Radiation Management Plan

PURPOSE

This Management Plan stipulates the company’s method for control of radiation encountered in mining and processing of mineral sands. It addresses the requirements for occupational dose control and environmental impact, transport regulations, and formal reporting.

REFERENCES

- ARPANSA Code of Practice for Radiation Protection in Mining and Mineral Processing
- Australian Standard AS3640–2009 - Method for sampling and gravimetric determination of inhalable dust
- The National Road and Rail Dangerous Goods Transport Regulations
- NSW Work Health and Safety Regulations 2011
- Cristal Waste Management Plan

DEFINITIONS

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NORM</td>
<td>Naturally Occurring Radioactive Material</td>
</tr>
<tr>
<td>RMP</td>
<td>Radiation Management Plan</td>
</tr>
<tr>
<td>RSO</td>
<td>Radiation Safety Officer</td>
</tr>
<tr>
<td>EPA</td>
<td>Environmental Protection Authority</td>
</tr>
</tbody>
</table>
# TABLE OF CONTENTS

Company General Operations Description ................................................................. 4  
Reason for RMP .............................................................................................................. 4  
Regulatory Regime ...................................................................................................... 5  
Requirements of RMP .................................................................................................. 6  
Radioactive Decay Chains ............................................................................................ 8  
Potential Dose Delivery Pathways ............................................................................... 11  
Description of Operational processes ......................................................................... 11  
Radionuclide contents: ................................................................................................. 12  
Radiation Dose Control Methods ................................................................................ 13  
Access to Radiation Safety Professional Expertise and Resources ............................. 14  
Plans for monitoring radiation in workplaces and for assessing doses to workers ...... 14  
Provision of appropriate equipment, staffing, facilities and operational procedures..... 15  
Worker Inductions and Training .................................................................................. 15  
Record keeping and Reporting .................................................................................... 16  
Plan for incidents accidents and emergencies .............................................................. 16  
Periodic review and audit ............................................................................................. 16  
Management of radioactive waste: ............................................................................. 16  
Periodic assessment and review of the adequacy and effectiveness ............................ 17  
Other ‘Best Practice’ organisational Arrangements ..................................................... 17  
Other procedural rules for dose and contamination control ........................................ 17  
Transport of Radioactive Materials .............................................................................. 18  
Fixed Radiation Gauges ............................................................................................... 19  
  Introduction .................................................................................................................. 19  
  Responsibilities of the Employer – Cristal Mining ...................................................... 19  
  Working Rules .............................................................................................................. 21  
Maintenance and Inspection of Fixed Radiation Gauges ............................................. 22  
Emergency Procedures ............................................................................................... 23  
Security ......................................................................................................................... 25  
Storage .......................................................................................................................... 25  
Transport ...................................................................................................................... 26
Disposal
Records
Radiation Safety Officer

APPENDIX 1 Register of Radioactive Sources
Company General Operations Description

Cristal Mining Australia Limited is the local arm and main mining operations of Cristal, which has as its primary purpose the commercial production of high quality titanium source materials and associated by-products including zircon and other Heavy Mineral concentrates for world markets.

This Radiation Management Plan (RMP) is intended to cover all present and proposed future Cristal NSW Operations. These comprise mining operations at the present Ginkgo and Snapper mines and at the new Atlas and Campaspe mines yet to come on-line. The RMP will cover initial mining activities at the mine sites, transport by road and rail to, and operations at the Broken Hill Mineral Separation Plant and transport of waste by road and rail back to mine sites followed by final in-pit disposal.

Reason for RMP

Heavy mineral sand ores generally contain the minerals ilmenite, rutile, zircon, monazite, leucoxene, and xenotime. Thorium and uranium are present in monazite in the range of about 5% and about 0.5% respectively, and at lower concentrations in xenotime and leucoxene.

Thorium in ordinary soils averages about 10 parts per million (ppm) world-wide, and uranium averages about 3 parts per million (ppm). These values go up by a factor of approximately 10 in some granites.

The uranium and thorium concentrations of the Atlas and Campaspe ores are approximately 5 and 25 parts per million (ppm) respectively. This implies that the total (all nuclides) activity concentration of the Atlas and Campaspe ore is therefore approximately 1.8 Bq/g.

The activity concentration of radioactive elements which makes a material legally 'radioactive' in NSW is 100 Bq/g. Thus the ore itself is not radioactive.

However, the HMC, some MCs, and the MSP plant wastes, are all over 100 Bq/g and thus radioactive.

Corporate ‘duty of care’ and proactive risk management therefore indicate the need to monitor radiation levels, and manage radiation using proper control measures so as to minimise workers’ doses. It is also important to control and contain spills and releases, which could cause contamination of the environment, and to avoid release of radioactively contaminated items and equipment from worksites before they have been cleaned. All transport of feed from mine to MSP, and of both product and waste from the MSP, must be in accordance with the ARPANSA Code of Practice for Safe Transport of Radioactive Materials.
This document describes the ways by which radiation doses to workers are measured and controlled. It also documents the methods undertaken to control and prevent environmental dispersion of mineralised material. The document also lists the undertakings which Cristal gives (to the regulators, its workers, and the people of Broken Hill) to monitor and actively manage radiation in the course of the Cristal operational activities.

