspection Act 1994*;
- *Radiation Safety Act 1975*;
- *Rights in Water and Irrigation Act 1914*; and
- *Wildlife Conservation Act 1950* (WC Act).

2 Background

2.1 Processes generating waste

2.1.1 Mining

Open cut pits will be operated as blast and haul. Waste rock landforms will be constructed next to each respective pit. Radiation levels are low (averaging 0.3 – 0.9 Bq/g) in waste rock and are not classified as radioactive material using the 1 Bq/g value adopted by ARPANSA (2014) (Radiation Professionals 2016b). This material is also relatively inert geochemically, being classified as Non-acid Forming (NAF) and with low metal and metalloid concentrations (Trajectory and Campbell and Associates 2016).

2.1.2 Processing

An on-site beneficiation plant would treat up to 1 million tonnes per annum (tpa) of mineralised monazite ore. Approximately 30,000 tpa of mineral concentrate would be produced and then further processed via a hydrometallurgical process. Approximately 12,000 tpa of rare earth oxide (REO) concentrate (product) would result from the process plant. The REO concentrate will be stored in secure containment in the preparation for transport to port.

The beneficiation process would involve crushing and grinding, and flotation of the ore. The majority of tailings (waste product) will be generated during this stage, and be sent to Tailings Storage Facility 1 (TSF1) (approx. 930,000 tpa). Regrinding and flotation of the ore will then generate additional tailings and a clean concentrate. A thickener will be added to tailings before being sent to TSF2 (approx. 37,000 tpa). Following thickening and filtering, the concentrate will then be sent to the hydrometallurgical plant.

The hydrometallurgical plant will involve sulphation bake in a kiln, and then water leach to liberate and leach the rare earths into solution. The acidic solution is then neutralised with a magnesium oxide, he residue of which is filtered and separated from the solution. The residue is further treated prior to disposal in TSF3 (approx. 56,000 tpa). The leach liquor will then be purified to remove any impurities present prior to precipitation of the REO concentrate. The effluent (approx. 480 000 m^3/annum) from the precipitation stage is directed to the evaporation pond.

2.2 Description of waste

2.2.1 Nature of material (chemical, physical and radiological)

Tailings from a bench-scale process have been generated as a component of metallurgical testing. Preliminary characterisation analysis of the bench-scale tailings samples has provided a reasonable indication of the general classifications of the tailings. Trajectory (2016) summarises the outcomes from characterisation studies as follows:

TSF 1 is expected to be benign geochemically (i.e. non-acid forming (NAF)) with slight enrichments of metals in both the tailings solids and contact waters that were analysed. TSF 1 tailings will have radionuclide readings below the probable relevant thresholds (< 1Bq/g) (Radiation Professionals 2016a).

TSF 2 is expected to be benign geochemically (NAF) with slight to moderate enrichments of metals in both the tailings solids and contact waters. TSF 2 tailings will have radionuclide levels that exceed probable relevant thresholds (~7 Bq/g; Radiation Professionals 2016a). Radionuclides will not be water soluble in these tailings.

TSF 3 tailings-solids are also expected to be NAF, though strongly gypsiferous (Total-S ca. 10 %), due to neutralisation of the acidic raffinate with calcite. The tailings may be slow / difficult to drain and consolidate to a trafficable surface. Radionuclide levels are in excess of expected thresholds (~24 Bq/g; Radiation Professionals 2016a) and are water soluble due to the 'cracking' of the chemicals during the sulphation bake treatment in the hydrometallurgy process.

Further detailed information can be obtained in Trajectory (2016). The next stage of waste characterisation studies will occur when more representative tailings samples are produced from a pilot plant.

2.2.2 Contaminants

Elevated radionuclide concentrations in TSF 2 and 3 are the only contaminants that will trigger consideration under the *Contaminated Sites Act 2003* (WA).

2.2.3 Quantities and rate of production

Three separate tailings streams will be produced from the processing plant, disposed of in distinct TSFs. The design specification for each TSF will differ due to varying chemical and radionuclide composition. Chemical and physical characteristics, source and disposal location of each tailings stream is summarised in Table 1. Over the life-of-mine, approximately 7.2 million tonnes of tailings will be produced. Less than 9% of tailings will be considered radioactive.

Table 1 Source, Disposal and General Characteristics of Tailings Streams

Processing source	Tailings mass (%)	Annual rate (tpa)	Physical processing	Chemical properties	Radionuclide concentration	Disposal
Beneficiation	95.5%					
1. Rougher circuit	91%	932,100	Crushed and milled ore, flotation	Trace flotation reagents; pH 10-11.5	<1 Bq/g (head of chain)	TSF 1
2. Cleaner circuit	4.5%	37,200	Crushed and milled ore, flotation	Trace flotation reagents; pH 10-11.5	~ 7 Bq/g (head of chain)	TSF 2
Hydrometallurgical	5.5%	56,000	Acid Heating Water leach Neutralisation and waste removal Thickening	Trace sulphuric acid; U and Th; Iron phosphates Aluminium; Gypsum Metal hydroxides; pH 7-8	~24 Bq/g (head of chain)	TSF 3
TOTAL	**100%**	**1,025,300**				

2.3 Description of environment

A summary of the following environmental values at the Project site are described in Appendix A:

- Climate
- Terrain
- Vegetation
- Hydrology

2.4 Baseline radiological characteristics

Environmental monitoring programs have been implemented to coincide with ongoing occupational monitoring programs during exploration programs (Radiation Professional 2016b). Surveys have been completed over areas that are significant to the operation, prior to any disturbance of local conditions (Radiation Professional 2016b).

The baseline data includes:

- Gamma radiation.
- Radionuclides in dust.
- Radon and thoron concentrations.
- Radionuclides in soil.
- Radionuclides in water (surface and groundwater).

This Baseline Radiation Report (Radiation Professionals 2016b) is based on data collected in monitoring programs that have been running for at least 12 months. Monitoring on site is ongoing. Data is also available in the Yangibana Rare Earths Project Annual Radiation Reports.

2.4.1 Gamma radiation

Baseline gamma radiation levels have been determined via three methods; handheld instrument gamma surveys, integrating monitors and interpretation of an aerial radiometric survey (Radiation Professionals 2016b).

The monitoring shows that gamma radiation levels are elevated above mineralisation as expected, which is associated with the outcropping ironstone. Radiation Professionals (2016b) reported average gamma radiation dose rates are 0.23 $\mu Gy.h^{-1}$ in areas away from the outcropping mineralization. Average gamma radiation dose rates are 0.37 $\mu Gy.h^{-1}$ over the deposit areas and range up to 1.26 $\mu Gy.h^{-1}$.

2.4.2 Radionuclides in dust

Baseline environmental dust sampling was conducted across the project area, from 2015 onwards, using low volume pumps (SKC AirLite and SKC Airchek 52) to collect samples over a period of at least four hours (Radiation Professionals 2016b). Airborne alpha activity concentrations are similar for all areas of the project, both over the prospects and in areas away from radiologically enhanced mineralization (Radiation Professionals 2016b). The average airborne activity on and off the deposit was 0.01 and 0.009 $\alpha dps.m^{-3}$, respectively (Radiation Professionals 2016b).

2.4.3 Radon and thoron concentrations

Radon and thoron monitoring, commenced in 2015 using Landauer Radtrak devices, which were placed at four locations around the Project areas, with one pair measuring a background location at Gifford Creek Station Homestead, approximately 20 km south of the Project area (Radiation Professionals 2016b). Monitors were placed in pairs, one measuring radon only and the other measuring radon and thoron. Monitors were replaced at intervals determined by access to site, and exposure periods have ranged from 144 days up to 173 days.

Many of the radon-only monitors returned results below the minimum detection level (MDL). For estimation of values for radon and thoron concentrations, it was assumed that any result below the MDL is equivalent to the MDL value (Radiation Professionals 2016b). Radon and thoron results are presented in Table 2.

In addition to passive monitoring, real time monitoring was conducted using a portable radon detector (Durridge RAD7, 2010; see Radiation Professionals 2016b)).

Table 2 Radon and thoron levels (Radiation Professionals 2016b)

Location	Average Radon ($Bq.m^{-3}$)	Average Thoron ($Bq.m^{-3}$)
Bald Hill	9.9	24.6
Fraser's	9.9	29.1
Yangibana North	10.4	16.9
Gifford Creek H.S	9.1	15.5

2.4.4 Radionuclides in soil

Both subsurface and topsoil samples were collected and analysed for uranium and thorium (Radiation Professionals 2016b).