During all activities involving handling or contact with radioactive materials, radiation monitoring is and will be carried out so as to provide data for radiation dose control, and to provide feedback to workers, management, and the regulatory agency. This monitoring has been undertaken since 2008. This RMP represents the outcome of a review and update of the monitoring plan to take into account the move from dredge-based mining to open pit mining.

**Regulatory Regime**

The regulatory control and oversight for the Cristal operations rests with the NSW Department of Primary Industries (DPI). The basic rules specific to the operation are given in the Director General’s Requirements (DGR).

NSW EPA Radiation Control Branch has informed that the radiation requirements will be interpreted in accordance with the specifications given for a Radiation Management Plan (RMP), stated in the Code of Practice and Safety Guide on Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing (Radiation Protection Series # 9, 2005), issued by ARPANSA (Australian Radiation Protection and Nuclear Safety Agency).

This document has been written so as to address each requirement listed under the ARPANSA specifications for the RMP.

The Atlas-Campaspe Environmental Impact Statement (EIS) has been prepared under the Environmental Planning and Assessment Act, 1979 and compiles the various requirements on operation of these mines under the state regulatory authorities.

A specific requirement of the DGR obligations is that radiation encountered in the operations will be subject to control via a Radiation Management Plan, which will be in compliance with the specifications and requirements of the ARPANSA Code of Practice and Safety Guide for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing, and subject to review and audit by the Radiation Control Branch of the NSW EPA.

In addition, the International Atomic Energy Agency (IAEA) Regulations for Safe Transport of Radioactive Materials TS-R-1 (2005) are also applicable to this project, as it is universally imposed internationally, and in Australia, where it is ‘re-badge’ as ARPANSA RPS # 2. In Australia, RPS#2 is called up in the Road and Rail Dangerous Goods Transport Regulations (‘ADG Regs’). Internationally, the IAEA Transport...
Regulations are referenced in International Air Transport Association (IATA) and International Maritime (IMO) Dangerous Goods Regulations and thus used for regulating the transport of radioactive samples and of radioactive products.

**Compliance with this RMP will ensure that good practice is established, and give assurance to Cristal, to its contractors and workers, and to the regulators, that proper controls are in place.**

**Requirements of RMP**

The RMP requirements in the ARPANSA Mining and Processing Code Section 2.7 are as follows:

“Before the start of any stage of an operation to which this Code applies, a RADIATION MANAGEMENT PLAN for that stage must be devised and presented to the regulatory authority for approval. The Plan must be in accordance with best practicable technology and taking into account the potential dose delivery pathways.

The RMP must include a description of the operations to which it applies, and the measures that are intended to be taken to control the exposure of employees and members of the public to radiation at or from the practice including:

(a) Demonstrated access to appropriate professional expertise in radiation protection;

(b) A plan for monitoring radiation exposure and for assessing doses received by exposed employees;

(c) The provision of appropriate equipment, staffing, facilities and operational procedures;

(d) Details of induction and training courses;

(e) Record keeping and reporting;

(f) A plan for dealing with incidents, accidents and emergencies and

(g) A system of periodic assessment and review of the adequacy and effectiveness of procedures under the RMP to ensure currency and to facilitate a process of continual improvement.
And from the ARPANSA Code, Section 2.8:

A Radioactive Waste Management Plan (RWMP) must be developed to provide for the proper management of radioactive waste arising from the operation and will include:

(a) An outline of the processes generating waste, and a description of the waste generated;

(b) A description of the environment into which the waste will be disposed, including the baseline radiological characteristics;

(c) A description of the proposed system for waste management including (details of) the handling, treatment, storage and disposal of radioactive waste;

(d) Prediction of environmental concentrations of radionuclide’s and radiation doses to people from the proposed waste management practices;

(e) A program for monitoring the concentration of radionuclides in the environment and assessment of (resulting) radiation doses to members of the public;

(f) Contingency plans for dealing with accidental releases, or circumstances which might lead to uncontrolled releases of radioactive waste, to the environment;

(g) A schedule for reporting on the operation and results of monitoring and assessments;

(h) A plan for decommissioning and rehabilitating the site and waste management facilities; and

(i) Periodic assessment and review of the adequacy and effectiveness of the RWMP

It is normal, in the Australian regulatory regime, for operations which are clearly ‘low-dose’ situations, for the RWMP specifications to be addressed within the RMP (that is, within a single document).
Radioactive Decay Chains

Several components of heavy mineral sands (monazite, leucoxene, xenotime) contain thorium and uranium. Thorium and uranium are the ‘parents’ of three series of radioactive elements, shown below. All of these radionuclides are present in the ore, and in the HMC and MC, and they report mainly into the MSP waste.

Table 1 – Th-232 Decay Chain

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Radiation</th>
<th>Energy (MeV)</th>
<th>Half-life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thorium 232</td>
<td>$\alpha$</td>
<td>4.0</td>
<td>14 billion yrs.</td>
</tr>
<tr>
<td>Radium 228</td>
<td>$\beta$</td>
<td>0.06</td>
<td>6.7 yrs.</td>
</tr>
<tr>
<td>Actinium 228</td>
<td>$\beta$</td>
<td>1.2, 1.7, 2.1</td>
<td>6.1 hrs</td>
</tr>
<tr>
<td></td>
<td>$\gamma$</td>
<td>0.91, 0.96</td>
<td></td>
</tr>
<tr>
<td>Thorium 228</td>
<td>$\alpha$</td>
<td>5.4</td>
<td>1.9 yrs.</td>
</tr>
<tr>
<td></td>
<td>$\gamma$</td>
<td>0.08, 0.21 (weak)</td>
<td></td>
</tr>
<tr>
<td>Radium 224</td>
<td>$\alpha$</td>
<td>5.7</td>
<td>3.6 days</td>
</tr>
<tr>
<td></td>
<td>$\gamma$</td>
<td>0.24 (weak)</td>
<td></td>
</tr>
<tr>
<td>Radon 220 (‘Thoron’)</td>
<td>$\alpha$</td>
<td>6.3</td>
<td>55 seconds</td>
</tr>
<tr>
<td>Polonium 216</td>
<td>$\alpha$</td>
<td>6.8</td>
<td>0.15 seconds</td>
</tr>
<tr>
<td>Lead 212</td>
<td>$\beta$</td>
<td>0.35, 0.59</td>
<td>10.6 hrs</td>
</tr>
<tr>
<td></td>
<td>$\gamma$</td>
<td>0.24, 0.3</td>
<td></td>
</tr>
<tr>
<td>Bismuth 212</td>
<td>$\beta$ (64%)</td>
<td>2.3</td>
<td>61 minutes</td>
</tr>
<tr>
<td></td>
<td>$\alpha$ (36%)</td>
<td>6.0</td>
<td></td>
</tr>
<tr>
<td>Polonium 212 (64%)</td>
<td>$\alpha$</td>
<td>8.8</td>
<td>300 nanoseconds</td>
</tr>
<tr>
<td>Thallium 208 (36%)</td>
<td>$\beta$</td>
<td>1.3, 1.5, 1.8</td>
<td>3.1 minutes</td>
</tr>
<tr>
<td></td>
<td>$\gamma$</td>
<td>2.6, 0.51, 0.58, 0.86</td>
<td></td>
</tr>
<tr>
<td>Lead 208</td>
<td>nil, stable</td>
<td></td>
<td>infinite, lasts forever</td>
</tr>
</tbody>
</table>

Main gamma emitters above are Actinium 228 and Thallium 208

$\alpha$ = doubly-ionized Helium atom, ejected from nucleus at very high speed
$\beta$ = electron emitted from nucleus at nearly speed of light ($n \rightarrow p + e$)
$\gamma$ = gamma ray, like x-rays: penetrating electromagnetic radiation
Table 2 – U-238 Decay Chain

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Radiation</th>
<th>Energy (MeV)</th>
<th>Half-life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uranium 238</td>
<td>α</td>
<td>4.2</td>
<td>4.5 billion yrs.</td>
</tr>
<tr>
<td>Thorium 234</td>
<td>β, γ (weak)</td>
<td>0.2</td>
<td>24 days</td>
</tr>
<tr>
<td>Protactinium 234</td>
<td>β</td>
<td>2.3</td>
<td>1.2 minutes</td>
</tr>
<tr>
<td>Uranium 234</td>
<td>α</td>
<td>4.7</td>
<td>250 000 yrs.</td>
</tr>
<tr>
<td>Thorium 230</td>
<td>α</td>
<td>4.7</td>
<td>80 000 yrs.</td>
</tr>
<tr>
<td>Radium 226</td>
<td>α</td>
<td>4.8</td>
<td>1600 yrs.</td>
</tr>
<tr>
<td></td>
<td>γ</td>
<td>0.186 (weak)</td>
<td></td>
</tr>
<tr>
<td>Radon 222 (gas)</td>
<td>α</td>
<td>5.5</td>
<td>3.8 days</td>
</tr>
<tr>
<td><strong>Polonium 218</strong></td>
<td>α</td>
<td>6.0</td>
<td>3 minutes</td>
</tr>
<tr>
<td><strong>Lead 214</strong></td>
<td>β</td>
<td>0.7</td>
<td>27 minutes</td>
</tr>
<tr>
<td></td>
<td>γ</td>
<td>0.3, 0.35</td>
<td></td>
</tr>
<tr>
<td><strong>Bismuth 214</strong></td>
<td>β</td>
<td>1.0, 1.5, 3.3</td>
<td>20 minutes</td>
</tr>
<tr>
<td></td>
<td>γ</td>
<td><strong>0.6, 1.1, 1.8</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Polonium 214</strong></td>
<td>α</td>
<td>7.7</td>
<td>160 microseconds</td>
</tr>
<tr>
<td>Lead 210</td>
<td>β</td>
<td>0.016</td>
<td>22 yrs.</td>
</tr>
<tr>
<td></td>
<td>γ</td>
<td>0.047 (weak)</td>
<td></td>
</tr>
<tr>
<td>Bismuth 210</td>
<td>β</td>
<td>1.16</td>
<td>5 days</td>
</tr>
<tr>
<td>Polonium 210</td>
<td>α</td>
<td>5.3</td>
<td>140 days</td>
</tr>
<tr>
<td>Lead 206</td>
<td>nil, stable</td>
<td></td>
<td>infinite, lasts forever</td>
</tr>
</tbody>
</table>