Subsurface samples were taken from eight drill holes below the surface, within or immediately adjacent to mineralisation and were selected to be approximately representative of the Project target resource material. Samples were analysed for total uranium and thorium, and by gamma spectroscopy (ESR) for members of each decay chain (Radiation Professionals 2016b).

Analysis shows that concentrations of uranium and thorium in mineral samples vary widely. Comparison with the wider data set indicated that higher concentrations of radionuclides are found with the target rare earths oxides in mineralised areas compared to surrounding granites and metamorphics (Radiation Professionals 2016b).

A single topsoil sample was taken from a location in the Gossan prospect area of the Project site (Table 3).

Table 3 Concentration of radionuclides in a single topsoil sample (Radiation Professionals 2016b)

ID	Elemental Analysis		Potassium Mass		Radionuclide Analysis			
	U ($mg.kg^{-1}$)	Th ($mg.kg^{-1}$)	K ($Bq.kg^{-1}$)	K (Mass %)	Ra^{226} ($Bq.kg^{-1}$)	Ra^{228} ($Bq.kg^{-1}$)	Pb^{210} ($Bq.kg^{-1}$)	Th^{228} ($Bq.kg^{-1}$)
RP1163/ CS002	0.368	7.87	1080 ± 120	3.49 ± 0.40	16.9 ± 1.4	36.5 ± 2.7	30.3 ± 5.1	38.6 ± 4.1

2.4.5 Radionuclides in water (surface and groundwater)

2.4.5.1 Groundwater

Water sampling and analysis was conducted by ATC Williams in 2015 and Hastings in 2016 at a number of existing bores within the pit footprints of the Project, within approximately 5 km of the Project and the surrounding region. Available data outputs from both ATC Williams and Hastings' commissioned analysis show a high level of regional and local variation ranging from 0.004 to 0.038 mg/L and <0.001 mg/L of uranium and thorium levels, respectively.

A sample was collected by Radiation Professionals (2016b) from an exploration hole within the Yangibana West prospect in mid-2015 for analysis by gamma spectroscopy to determine concentrations of soluble radionuclides (Table 4).

Table 4 Concentrations of soluble radionuclides from Yangibana West pit footprint

Sample ID	Ra_{226} ($Bq.kg^{-1}$)	Ra_{228} ($Bq.kg^{-1}$)	Pb_{210} ($Bq.kg^{-1}$)
YW-RC0003A	0.0308 ± 0.0077	0.046 ± 0.019	<0.080

2.4.5.2 Surface water

In October 2016, Hastings collected water samples from two ephemeral pools (LC - Pool 800US and FR – Pool) on the Lyons River, which only flows after heavy rainfall events. The pools are located approximately 5-10 km from the proposed processing plant area. Results are presented in Table 4.

Table 5 Uranium and thorium concentration in Lyons River and Frasers Creek ephemeral pools

Location	Total uranium ($mg.L^{-1}$)	Total thorium ($mg.L^{-1}$)
LC-Pool 800US	0.004	<0.001
FR - Pool	0.001	<0.001

2.5 Heritage

2.5.1 Aboriginal

Consultation with Yamatji Marlpa Aboriginal Corporation (YMAC) and Kulyumba Aboriginal Corporation has been undertaken to identify relevant Traditional Owner groups. Recently the combined Tiin-Mah Warriyangka, Tharrkari, Jiwarli submitted a native title claim (WC2016/003) (WAD464/2016) over the Project area and beyond. This means that Mining Agreements will be formally negotiated and implemented. Hastings is building a good relationship with the Traditional Owners, and will formally negotiate the necessary agreements.

A search of the Aboriginal Heritage Inquiry System on the DAA website on the 8th of March, 2016 reported no previously recorded Aboriginal heritage sites or other places within the Project area (Brad Goode and Associates, 2016). There are 4 sites within a 45km radius of the Project area, however these will not be impacted by the Project. One of these sites is located 800 m from the proposed accommodation facilities (Brad Goode and Associates, 2016).

During heritage surveys, several sites were found within or adjacent to Project areas (Brad Goode and Associates, 2016). The Combined Thiin-Mah Warriyangka, Tharrkari, Jiwarli WC2016/003 Native Title Claim group representatives' requests that:

- A 150m exclusion buffer zone is placed on either side of all natural waterways;
- Native vegetation clearing is to be kept to a minimum; and
- The Traditional Owners be re-consulted when the location of the proposed tailings storage facilities have been finalized, and that the TSFs be actively managed in order to ensure that they do not contaminate or pollute any natural waterways (Brad Goode and Associates, 2016).

A Cultural Heritage Management Plan (Hastings Technology Metals Limited, 2016c) describes management of cultural heritage values associated with the Project.

2.5.2 European

The existence of European heritage values within the Yangibana Project area has been investigated through the Australian Heritage Commission and Heritage Council of Western Australia databases. No sites of European heritage were identified within or immediately adjacent to the mine activities envelope.

Two European heritage sites were located within the region of the Yangibana tenements - Cobra Station (formerly Bangemall Hotel), Place 04129 and the old Cobra Station, Place 15419. Both are listed on the Western Australian heritage register.

2.6 Land use (present and potential)

The predominant land use in the area is pastoralism with limited tourism.

Historically the Gascoyne Bioregion has been used extensively for pastoralism i.e. grazing of sheep, goats and cattle on pastoral stations (Ecoscape 2016c). Currently, pastoralists only graze cattle due to feral dogs significantly reducing sheep and goat numbers. Ecoscape (2016c) quotes the *Rangelands-Taking the Pulse Report* (Department of the Environment 2008), which describes the Gascoyne bioregion as being grazed at between 70-80% from 1992 to 2005.

Wanna, Edmund and Gifford Stations occur in the near vicinity of the project, with Wanna Station being the closest at approximately 10 km from the TSFs. Pastoral bores are located within the shallow calcretes along the Lyons River and Frasers Creek. The nearest pastoral bore is situated approximately 2 km from the TSFs.

Gascoyne Junction is the nearest town (population of approximately 250), and occurs downstream at the junction of the Lyons River and Gascoyne River, approximately 150 km from the Project area. This town is a centre for mining, tourism and pastoralism.

3 Management

3.1 Risk Assessment

A risk based approach has been used to identify hazards, unwanted events and risks associated with the processing and disposal of radioactive waste. A risk assessment, based on the *Leading Practice Sustainable Development Program for the Mining Industry - Risk Assessment and Management* (Department of Resources, Energy and Tourism (DRET) 2008), is a component of the Hastings EMS (*Risk Procedure*). The risk assessment is applicable to the all phases of the Project, including the Definitive Feasibility Study (DFS). The risk assessment and associated register is a living process and will be updated during subsequent phases of the Project and then annually following commencement of operations (unless change management or major incidents dictate that it should be sooner):

- Detailed Engineering phase;
- Construction phase; and
- Operations phase.

Nearest sensitive environmental receptors include:

- Lyons River and Frasers Creek (significant cultural heritage values, and associated aquifers downstream from the TSFs);
- Pastoral bores (closest one is 2 – 3 km from TSF 2 and 3); and
- Employees at the Project site.

The risks associated with the radioactive waste, namely tailings to be deposited in TSF 2 and 3, include:

- Seepage of leachable heavy metals and contaminants;
- Dust generation at ROM pad, processing plant and TSFs;
- Contaminated surface water; and
- Long-term TSF integrity following decommissioning and closure.

The risks associated with radioactive waste are also applicable to other contaminants in the tailings materials. The following describes mitigation actions to be implemented.

3.2 Mitigation of Risk

3.2.1 Design criteria

Design and engineering of TSF 2 and 3 will be a critical component of the Definitive Feasibility Study and Detailed Design phases of the Project.

Studies that have been or will be completed to inform the TSF design include, but not limited to:

- Climate
- Physical and geochemical assessment of tailings and waste rock
- Surrounding environmental, heritage and social values
- Surface water and groundwater assessment
- Water inputs and outputs i.e. water balance
- Water quality
- Description of the process
- A geotechnical assessment

Design features of TSFs taking into consideration the concentration of radionuclides is summarized in Table 6.