Note: Main gamma emitter is Bismuth 214; bold nuclides above are the radon daughters.
Table 3 – U-235 Decay Chain

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Radiation</th>
<th>Energy (MeV)</th>
<th>Half-life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uranium 235</td>
<td>$\alpha$</td>
<td>4.4</td>
<td>710 million yrs.</td>
</tr>
<tr>
<td></td>
<td>$\gamma$</td>
<td>0.185</td>
<td></td>
</tr>
<tr>
<td>Thorium 231</td>
<td>$\beta$</td>
<td>0.14, 0.3</td>
<td>25.5 hrs</td>
</tr>
<tr>
<td>Protactinium 231</td>
<td>$\alpha$</td>
<td>5.0</td>
<td>33 000 yrs.</td>
</tr>
<tr>
<td>Actinium 227</td>
<td>$\beta$</td>
<td>0.04</td>
<td>22 yrs.</td>
</tr>
<tr>
<td>Thorium 227</td>
<td>$\alpha$</td>
<td>6.0</td>
<td>18 days</td>
</tr>
<tr>
<td>Radium 223</td>
<td>$\alpha$</td>
<td>5.7</td>
<td>11 days</td>
</tr>
<tr>
<td>Radon 219 ('Actinon')</td>
<td>$\alpha$</td>
<td>6.8</td>
<td>4 seconds</td>
</tr>
<tr>
<td>Polonium 215</td>
<td>$\alpha$</td>
<td>7.4</td>
<td>1.8 milliseconds</td>
</tr>
<tr>
<td>Lead 211</td>
<td>$\beta$</td>
<td>1.4</td>
<td>36 minutes</td>
</tr>
<tr>
<td>Bismuth 211</td>
<td>$\alpha$</td>
<td>6.6, 6.3</td>
<td>2.1 minutes</td>
</tr>
<tr>
<td></td>
<td>$\gamma$</td>
<td>0.35</td>
<td></td>
</tr>
<tr>
<td>Thallium 207</td>
<td>$\beta$</td>
<td>1.4</td>
<td>4.8 minutes</td>
</tr>
<tr>
<td>Lead 207</td>
<td>nil, stable</td>
<td></td>
<td>infinite, lasts forever</td>
</tr>
</tbody>
</table>

*Note: The U-235 chain is about 5% of the activity of the U-238 chain, in nature.*

All of the above radionuclides are present in the ore (and are expected to be in secular equilibrium, because of the insoluble nature of mineral sands). Several are emitters of gamma radiation, which is similar to x-rays. Other radionuclides are alpha emitters. These can only deliver a dose to a person following their ingestion or inhalation. Beta emitters are not generally a concern in uranium or thorium mining because controls which are put in place for gamma and alpha emitters are usually (except in very high grade situations) also effective in controlling beta radiation.
Potential Dose Delivery Pathways

There are four possible pathways for delivery of radiation doses to the human body that should be considered in mining industry situations, and that may require active control, depending on the circumstances. They are:

- Direct irradiation (‘shine’) by gamma radiation from bulk thorium-bearing (i.e., primarily monazite bearing) materials. This is only significant if long periods are spent close to large volumes of these materials.

- Inhalation of radon progeny (radon daughters). This is only a concern in underground U mining activities or in enclosed but unventilated volumes (such as warehouse full of baulker bags of monazite or leucoxene or xenotime concentrates).

- Inhalation of airborne dust containing long-lived alpha-emitting uranium, thorium, and radium.

- Ingestion of radioactive contamination transferred from hands to mouth when eating or smoking. This is controlled by personal hygiene (washing of hands and face before meals).

For the mineral sands industry, therefore, radiation dose control therefore requires primarily (a) dust minimisation and, if necessary, the use of respiratory protection; (b) spillage control, effective clean-up of workplaces and personal hygiene; and (c) planning to ensure that there are no major quantities of gamma-emitting materials which are close to continuously occupied workplaces.

Description of Operational Processes

In further detail, the operations comprise of dredge excavation of ore at Ginkgo and Snapper mines, then initial on-site beneficiation of the ore by wet gravity concentrator to produce a Heavy Mineral Concentrate (HMC), then further on-site separation by Wet High Intensity Magnetic Separation (WHIMS) plant to produce separate Mag and non-mag mineral concentrates. These concentrates are transported via road transport to the Broken Hill MSP for production of final separated mineral concentrates.

The Atlas and Campaspe mines, which are open pit (dozer-and-scaper) operations yet to be developed, are located on Exploration Licence EL5359, approximately 140 km north-east of Wentworth and 270 km south-west of Broken Hill in New South Wales (NSW). Together, they have an operational life of approximately 15 years, and will also produce an on-site mineral concentrates via wet plant and WHIMS. As they come on stream they will complement and then replace Ginkgo and Snapper as source feed of mineral concentrates for the MSP. The Atlas and Campaspe operations will include a rail transport component (both directions); due to the greater haul distances involved.
The MSP separates mineral concentrates to produce the saleable minerals ilmenite, leucoxene, rutile and zircon. The MSP is currently approved to process up to 650,000 tonnes per annum (TPA) of mineral concentrate produced by the Snapper and Ginkgo Mines. As these mines reach depletion, production from Atlas and then Campaspe, which will be open pits mined dry, will take over.

The Atlas-Campaspe pits will mine up to 7.5 million tonnes of HMC ore per year, to obtain from onsite primary wet concentrator and Wet High Intensity Magnetic Separator (WHIMS) Unit, some 500,000 TPA of mineral concentrate, for transport to the MSP.

All radionuclide bearing process waste generated as a result of MSP operations is combined and back-loaded to the Snapper and Ginkgo Mines for dilution and disposal. After completion of backfilling of these pits, disposal will be into Campaspe pit. In this case, transport will utilise rail as well as road transport, because of the longer travel distance involved. This will involve construction and operation of a transfer facility at Ivanhoe.

A maximum of about 50,000 TPA of MSP process waste will be disposed of at the Campaspe Mine.

The maximum workforce (employees and contractors) on the mine sites at any time will be generally in the order of 250 personnel. The MSP workforce is approximately 60 in total.

**Radionuclide Contents**

The uranium (U) and thorium (Th) concentrations of the Atlas and Campaspe ores are approximately 5 and 25 parts per million (ppm) respectively. This implies that the total (all nuclides) activity concentration of the Atlas and Campaspe ore is therefore approximately 1.8 Bq/g.

The U and Th concentrations in the HMC are higher than in the ore as a result of concentrating the heavy minerals in the primary gravity concentrator. The Atlas HMC will have U and Th concentrations of about 45 and 250 ppm respectively, while the Campaspe HMC will have U and Th concentrations of about 80 and 500 ppm respectively. The total activity concentration of the Atlas and Campaspe HMC will thus be about 189 and 357 Bq/g, respectively, making them legally radioactive under the NSW Radiation Control Act and Regulation.

The WHIMS circuit follows the wet gravity concentrator to separate the HMC into ilmenite-rich, leucoxene-rich and non-magnetic (containing rutile-rich and zircon-rich) mineral concentrate streams, which are stacked for draining and drying then transported to the MSP.
At the MSP these mineral concentrates from the mine site are processed to produce mineral products (i.e. leucoxene, non-magnetic concentrate, rutile, and zircon, unroasted and roasted ilmenite) Monazite is directed to the MSP process waste streams.

The U and Th are mainly found in the monazite which is rejected into the MSP process waste stream, which will have an initial projected U concentration of about 300 ppm and Th concentration of about 3,350 ppm, giving an all-nuclides activity concentration in this stream of about 190 Bq/g. The MSP process waste generated from the processing of later Campaspe-only mineral concentrates (i.e. the material that will be returned to the Campaspe Mine) will have approximately 460 ppm U and 6260 ppm Th. The total activity concentration of the Campaspe-only MSP process waste will be about 335 Bq/g.

**Radiation Dose Control Methods**

Gamma doses do not require active control at this stage other than restriction from continual occupancy / work in any areas immediately next to large storages of monazite waste.

Gamma radiation surveys will be monitored by a gamma survey meter and the results will be reported as described in the Radiation Logbook (attached). Stores containing bulk monazite bearing material will also be surveyed regularly, in order to control any potential dose to workers nearby. Radon progeny (radon daughters) in air will not require regular monitoring.

As in all mining and mineral processing work, control of airborne ore dust is very important. Airborne long lived alpha emitters in dust (airborne dust dose) will be controlled by dust minimisation equipment (e.g. dust extraction systems where appropriate) and work practices (e.g. use of wet rather than dry methods for cleaning of work areas), and by use of respiratory protection (dust masks) whenever work is being carried out in visibly dust conditions. The company will require the use of PPE for any visible dust conditions. Personal dust monitoring will be performed to determine worker doses from inhalation of radionuclide’s in dust, although these doses are expected to be low.

Ingestion of radioactive material will be prevented by maintaining proper levels of workplace and personal cleanliness, and by requiring washing of hands and face before meal and smoke breaks. Visual contamination checks will be carried out regularly on work surfaces, desks, tables, clothing, footwear, and skin. Where the alpha contamination probe is available, this will be used in addition to visual checks for surface contamination.
Access to Radiation Safety Professional Expertise and Resources

Cristal has access to, and makes use of advice from, Radiation Advice and Solutions Pty Ltd (RAS), of Brisbane (Mr Mark Sonter), Joe Slecha from Hunter Valley Radiation Services (fixed Radiation Gauge) sand other consultants as needed.

A two day Radiation Safety course has been run at the MSP, by RAS, which was attended by various personnel. Additionally, training of the Occupational Hygiene Technician in use of the equipment and in maintenance of the Radiation Logbook has taken place and will be subject to continual review. An expanded suite of monitoring equipment has recently been acquired based on recommendations by RAS so as to enable on-site analysis of dust monitoring samples. The monitoring program as here described expands on earlier work so as to cover the expanded situation due to move to open pit mining.

Plans for Monitoring Radiation in Workplaces and for Assessing Doses to Workers

The radiation monitoring program will address gamma radiation, airborne alpha-emitting dust, and surface contamination of long-lived alpha emitters in dust. It is presented in tabular form below.

Results will be recorded in the Site Radiation Logbook, and electronically. All results will also be made available to the workforce, and will be collated into a formal report for management and the regulatory agencies.