Table 6 Proposed TSF Design Features

Design feature	TSF1	TSF2	TSF3
Proportion of process tailings	91%	4%	5%
Radionuclide concentrations	< 1 Bq/g	~ 7 Bq/g	~ 24 Bq/g
Maximum height (m)	Perimeter embankments – 6 m Tailings stack – 15 m	Perimeter embankments – 6 m	Perimeter embankments – 6 m
Area (ha)	100 ha	7 ha	11 ha
Number of cells	1	1	1
Construction	Downstream perimeter embankment raising	Downstream perimeter embankment raising	Downstream perimeter embankment raising
Discharge method	Single point Central Thickened Discharge (CTD)	Perimeter spigots	Perimeter spigots
Lining	Proof compacted basal clayey sand layer	HDPE / other + compacted clayey sand	HDPE / other + compacted clayey sand
Encapsulation	Nominal capillary break/erosion protection + topsoil	HDPE/ compacted clayey sand base. HDPE/CCL engineered capping with waste rock cover and topsoil. Design in accordance with IAEA safety standards to provide safe containment of LLW / NORM radionuclides for periods beyond the extent of institutional control.	HDPE/ compacted clayey sand base. HDPE/CCL engineered capping with waste rock cover and topsoil. Design in accordance with IAEA safety standards (WS-G-6.1) to provide safe containment of LLW / NORM radionuclides for periods beyond the extent of institutional control. Leak detection.
Leak detection	Downstream groundwater monitoring holes	Downstream groundwater monitoring holes	Downstream groundwater monitoring holes + underdrain between the clay layer and the HDPE with sump

The site will be designed to retain surface water runoff around the ROM, processing plant and TSF 2 and 3 from a significant storm event.

Third party review will occur in accordance with industry best practice and recommendations by ANCOLD (2012). Ensuring the construction and operation of the TSFs occur in accordance with the design and engineering criteria will also be critical, while monitoring and review of the performance of each TSF will occur as described in Sections 5 and 8, respectively.

Design of the TSFs will be guided by the following documents:

- *Code of Practice for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing* (ARPANSA 2005) (the Mining Code);
- *Managing naturally occurring radioactive material (NORM) in mining and mineral processing guideline. NORM 4.2. Management of radioactive waste* (DMP 2010) (NORM Guideline 4.2);
- *Code of Practice – Tailings Storage Facilities in Western Australia* (DMP, 2013);
- *Guide to the Preparation of a Design Report for Tailings Storage Facilities* (DMP, 2015);
- *Guidelines on the Safe Design and Operating Standards for Tailings Storage* (DMP 2013, prev. DME);
- *Guidelines on the Development of an Operating Manual for Tailings Storage* (DMP, 1998; prev. DME);
- *Guidelines on Tailings Dams - Planning, Design, Construction, Operation and Closure* (ANCOLD, 2012);
- *Guidelines on the Consequence Categories for Dams* (ANCOLD, 2012);
- *Storage of Radioactive Waste: Safety Guide (IAEA, 2006);* and
- *Tailings Management: Handbook in the Leading Practice Sustainable Development Program for the Mining Industry Series* (Australian Government Department of Industry, Tourism and Resources, 2007).

Following TSF design, a TSF operating manual will be developed and include the following minimum requirements as set out by the DME (1998; now DMP):

- Objectives of the Operating Manual;
- Project background;
- Life of mine and life of TSFs;
- Figure indicating general location of TSFs;
- Drawing showing general arrangement of TSFs;
- Hazard rating;
- General description of mineral processing and tailings storage;
- Timelines (i.e. construction, operations, closure);
- All pertinent information with respect to operation, rehabilitation and closure of the TSFs including:
    - Deposition methodology;
    - Water management;
    - Seepage control (including drain details and requirements)
    - Pipeline management;

- All measures that should be followed during the operating phase to reduce the amount of work required at decommissioning;
- Planned measures to reduce impact(s) to the surrounding environment;
- Planned measures for progressive rehabilitation during operations.

3.2.2 Construction and operations

The as-built geometry should comply with the design geometry as closely as possible, and any discrepancies will be recorded in the Operating Manual, together with a certification by the designer that the safety of the TSF has not been compromised (DME 1998). The phreatic surface will be measured during the life of the TSF to ensure that the design assumptions are reasonable and that any deviations will not pose a threat to the stability of the wall. The Operating Manual will include limits of the expected variation in piezometric levels. Actions to be taken in the event that actual values or measurements exceed those expected will be detailed in the Operating Manual. The instruments should be read on a monthly basis as a minimum requirement, and more frequently if the piezometric levels are approaching the anticipated maximum levels.

The Operating Manual will contain details of any underdrainage that is installed in the TSF, including:

- Drawings showing details of filter drains;
- A plan showing the location and reference numbers of underdrain outfall pipes;
- A plan showing the location and reference numbers of any dewatering bores;
- The expected flows or rest water levels associated with the drainage systems; and
- A procedure for action in the event of flows or levels falling outside the expected values.

The following management measures for pipelines shall be considered in the TSF Operating Manual:

- Periodic rotation of steel pipelines (flanges to be date stamped for reference);
- Pipe wall thickness checking (steel pipes);
- Preventative maintenance through a periodic replacement policy;
- Regular pipeline inspections;
- Automatic shut-off valves linked to pressure transducers located on the pipelines;
- Bunds on either side of pipelines;
- Periodic clearing of vegetation under and around the pipelines to prevent damage from bush fires.

Generation of, and exposure to, dust will be controlled through standard dust management procedures including:

- All mining vehicles would be fitted with air conditioners and air filters;

- Ensuring wet processes are used and where this is not possible, ensuring that adequate watering occurs to significantly reduce dust generation on roads and in the processing plant;
- Covering and/or misting on conveyor belts, where used;
- Spillage management and control;
- Watering of roads and ore stockpiles;
- Maintaining 'wet' tailings in TSF 2 and 3; and
- Progressive covering of drying tailings during decommissioning, where possible.

Water that has come in contact with radioactive waste, such as storm water runoff from the processing plant or direct rainfall on to TSFs will be managed on-site. The evaporation pond, and appropriate collection bunds and channels will be used to manage potentially contaminated surface water runoff.

Waste water collected from the site including wash down areas and clean-up water would be either reused in the processing plant or directed to the evaporation pond.

Requirements and constraints to be considered[1], specific to the current state of knowledge, and relevant to the Project, include:

- Solubility of thorium is very sensitive to pH at around 4. The pH of tailings in TSF 2 and 3 range from 10-11.5 and 7-8, respectively. This will reduce the concentration of thorium in water (NORM Guideline 4.2; DMP, 2010). Any changes to the process that may result in a change to the chemistry of the tailings will need to assess the implications to pH and solubility of thorium.
- Modelling is required to design a cover, which will be effective for the TSF location (with consideration of climate regime, net water balance in the area, and the reactivity of the tailings material) (NORM Guideline 4.2; DMP, 2010). The cover depth will be optimized taking into account radon emissions.
- Encapsulation of radioactive tailings waste (TSF 2 and 3) with impervious cover materials.
- Drainage and water management pre- and post-closure.
- The maintenance of an adequate freeboard on each TSF. The freeboard will need to be sufficient to contain unforeseen increases in the level and movement of fluid within the storage caused by the following:
    - Tailings spills or overflow from spigot malfunctioning.
    - Back flow and overtopping as a result of mounding of tailings at discharge points.
    - Outlet and/or recovery system failures.

[1] Continuing consultation between the operator and the relevant regulatory authority (i.e. DMP, Radiological Council, DER) is required to ensure an optimum design of TSFs will be achieved to meet the requirements for radiation protection and waste management (the Mining Code; ARPANSA, 2005). Consultation will allow all parties to be clear on the requirements and constraints that should be considered (the Mining Code; ARPANSA, 2005).

- Uncertainties in the design rainfall estimates.
- Uncertainties in the design catchment and runoff estimates.
- Extreme wind effects.
- Seismic events.

- Maintaining 'wet' tailings in TSF 2 and 3 during operations to reduce dust generation.
- Design criteria to consider integrity of TSFs post-closure.
- Planning for closure.

3.2.3 Decommissioning and Closure

A Mine Closure Plan (MCP) will be developed in accordance with the *Guidelines for Preparing Mine Closure Plans* (DMP/EPA, 2015). Planning for decommissioning and closure of the TSFs will occur during all phases of the Project based on:

- Research outcomes
- Environmental performance of the TSFs during operations
- Progressive rehabilitation outcomes
- Monitoring results
- Annual review of the risk register against performance indicators
- Lessons learned from environmental performance of other TSF designs and management measures in the mining industry.

3.2.3.1 Decommissioning

The MCP has a whole-of-site approach to decommissioning activities. In addition to the MCP, a Decommissioning Plan must be approved by the DMP Resources Safety Branch and the Radiological Council prior to any site closure activities commencing. The disposal of contaminated plant and equipment will be the focus during the decommissioning phase.

An inventory will be developed and an assessment of contamination will be conducted for all plant and equipment. Where recycling or reuse of plant or equipment is feasible, items will be decontaminated to radiation levels less than 1Bq/g before leaving site. An appropriate disposal method will then be determined for each plant and equipment, identified as waste, based on level of contamination.

TSF 2 and 3, as well as the Evaporation Pond will be drying during the decommissioning phase. Cover materials will need to allow drying to take place without generating excessive dust while the drying occurs from the outside of the facilities in the first instance.

3.2.3.2 Closure

The closure activities of the mine site are described in detail within the MCP. Specific to radiation, the TSFs will be capped, covered with overburden and rehabilitated. Following rehabilitation, no alpha-emitting dust or radioactive gas emanations will occur above that of background levels.

Radioactive material that is mobile (TSF 3) and picked up via water flows will be captured by an underdrain between the clay layer and the HDPE and retained by a sump.

Gamma emissions will be within background levels reducing the threat to members of the public.

The Department of Environment Regulation (DER) will be notified of all landforms containing radioactive waste material, as required under the *Contaminated Sites Act 2003*. If land use is restricted due to radioactivity levels, covenants on land use will be applied through the *Contaminated Sites Act 2003* and exclusions zones put in place by DER and/or Radiological Council.

An assessment of final void water quality will be undertaken to determine if management of the pit lakes is required, and determine potential impacts to any fractured rock aquifers associated with the target ore body.

Further closure considerations for TSF 2 and 3 are detailed in Hastings Technology Metals Limited, 2016d.

4 Monitoring

4.1 Pre-operational monitoring

A pre-operational monitoring program has been undertaken during the exploration phase (2015 -on-going) taking into account *NORM Guideline 3.1. Monitoring NORM – pre-operational guideline* (DMP, 2010b) and provided in the Baseline Radiation Report (Radiation Professionals 2016b). The results to-date are interpreted by Radiation Professionals (2016a and 2016b) and summarised in Section 3.3.6.

Monitoring of the construction process to ensure the TSFs are built in accordance with design specifications will occur during the construction phase. A TSF construction management plan with quality assurance procedures will be developed and implemented to ensure that the TSF construction meets design specifications and tolerances. A competent person will be engaged to certify that the construction of the TSF meets design specifications and tolerances (as specified in DMP, 2013). The competent person will produce a report, which will include:

- conditions encountered during construction (including field and laboratory testing) and verify them against assumptions of each TSF design;
- a non-compliance report with documented remedial measures if the conditions encountered did not meet the original design assumptions or specifications;
- a variance report if the construction was required to deviate from the original design;
- a demonstration that the testing and measurement regime was appropriate and sufficient to validate the design parameters; and
- survey drawings of each TSF showing the true positions of features such as borrow pits, embankments, drains, topsoil stockpiles, capping material sources, process water and return water ponds, seepage trenches, monitoring instrumentation, and buried pipework and cables.

4.2 Operational monitoring

During operations, an environmental radiation monitoring program will be developed taking into account *NORM Guideline 3.2. Monitoring NORM – operational monitoring requirements* (DMP, 2010c). In the design of the monitoring program, the following elements are or will be considered:

- A change in the physical and chemical characteristics of radionuclides due to the hydrometallurgical process. TSF 3 contains mobilised radionuclides at concentrations of approximately 24 Bq/g.

- Possible pathways of exposure of workers includes dust generation from the processing plant and TSF 2 and 3 (note TSF 1 contains radionuclides at < 1 Bq/g). The tailings of TSF 2 and 3 will remain 'wet' during the operations phase.
- Possible pathways of exposure for members of the public and local environment include potential seepage into groundwater via lateral movement and surface hydrology of drainage channels, creeks and the river. TSF 2 and 3 have been designed to encapsulate and contain the tailings. Design parameters that have addressed the possible pathways of exposure will be monitored to ensure their effectiveness.
- Ensure the TSF actual performance occurs in accordance with the expected performance as described in the Mining Proposal for the Project.
- All areas on-site will be classified as supervised or controlled areas.

4.2.1 Sources

An *Environmental Radiation Monitoring Work Instruction*, a component of the Hastings EMS, will be developed to provide specific protocols for environmental radiation monitoring from the following sources:

- Direct gamma radiation: A survey of the perimeter of the Development Envelope to measure gamma radiation levels will be conducted on an annual basis.
- Radon decay products: Track etch monitors will rotate between off-site locations.
- Seepage into groundwater: A network of monitoring bores will be established down gradient from the TSFs, sampled and analysed for heavy metals including radionuclides, on a quarterly basis.
- Contamination of surface water run-off: Surface water sampling will be conducted opportunistically following significant rainfall events or on a quarterly basis.
- Contamination of potable water supply: Sampling and radiometric analysis will be conducted as detailed in the Drinking Water Quality Management Plan (to be developed and as required by the Department of Health).
- Dust containing long-lived alpha-emitting radionuclides: Dust deposition gauges and high volume samplers will collect dust samples at pre-determined locations for composite analysis on an annual basis and rotate between approved off-site locations, respectively.

NORM Guideline 6 Reporting Requirements (DMP 2010d) states that *each measurement must be undertaken using an agreed technique and appropriate monitoring equipment. Once approved these techniques do not need to be detailed in the reports. However, any changes in the techniques must be approved before being used as the basis of the reports.*

4.2.2 Containment Controls

Monitoring of controls for containment of radioactive waste will include:

- Weekly visual inspection of surface water management structures including bunds, drainage channels, tailings and water pipelines, and evaporation ponds.
- Weekly inspection of the walls of TSF 2 and 3 for erosion or other signs of potential compromise to the integrity of their structure, including signs of seepage of tailings or water from tailings into the environment immediately surrounding the TSFs.
- Inspections of management controls following major rainfall or extreme weather events.
- Annual inspection/audit by closure specialist to identify potential hazards, risks and opportunities for continual improvement, including aspects that require further investigation or research.
- Internal audits (in accordance with the EMS Audit Operating Procedure) of the implementation of this RWMP.

Monitoring of TSF 1, TSF 2 and TSF 3 performance will also be described in detail in the TSF Operating Manual (DME 1998). The operating manual will detail procedures for routine inspections of TSFs, operational audit of TSFs, groundwater monitoring, monitoring instrumentation and environmental aspects. DME (1998) specifically states:

Details pertaining to monitoring instrumentation (e.g. piezometers) should describe the method and frequency of measurement. The Operating Manual should describe the short and long term range of readings that are anticipated for all monitoring instruments, underdrain flows, open channel flows etc, throughout the life of the TSF. Actions to be followed in the event that readings are recorded outside an anticipated envelope of measurements should be stipulated in the Operating Manual.

4.2.3 Trigger values

Trigger values are based on authorised limits and/or baseline values and take account those identified in NORM Guideline 6 Reporting Requirements (DMP, 2010d) (Table 7).