Gamma surveys will be carried out periodically through the MSP and its immediate surrounds so as to provide trend data for reference. Routine gamma radiation monitoring will be carried out quarterly wherever bulk quantities of mineralised material are collected and stored. Radiation badges are issued to relevant personnel for quarterly wearing periods.

Airborne alpha emitting dust (ore dust) concentrations will be measured at any potential dust-making activities. Personal dust monitoring will be performed on selected subset of workers.

Visual checks for contamination (dust) will be carried out on a regular basis, to ensure appropriate housekeeping and personal hygiene standards.

Radiometric surface alpha contamination monitoring will be performed monthly. Checks will cover office and plant tables and desks, ablutions area, and opportunistically, workers’ hands, clothes, etc.

Surface alpha contamination checks will also be used to ensure cleanliness of any equipment, vehicles or packages of samples or shipments of product or waste which are to be released from site.
**Radiation Monitoring Program**

<table>
<thead>
<tr>
<th>How</th>
<th>What</th>
<th>When</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area Gamma survey (GM probe)</td>
<td>Wet concentrator, WHIMS, MSP: work areas and storage areas</td>
<td>Quarterly</td>
</tr>
<tr>
<td>TLD badges for gamma doses</td>
<td>Personal badge issue, all radiation workers</td>
<td>3 month wearing period</td>
</tr>
<tr>
<td>Airborne radioactive dust (personal air sampler with count by alpha drawer assembly and scaler - rate meter)</td>
<td>Workers in dusty areas: 6 hrs if possible. Fixed samplers for investigational studies</td>
<td>To give minimum of 12 valid samples per Similar Exposure Group (SEG – i.e. workgroup) per year.</td>
</tr>
</tbody>
</table>
| Surface alpha contamination (alpha probe) | ➢ Vehicles  
➢ Work surfaces  
➢ Crib room tables, Offices  
➢ Ablutions area  
➢ Workers’ hands and clothes | Quarterly |
| | Any vehicles, equipment or packages of samples leaving site | Whenever such items are to leave site |

**Provision of appropriate Equipment, Staffing, Facilities and Operational Procedures**

Cristal undertakes to ensure appropriate equipment, staffing and facilities to provide world standard radiation safety capability. Operational procedures will be periodically subject to internal or external review. External advice will be sought on this and it will be reviewed annually.

**Worker Inductions and Training**

All workers are given a Radiation Safety Induction briefing shortly after arrival on site and will be issued with a Radiation Safety Induction Manual. Records of inductions are kept, along with a signed receipt. The Inductions are to be given by competent personnel, following the ‘script’ of the Radiation Safety Induction Manual.
Record keeping and Reporting

All radiation monitoring results will be recorded and reported, both to workers and management, and to the regulatory agency. All radiation records will be kept in a hardcopy Site Radiation Logbook, maintained by the RSO, as well as in computer files. NSW EPA and Mining Inspectors will be provided access to these files as requested. A template Radiation Logbook is attached as an Appendix.

A formal radiation report will be made on a 3 monthly basis. The report will review the data and report on latest and planned activities as they relate to radiation monitoring and control. On an annual basis, workers’ doses will be estimated and reported.

Any unusual incidents, such as a spill of radioactive material on a public road, will be reported by phone promptly to the regulatory agency, followed up by email.

Plan for Incidents Accidents and Emergencies

The company shall develop plans for radiation related emergencies. Conceivable emergencies may include, an accident in transport resulting in spillage of sample material and damage to a fixed radiation gauge. A road transport accident response plan is in existence and will be amended to include coverage of rail as well as road movements. Training in what to do in the event of identifying a damaged radiation gauge is also given during the induction process.

Periodic Review and Audit

The Operations Manager will review all radiation data via the proposed quarterly meetings, and annually. The Operations Manager will engage an external consultant to review the ‘adequacy and effectiveness’ of the Radiation Management Plan on an annual basis. This review will be made available to the regulators.

Management of Radioactive Waste

The main requirement in order to minimise impact on the environment is to limit dispersion of radioactive (mineralised) materials, both by airborne and by waterborne transport.

Following disposal of MSP waste by dilution and slurry placement in mined-out segments of the pit, this material will be covered by replacement of pit overburden, to a depth specified to be 10 metres. Monitoring will be undertaken to confirm the area does not exceed measured baseline radiation levels, and the location of all disposal sites will be GPS recorded and mapped.
Periodic Assessment and Review of the Adequacy and Effectiveness

As with the RMP, an annual review of effectiveness will be carried out and reported.

Other ‘Best Practice’ Organisational Arrangements

Responsibility: The Operations Manager has ultimate responsibility for all safety and occupational hygiene on site, including worker radiation dose control, and control over the transport of radioactive material. The Operations Manager affirms this by signing off and authorising the RMP.

The responsibility for ensuring compliance with the spirit and details of this RMP, and for radiation protection of workers and avoidance of radioactive contamination, will rest with the Operations Manager, who will take advice from the site OHS Manager, and any radiation safety consultants that are engaged by him, and will delegate tasks to the OHS Manager and others as required. The OHS Manager and Occupational Hygiene Technician will be trained and assigned the tasks to keep the monitoring program and record keeping up to date. These personnel will be nominated and trained to enable their approval as project/operation Radiation Safety Officers by the regulatory agency.