Table 7 Investigation level recommended for each radiation parameter (DMP, 2010d)

Radiation Parameter	Investigation Level	Comment
1. *Area gamma dose rate*		
1.1 Site boundary	>1.1 μGy/hr above background	> 1 mSv/year for a member of the public (8760 hrs/year)
1.2 Supervised area	> 0.5 μGy/hr above background	> 1 mSv/year for an employee (2000 hrs/year)
1.3 Controlled area	> 2.50 μGy/hr above background	> 5 mSv/year for an employee (2000 hrs/year)

Radiation Parameter	**Investigation Level**	**Comment**
1.4 Restricted	> 7.50 µGy/hr above background	> 15 mSv/year for an employee (2000 hrs/year)
2. Personal external dose		
2.1 Designated worker	> 2.5 mSv in a quarter	> 10 mSv/year
2.2 Non-designated worker	> 0.5 mSv in a quarter	> 2 mSv/year
3. Personal internal dose		
3.1 Designated worker	> 5.0 mSv in a quarter	Assessed from air sampling
4. Airborne radioactivity		
4.1 Total alpha activity on the personal air sample – U dust	> 9.9 Bq/m³ for 12-hr shift sample	~ 0.5 mSv/shift
4.2 Total alpha activity on the personal air sample – Th dust	> 4.3 Bq/m³ for shift sample	~ 0.5 mSv/shift
4.3 Total alpha activity on the personal air sample – U dust	4 consecutive samples > 2.4 Bq/m³	Indicates potential for significant exposure
4.4 Total alpha activity on the personal air sample – Th dust	4 consecutive samples > 1.0 Bq/m³	Indicates potential for significant exposure
4.5 Total alpha activity	> Mean + 3 standard deviations	Indicates potentially unusual working conditions
4.6 Total alpha activity on environmental air sample – U dust	> 2 mBq/m³ on high volume air sampler	> 100 µSv/year for a member of the public continuously exposed (> 10% of exposure limit)
4.7 Total alpha activity on environmental air sample – Th dust	> 1 mBq/m³ on high volume air sampler	> 100 µSv/year for a member of the public continuously exposed (> 10% of exposure limit)
5. Airborne dust		
5.1 Inhalable dust on personal air sample	> 10 mg/m³	Statutory limit for respirable dust concentration
5.2 Respirable dust on personal air sample	> 3 mg/m³	Statutory limit for respirable dust concentration
6. Radon/Thoron in air		
6.1 Radon (^{222}Rn) in air - workplaces	> 3.5 mJh/m³	> 5 mSv/year for an employee (2000 hrs/year)
6.2 Thoron (^{220}Rn) in air - workplaces	> 10.7 mJh/m³	> 5 mSv/year for an employee (2000 hrs/year)
7. Radionuclides in water		
7.1 ^{226}Ra in ground water or surface water	> 0.5 Bq/L ^{226}Ra or 2x average pre-operational levels for waters containing high levels of radium	100 µSv/year for ingestion of 2L/day for a year

Radiation Parameter	Investigation Level	Comment
7.2 ^{228}Ra in ground water or surface water	> 0.2 Bq/L ^{228}Ra or 2x average pre-operational levels for waters containing high levels of radium	100 µSv/year for ingestion of 2L/day for a year

Exceedances of a trigger value will be considered an incident unless significant seasonal environmental variation of background levels are expected, e.g., salinity levels in permanent ponds. In such instances, a trend of exceedances in trigger values will then be treated as an incident.

4.2.4 Quality Assurance

NORM Guideline 3.2. Monitoring NORM – operational monitoring requirements (DMP, 2010c) highlights the importance of having a quality assurance program. ARPANSA (2005) requires *that the quality assurance program which is compliant with Australian Standards should be implemented, including traceability of all radiation measurements to Australian metrological*[2] *standards where possible.*

Quality assurance is integrated throughout the Hastings EMS. Other applicable systems include a Quality Management System, and Occupational Health and Safety System. Hastings management system framework integrates the requirements of the above listed systems international standards (ISO 14001, 9001 and AS/NZS 4801 and 4804), which is currently in development and will be implemented.

4.2.4.1 Equipment

Quality assurance of equipment and instruments, including calibration and maintenance, will form a component of the *Environmental Radiation Monitoring Work Instruction*.

4.2.4.2 Sample Analysis

Hastings will only engage recognised, accredited laboratories to conduct sample analysis. Accurate records of sampling and sample analysis will be maintained using Yangibana *Field Record Form* and *Chain of Custody Form*. Use of these forms and records to be maintained will be detailed in the *Environmental Radiation Monitoring Work Instruction* and will be in accordance with Yangibana *Records Procedure.*

Control samples and the consistent use of standard methods for analysis will verify monitoring procedures detailed in the *Environmental Radiation Monitoring Work Instruction*.

[2] Metrology is defined by the International Bureau of Weights and Measures (BIPM) as `the science of measurement, embracing both experimental and theoretical determinations at any level of uncertainty in any field of science and technology.'

4.2.4.3 Personnel

Hastings will employ competent, qualified and experienced environmental professionals to conduct the monitoring activities. Prospective employees will be assessed and employed based on their experience in conducting environmental monitoring.

4.2.4.4 Training

An on-going training program relevant to the RWMP will be in place in accordance with Hastings *Training Procedure*.

4.2.4.5 Audits and Inspections

An audit program in accordance with Hastings *Audit and Inspections Procedure* will assess whether or not monitoring is being undertaken against established requirements set out in this RWMP and the *Environmental Radiation Monitoring Work Instruction*.

5 Contingency Planning

Contingency planning will form a component of the risk assessment, in case pre-determined mitigation is not effective. Contingency plans will form a component of the Emergency Management Plan.

Where containment of radioactive waste fails, the Hastings *Emergency Management Plan* will include:

- Human health and safety first: response to exposure, evacuation, decontamination of the persons exposed to radiation;
- Stabilisation of the containment and prevention of impact to surrounding environmental receptors;
- Consideration of secondary containment and drainage;
- Clean-up procedures;
- Training of personnel on the Emergency Response Team to address radioactive waste containment failures;
- Identification of radiation specialists and TSF experts to review contingency plans; and
- Suspension of operations (also considered in the Care and Maintenance section of the MCP).

6 Reporting

6.1 Documentation

Reporting requirements are outlined taking into account *NORM Guideline 6 Reporting Requirements* (DMP, 2010d). The following reporting commitments (Table 8) align with the requirements of legislation or stakeholder concerns.

Table 8 Reporting Commitments

Stakeholder	Legal Requirement	Timing
DMP Environment Branch	Annual Environmental Report	Annually
DMP, DER	Incidents	At time of occurrence
DMP Resources Safety Branch	Environmental Radiation Monitoring Report for the period 1 October to 30 September. Details of the operation of the radioactive waste management system as approved in the Radiation Management Plan.	Annually (within 8 weeks from 30 Sept)
DER, public (via Hastings website)	Annual Compliance Report	Annually
DoH*	Water quality monitoring of potable water	Quarterly
DoH*	Where the estimated annual radiation dose from radionuclide analysis of radium-226 and radium-228 exceeds 0.5 mSv in potable water supply.	Within 24 hrs
Wanna Station	Monitoring results of pastoral bores	Annually or as requested
Employees	Monitoring results	Relevant to monitoring procedure

*DoH, 2013

The Environmental Radiation Monitoring Report shall be prepared by a suitably qualified professional, typically an approved radiation safety officer (RSO), signed by the RSO and counter-signed by the Registered Manager.

The statutory report shall contain, as detailed in *NORM Guideline 6 Reporting Requirements* (DMP, 2010d), for each radiation parameter listed in the radiation monitoring program, the following information:

Individual sample:

- Equipment used, calibration records, the type, number, date and time of the measurement.
- Name or another suitable identifier for a personal air sample.
- Sampling location for an area gamma radiation measurement and for a positional air sample.

A group of data:

- The range and the mean with estimates of accuracy and precision (e.g., a standard deviation).
- A suitably scaled map or plan with direction indicator.
- Indications of trends in data, preferably in a graphical form.
- Comparison of the obtained results with authorised limits and/or baseline values collected prior to the commencement of operations.
- Reference to the techniques or equipment used.

The minimum contents of the annual Environmental Radiation Monitoring Report are listed in *NORM Guideline 6 Reporting Requirements* (DMP, 2010d).

The annual environmental radiation monitoring report shall be submitted electronically with copies of all certificates of analyses obtained from off-site laboratories.

6.2 Incidents

All hazards and incidents will be reported in accordance with Hastings *Hazards and Incident Reporting Procedure.*

7 Review

Constant review, application of latest scientific knowledge and 'lessons learnt' from similar operations are considered. An adaptive management approach will ensure optimum performance and management of risks are applied via this RWMP document.

This RWMP will be further developed throughout each phase of the Project, and will also be reviewed whenever there is a significant change in the operation of the TSFs or process plant that may impact the engineering considerations in the TSF design and implementation of the design criteria.

Review of this RWMP will include adaptive management actions or procedures to learn from the implementation of mitigation measures, monitoring and evaluation against trigger values. The following approach will be implemented:

- Monitoring data will be evaluated and compared to baseline and reference site data following the collection of monitoring data (as outlined in Section 5). Trends will also be assessed to verify modelling or the anticipated performance of mitigation measures.
- On-going research and assessment outcomes will identify opportunities or risks, which will be considered in the context of radioactive waste management and TSF performance.
- When trigger level actions do not have the anticipated outcomes, revise mitigation measures and obtain specialist advice.
- Continue to gain an increased understanding of site-specific environmental aspects (i.e. hydrological processes, sensitive receptors).
- External changes during the life of the proposal (e.g. changes to the sensitivity of the key environmental factor, implementation of other activities in the area);
- Review of risk register against performance measures, including (but not limited to) monitoring results, company culture, personnel changes, economic conditions or changes to process plant.