Recording of Management Decisions: The system for recording and reporting all aspects of radiation management will be via quarterly reports to management with follow up review meetings.

Other Procedural Rules for Dose and Contamination Control

(a) Personal Hygiene Control

Workers will be instructed to wash hands and face before meal breaks and before smoking. Workers carrying out dirty work will be instructed to shower and change at the end of shift. Basic washing facilities are provided at the mine sites and at the MSP.

Workers will be required to wear dust masks if conditions are visibly dusty or if monitoring indicates airborne activity concentrations over approximately 25% of the DAC.

(b) Equipment Contamination Clearance Control

Any equipment or sample packages or product shipments leaving the site or being despatched for export will first be cleaned and checked for surface contamination.

Any equipment, large or small, leaving site must be washed and checked and only released after it is certified clean and uncontaminated by the RSO. Certificates will be issued for items which are permanently leaving site, such as hire equipment being returned to owners. These clearances are essential both for minimization of spread of
contamination and to provide defensive evidence in case of accusations by antinuclear critics. All clearances must be recorded in the Site Radiation Logbook.

(c) Controlled and Supervised Areas:

The MSP is designated as a Supervised Area. This means that procedures for control of access and of radiation doses will be in place.

(d) Storage and Signage

Any permanent storage areas for bulk radioactive material will be fenced, locked when unattended, and sign-posted “Caution Radioactive Materials Storage Area” with responsible person contact details. Temporary storage areas (such as MC drainage/drying piles) will also be signposted.

Transport of Radioactive Materials

Any samples or shipments of bulk products or wastes which are considered likely to contain in combination, thorium (Th-232) and uranium (U-238) in excess of 10 Bq/g (this being the exemption level under the ARPANSA Code of Practice for Safe Transport of Radioactive Materials, RPS #2, and the IAEA Regulations for Safe Transport of Radioactive Materials TS-R-1), must be transported as radioactive material and be properly labelled and placard as such. The Regulations sets out rules for (i) labelling of packages containing radioactive materials; (ii) placarding of vehicles which transport them, and (iii) issue to driver of a briefing and consignment note describing the material being transported.

Note that packages (including freight containers) giving dose rates of less than 5 μSv/hr on the external surface may be transported as an ‘Excepted Package, UN2910’. This allows them to be sent without the package labelling or vehicle placarding designating it as “Radioactive”, but does require labelling on the package and on the consignment note as “UN2910”, and an internal warning notice visible when the package is opened, stating that it may contain radioactive material.

Note also that packages which are known to have parent (Th232 + U238) activity concentration under 10 Bq/g are not captured under the scope of the ARPANSA and IAEA Transport Regulations and may be sent as general cargo, provided surface dose rate is under 5 μSv/hr.

Note also that packages must be cleared for removal from site, the same as equipment. It is necessary to carry out surface alpha contamination checks on the outside of the package, and clean if necessary.
Fixed Radiation Gauges

Introduction

In Australia, the ionizing radiation sources used in fixed radiation gauges are regulated by radiation control legislation in the various States, Territories and the Commonwealth. In NSW the regulatory authority is the NSW Office of Environment and Heritage (EPA) that administers the NSW Radiation Control Act 1990 and Regulations 2003. Industrial radiation gauges, which include sources of ionizing radiation, are used to control the manufacturing process and assist in quality control applications. These applications include the non-invasive measurement and control of the thickness, level, density, weight, composition or moisture content in an industrial production process.

The principle of operation of the gauge depends on the detection of radiation that is transmitted through, scattered by or emitted as a secondary emission from within, the item or material of interest. If the radiation sources used in fixed radiation gauges were not adequately shielded, the dose rates near them would generally be of a level that could constitute a significant health hazard. At Cristal, process slurry lines are controlled by fixed radiation gauges more commonly referred to as density gauges. These gauges are located in areas that are occupied by, adjacent to or remote from, employees or other individuals. From time to time it may be necessary for maintenance personnel to have access to these gauges or to the equipment on which they are mounted.

All fixed radiation gauges containing sealed radioactive sources must be registered with the NSW Office of Environment and Heritage (EPA), Hazardous Materials and Radiation Section. To register sealed radioactive substances in fixed radiation gauges, it is a requirement that they are in compliance with the NSW Radiation Control Act 1990, Regulations 2003 and the ARPANSA Code of Practice and Safety Guide for the Safe Use of Fixed Radiation Gauges 2007, Radiation Protection Series 13. The requirements of the ARPANSA Code generally make up this Management Plan. Compliance with this Management Plan should enable the site to comply with the Code.