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9 Appendices

Appendix A: Technical Note - Summary of Environment

Yangibana Rare Earths Project

TECHNICAL NOTE

Environment

Document	Technical Note: Environment		**Division**	App	**Status**	Approved	**Issued**	9/12/16
Number			**Author**	LJ	**Review Date**	9/12/16	**Version**	0

1 Introduction

1.1 Yangibana Rare Earths Project

Hastings Technology Metals Limited (Hastings) is proposing to develop the Yangibana Rare Earths Project (the Project), which is situated approximately 270 km north-east of Carnarvon and approximately 100 km north-east of Gascoyne Junction, in the upper Gascoyne region of Western Australia (Figure 1). Hastings is targeting rare earth elements in ferrocarbonatite veins in four deposits. An on-going exploration program across Yangibana tenements may discover other feasible deposits to mine. An open cut mining method will separate waste rock and ore. Waste rock landforms will be situated next to each pit. The ore will undergo processing: Beneficiation and Hydrometallurgy. Tailings from the process plant will be directed to Tailings Storage Facilities.

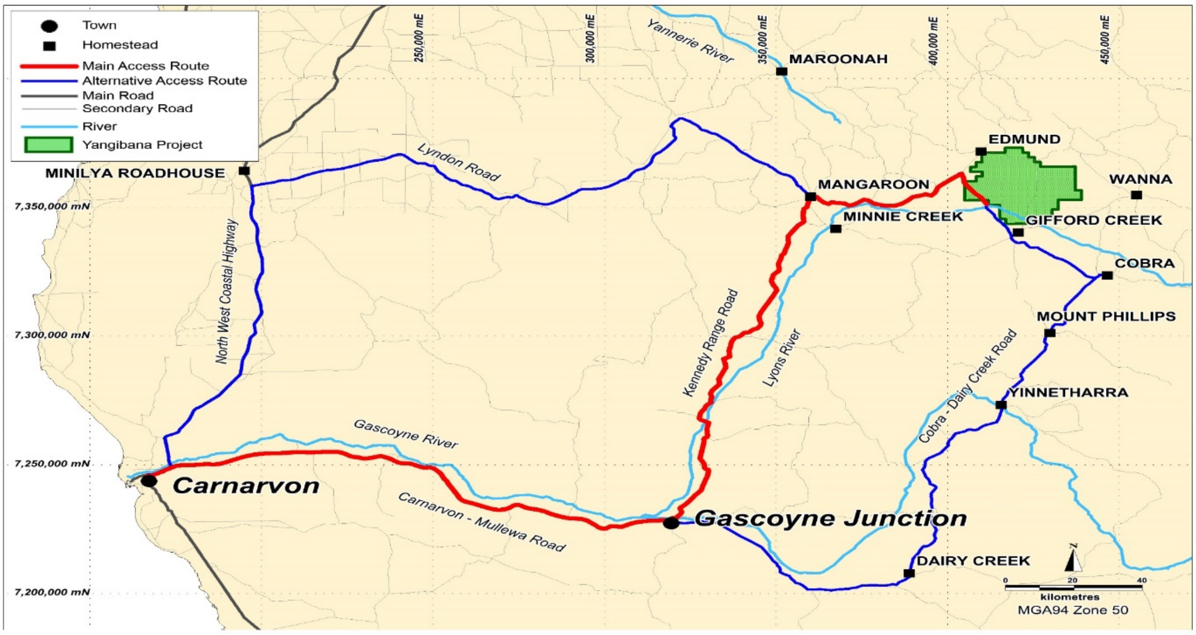


Figure 1 Location of the Yangibana Rare Earths Project

1.2 SCOPE

The purpose of this technical note is to provide an overview of the surrounding environmental values for the Project, with a focus on those aspects relevant to the management of radionuclides.

Specific environmental values considered include:

- Climate (Section 2)
- Terrain (Section 3)
- Soils (Section 4)
- Vegetation (Section 5)
- Hydrology (Section 6)

1.3 Relevant Documentation

This report should be read in conjunction with the following documentation should additional information or clarification be required:

- Vegetation and Flora Assessment Report (Ecoscape 2016a);
- Subterranean Fauna Assessment Reports (Ecoscape 2016b);
- Soils Assessment (Landloch 2016);
- Conceptual Hydrogeological Assessment (Global Groundwater 2016); and
- Preliminary Hydrology Report (JDA 2016).

2 Climate

The climate (as described by Ecoscape 2016a) is arid to semi-arid. Cool day time temperatures occur over winter and warm to hot day time temperatures occur over summer. The Project occurs in the low rainfall (less than 350 mm) zone and warm humid summer climate zone based on temperature and humidity (Figure 2). A number of climatic influences impact the area causing bi-modal average rainfall with an average annual total of about 220 mm. These climatic influences include the west coast trough, northwest cloudbanks, tropical cyclones, frontal systems and subtropical ridge.

A more detailed description of climate is provided in Ecoscape (2016a).

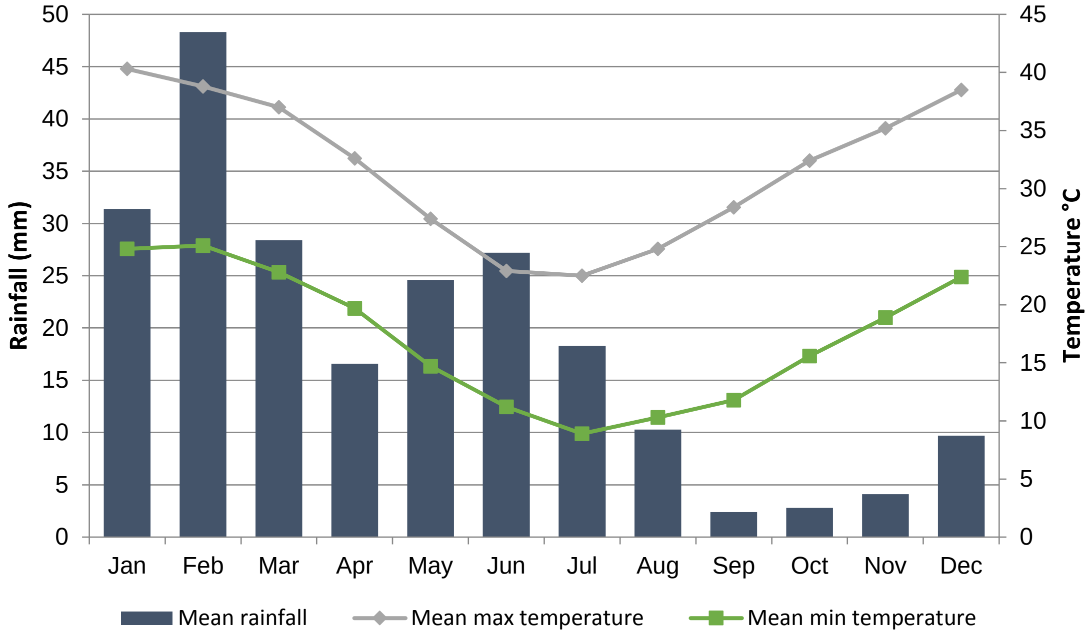


Figure 2 Monthly rainfall and daily maxima and minima for Mt Phillip (BoM 2015b) located approximately 70km south of the Yangibana Rare Earths Project (from Ecoscape 2016a).

3 Terrain

Ecoscape (2016a) describe the Project using the Interim Biogeographical Regionalisation for Australia (IBRA) (Department of the Environment [DoE] 2014a), which occurs within the Gascoyne region. Three major subregions, namely Ashburton, Augustus and Carnegie (Thackway and Cresswell 1995), occur within the Gascoyne region. The Project occurs within the Augustus subregion, which is described as:

Rugged low Proterozoic sedimentary and granite ranges divided by broad flat valleys. Also includes the Narryera Complex and Bryah Basin of the Proterozoic Capricorn Orogen (on northern margin of the Yilgarn Craton), as well as the Archaean Marymia and Sylvania Inliers. Although the Gascoyne River System provides the main drainage of this subregion, it is also the headwaters of the Ashburton and Fortescue Rivers. There are extensive areas of alluvial valley-fill deposits. Mulga woodland with Triodia occur on shallow stony loams on rises, while the shallow earthy loams over hardpan on the plains are covered by Mulga parkland. A desert climate with bimodal rainfall. The subregional area for GAS3 is 10,687,739 ha (Desmond et al. 2001).

Global Groundwater (2016) describe the bulk of the Project area being *underlain by granitic rocks characterised by subdued topography with some broad open flats and occasional rounded granitic hills with elevations to about 350 m AHD.*

Figure 3 Yangibana Rare Earths Project terrain

4 Soils

The broader Project area is located within the Gascoyne Province of the Capricorn Orogen. Proterozoic metasedimentary basement rocks of the Pooranoo Metamorphics underlie the broader Project area, which consist of metamorphosed feldspathic sandstone and psammitic schist and calc-silicate rocks. These have been intruded by Proterozoic granitic rocks (specifically the Pimbyana and Yangibana Granites), which are fresh to weathered (Global Groundwater 2016).

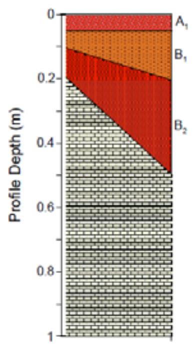
Global Groundwater (2016) further describe the geology as follows:

The earlier basement rocks have been intruded by later dolerite sills and dykes as well as veins of ferrocarbonatite, ironstone and quartz of the Gifford Creek Ferrocarbonatite Complex (GFC) as described by Piranjo and Gonzalez-Alvarez (2013). The ironstone veins have shallow (c. 10°) to steep (c. 65°) dips, consist of magnetite, hematite, and supergene goethite and are locally weakly radioactive. Lenses and pods up to 10 m wide of massive to vuggy iron oxide are contained within the veins. These are considered to have resulted from later alteration of intruded ferrocarbonatites by hydrothermal iron oxides and then subject to supergene alteration closer to the surface to produce massive goethite and gossanous outcrop (Piranjo and Gonzalez-Alvarez. 2013). They host the rare earth element (REE) mineralisation of the proposed development, and occur as sinuous pods and veins generally less than 10 m wide, that are traceable for up to 25 kilometres (Whittock, 2016).

Landloch (2016) defined and mapped the soils as Hill Soil and Plain Soil. Hill Soil is associated with the extensive granite geology that forms the low hills and rises across the site. Hill Soils are typically associated with extensive stone mantles and outcrops of granite and ironstone. The TSFs will be located on Hill Soils. A summary of the characteristics of Hill Soils are shown in Table 1 and further described by Landloch (2016). Plain Soils are found on low relief areas associated with the drainage lines across the Project area.

Table 1 Characteristics of Hill Soils (Landloch 2016a)

Property	Inspection Site Description
Brief description	Shallow dark brown sandy loam duplexes
Extent	17,613.7ha (mapped)
Soil samples	Pit 1 to 5, 7 to 14, 16 to 19
Gradient	Gently undulating to low rises
Soil Landscape	James, Agamemnon, Glenburgh
Soil classification	Brown shallow loamy duplex^/ Brown Chromosol#
Surface coarse fragments	50–100% abundance, sub-angular pebbles to rocks of granite, ironstone, and quartz origin
Surface condition	Soft to moderate
*Permeability**	Slow to Moderate
*Water repellent**	No
*Drainage**	Sheet wash and distinct drainage lines between hills
Soil depth (cm)	**Soil Profile Description**
0–5	A_1 Dark brown (2.5YR-2.5/3), weakly structured, sandy loam, <10% coarse pebble fragments, pH 6.5 (field)
5-20	B_1 Dark brown (2.5YR-2.5/4), weakly pedal, loam to clay loam, <5% coarse fragments, pH 6 (field)
20-40	B_2 Dark brown (2.5YR-2.5/4), weakly pedal, clay loam, <5% coarse pebble fragments, pH 6 (field)
>40	C Decomposing grey granite (but also red/yellow)



Vegetation communities associated with the soil types also differed. Hill Soils were associated with scattered low woodlands and shrublands of mulga/acacia species with grasses while Plain Soils had extensive bare sandy patches in low resource areas with scattered grass and shrubs in higher resource areas. Eucalypt and acacia species were noted along drainage lines. Further delineation of vegetation is described by Ecoscape (2016a) and in Section 5 below.

5 Vegetation

The vegetation association identified by Ecoscape (2016a) over the area of the process plant and TSFs is 'Low woodland; mulga and snakewood (*Acacia eremaea*)', as defined by Beard (1970). Twenty vegetation types were recorded from the study area. Specifically, two vegetation types, which occur within or in the near vicinity of the TSF footprint, are described as:

- EpAc*: Eremophila phyllopoda* subsp. *obliqua*, *Acacia tetragonophylla* and *Senna artemisioides* subsp. *helmsii* mid open shrubland over *Aristida contorta, Eriachne pulchella* subsp. *dominii* and *Portulaca oleracea* low grassland/forbland.
- EeAc: *Eremophila exilifolia, Acacia tetragonophylla* and *A. kempeana* mid open shrubland over *Aristida contorta* and *Eriachne pulchella* subsp*. dominii* low sparse tussock grassland.

A total of 472 vascular flora taxa were recorded in the Study Area (55,000 ha). No threatened flora listed under the EPBC Act (Cwth) and *Wildlife Conservation Act 1950* (WC Act) (WA) were recorded in the study area. Eight priority flora listed under the WC Act were recorded in the study area:

- *Acacia curryana* (listed as a Priority 1 (P1) taxon by the WA DPaW);
- *Rhodanthe frenchii* (P2);
- *Solanum octonum* (P2);
- *Wurmbea fluviatilis* (P2);
- *Gymnanthera cunninghamii* (P3);
- *Sporobolus blakei* (P3);
- *Goodenia berringbinensis* (P4); and
- *Goodenia nuda* (P4).

The Project will impact upon two priority flora species, namely *Acacia curryana* and *Rhodanthe frenchii*.

58 taxa were recorded as having significant range extensions or filling substantial range gaps in species distribution. Additionally, one undescribed species (*Elacholoma sp.* 'Showy Flowers') was recorded in the study srea but outside the Project development envelope. The proposed action will not impact this species.

Twenty-four introduced species (weeds) were recorded within the study area. Of these, *Argemone ochroleuca* (Mexican Poppy) and *Datura leichhardtii* (Thornapple) are Declared Pests listed under the *Biosecurity and Agriculture Management Act 2007* (WA).

Surface groundwater dependent ecosystems are associated with drainage lines, creeks and rivers in the near vicinity of the Project area (Ecoscape, 2016a). However, none occur within the footprint of the TSFs or processing plant. Associated with these is the Gifford Creek Priority Ecological Community, which is characterised by a network of shallow calcrete aquifers, typical habitat of subterranean fauna. The Project area intersects the northern portion of the PEC. Subterranean fauna have been found within drill holes intersecting the resource (see Ecoscape, 2016b for further information).

6 Hydrology

6.1 Surface Water

The Project area is located within the Gascoyne River catchment. The catchment area of the Lyons River to this crossing location is approximately 11,000 km^2 (JDA 2016). The catchment extends approximately 200 km east from the Study Area.

The Lyons River, a tributary of the Gascoyne River, is associated with the southern portion of the broader Project area, and flows in a general northwestern direction. The Lyons River is considered to be ephemeral, i.e. only flows after rainfall. Semi-permanent waterholes occur within the Lyons River in the general vicinity of the Project area.

Several tributaries of the Lyons River traverse the Project area, namely Yangibana and Frasers Creeks. There are also several drainage channels within the Project area. The TSFs do not intersect the Lyons River nor the creeks.

A detailed hydraulic model was developed for Fraser, Yangibana and Gifford Creeks, as well as the Lyons River adjacent to the Study Area to assess flood conditions that are likely to impact on the proposed mine infrastructure (JDA 2016). This model used rainfall on grid for the creek catchments, and includes flow in the Lyons River based on the larger Lyons River hydrological model. The detailed model allows for accurate delineation of flood extent, depth, flow rates and velocities, which will be used to inform mine design.

The impact of regional and local flood waters on the proposed mine infrastructure has been assessed by JDA (2016; Figure 4 represents the worst case outcomes from a 100 yr ARI over a 6 hour period). Based on JDA's assessment (2016) a combination of diversion channels, floodways and culverts are required to mitigate impacts associated with surface water flows in the Project area.

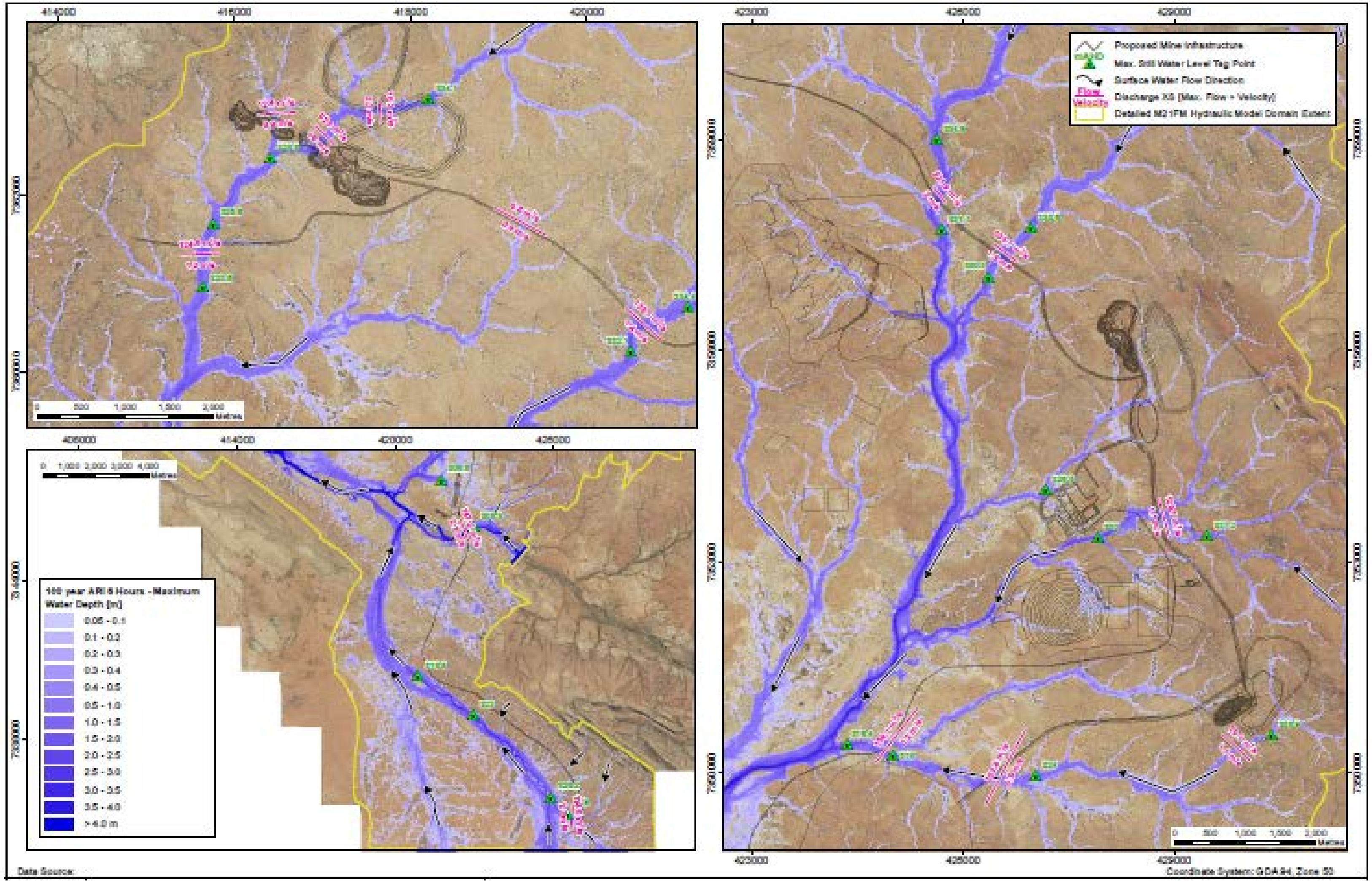


Figure 4 Modelling of surface water flows for a 100 ARI (6 hours) (JDA 2016)

6.2 Groundwater

The Project area is not characterised by regional aquifers. Global Groundwater (2016) report that aquifers are likely to be present in superficial strata (where sufficiently thick and saturated) or in basement rocks where fractured (Figure 5). However, these will be isolated and effectively disconnected from each other over much of the area. Some degree of hydraulic connectivity will occur locally depending on geological structure, weathering, landscape position and aquifer geometry (Global Groundwater 2016).

Geological profiling, topography and soils assessments define the area on which TSFs will be located to be basement rocks. Basement rocks in the study area have very low permeability and could be regarded as effectively impermeable throughout much of the area (Global Groundwater 2016). However, some zones of very high permeability will occur i.e. in the vicinity of bedding plane partings and fractures from faulting, folding, intrusives and where solution cavities and channels (vugs) have developed in ironstone veins (Global Groundwater 2016). These zones of high permeability occur where the target resource will be mined.

Groundwater from intake areas will flow down hydraulic gradients, most likely in the direction of surface water flow (Global Groundwater 2016). Regional flow systems are not likely to be generated. Local flow systems will have established in response to aquifer distribution and geometry, which is highly variable.

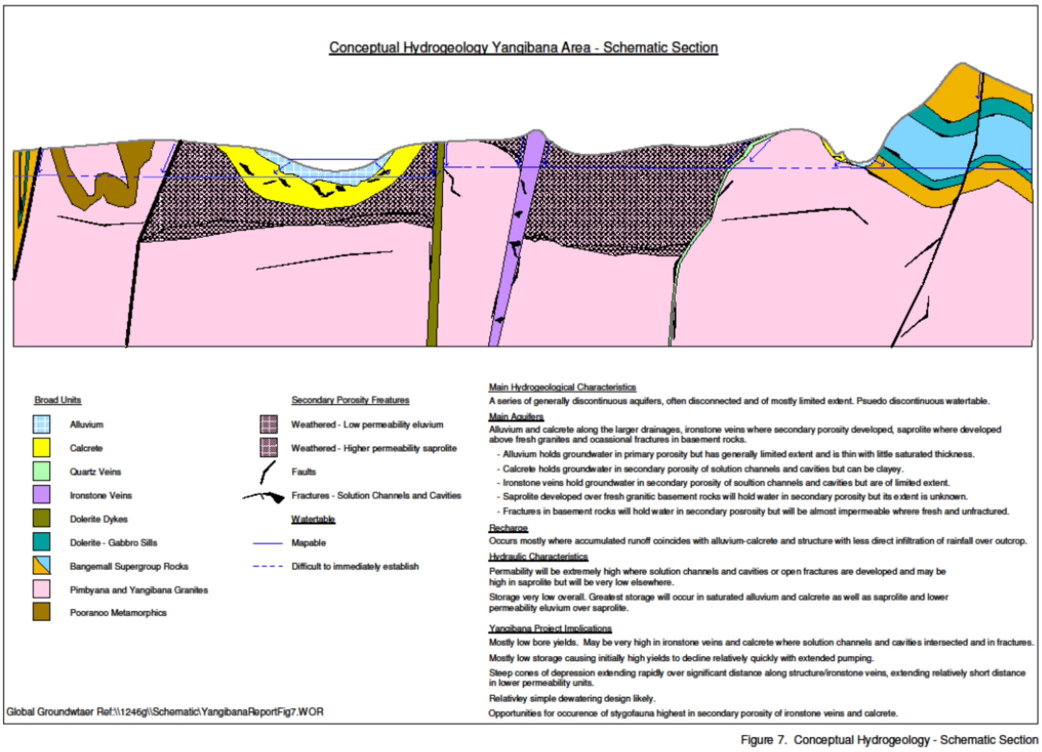


Figure 5 Conceptual Hydrogeology of the Yangibana Rare Earths Project area (Global Groundwater 2016)

7 References

Ecoscape. 2016a. *Yangibana Rare Earths Project Vegetation and Flora Assessment Report.* A report prepared by Ecoscape for Hastings Technology Metals Ltd.

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JDA and Associates. 2016. *Yangibana Rare Earths Project Surface Water Assessment*. A report prepared by JDA and Associates for Hastings Technology Metals Ltd.

Landloch 2016a. *Yangibana Rare Earths Project* Soils Assessment. A report prepared by Landloch for Hastings Technology Metals Ltd.