Responsibilities of the Employer – Cristal Mining

Cristal will ensure that a Radiation Management Plan is developed, documented, resourced, implemented and regularly reviewed to ensure safety in all applicable dealings involving a fixed radiation gauge. Cristal will ensure that all persons under their care follow and comply with the Cristal Radiation Management Plan and Cristal OHSE procedures.
Cristal will ensure that:

- before a new fixed radiation gauge is installed, the EPA is provided with details of the proposed disposal of the gauge or source(s) when no longer required; and
- before any gauge is installed or relocated, the EPA is provided with detailed plans of the plant or equipment to which the gauge is to be attached and its location
- the installation, maintenance and repair of the a fixed radiation gauge is carried out by a person or company authorised by the EPA
- a radioactive source used in a fixed radiation gauge complies with the requirements for registration under Section 7 of the Act with the EPA
- the fixed radiation gauge source housing, shutter and source control mechanisms comply with the requirements for registration with the EPA
- no person receives radiation exposure from a fixed radiation gauge in excess of the limits outlined in schedule 2 of the Regulation
- that the fixed radiation gauge is permanently and durably marked with:
  - the serial number or unique identifying number
  - a radiation warning sign which complies with Schedule 5 of the Regulations
  - the name of the radioactive substance
  - the activity and assay date of the radioactive substance
  - the maximum radiation level at 1 metre (shutter closed) and the date of measurement
  - the name and address of the manufacturer of the fixed radiation gauge
- the fixed radiation gauge is checked and maintained in accordance with the manufacturer’s recommendations and at intervals not exceeding 12 months which includes:
  - location of the gauge is verified and recorded
  - source housing has all of its component parts, is undamaged and in an acceptable condition
  - radiation pattern in the vicinity of the source housing substantially conforms to that expected for the design and installed radiation source
- shutter or source control mechanisms operate correctly
- labels are intact and legible
- A wipe test is carried out at regular intervals not exceeding 24 months or at intervals determined by the EPA.
- records of inspection audits for each fixed radiation gauge be maintained for the life of the gauge
- if the source housing or shutter mechanism are damaged, or an unusual variation in radiation pattern occurs:
  - the EPA is notified
  - the fixed radiation gauge is not used until damage repaired
  - the fixed radiation gauge is tested for proper function
  - any problem with radiation shielding is corrected
- following any catastrophic event such as fire, flood earthquake or similar:
  - the EPA is notified without delay
  - the gauge is inspected and, if necessary, tested to ensure that neither the source housing or its radiation source is damaged
  - the gauge and all its safety features are fully functional before using the gauge
- That approval from the EPA is obtained before disposing of any radioactive source.

**Working Rules**

All fixed radiation gauges installed at Cristal plants are density gauges which are fully automated and require no interaction with personnel. They are located where no personnel would normally be in close proximity. Only those persons who are licensed under the Radiation Control Act 1990 and Regulations may repair or remove gauges. Unauthorised persons should not remove, or in any way interfere with, the radioactive substances or carry out any maintenance, adjustment or modifications to radiation gauges.
Any work that is required within close proximity to a fixed radiation gauge should be assessed by the site RSO to determine the likely radiation exposure to an employee and the possibility of a radiation incident occurring. The radiation dose limit for members of the public (employees) is 1mSv. The RSO should ensure that the following safety controls are implemented:

- perform a radiation survey and inspection of the fixed radiation gauge as required by the Code of Practice and a record of results
- assess the possibility of unauthorised interference with gauge
- check the operation of the gauge shutter
- locking the shutter beam ‘OFF’ and confirmation
- supervise placement of personal Danger tags (or locks) or Out of Service as required
- monitor the duration of the work

If significant amount of work is required on, near the gauge, or replacement of the pipe on which the gauge is mounted, the RSO may determine that removal of the gauge is required for the duration of the work. The gauge must be removed by a licensed and authorised person. The radiation gauge is to be securely stored in compliance with the Code of Practice (section 5).

**Maintenance and Inspection of Fixed Radiation Gauges**

Cristal is responsible for implementing a Quality Assurance program for each fixed radiation gauge. The following inspections and procedures are to be performed and recorded for each fixed radiation gauge:

- **6 Monthly Checks**
  - Confirm location of gauge
  - Ensure legibility of warning signs and labels
  - Ensure correct operation of source shutter mechanism
  - Inspect condition of source housing

- **12 Monthly Checks (in addition to 6 monthly checks)**
  - Measurement of radiation dose rates on the external surfaces of gauge at 50mm and 1m
  - Ensure the physical integrity of the gauge and that it is securely mounted
Biennial Checks (in addition to 6 and 12 monthly checks)
  • Wipe testing of gauge external surfaces to check for indication of any leakage of radioactivity from the radioactive source
  • Compliance audit for registration renewal with EPA Hazardous Materials and Radiation Section

Emergency Procedures

Emergency procedures need to be taken to protect human life, limit injury and provide first aid where required. After a radiation incident, the following procedures should be followed to bring the incident under control:

  • Allay panic
  • Move persons to a safe distance and prevent access to the area
  • Secure an area of at least 5 - 10m radius from the radiation source as reasonably practicable), ensuring the radioactive source cannot be lost or carried away.
  • Notify the Radiation Safety Officer
  • Do not attempt to move or interfere with the radiation gauge or radioactive source unless directed by the RSO

The RSO or licensed and authorised person should;

  • Assess the nature and scope of the radiation incident
  • Where safe to do so, provide shielding to the source
  • Establish access control to the area
  • Monitor persons and equipment leaving the area
  • Implement any further action required to bring the incident under control
  • Investigate the circumstances of the incident including:
    • Assessments, calculation and measurements of radiation
    • Estimates of doses received by persons in vicinity
    • Corrective action plan
  • Prepare a report as soon as possible after the incident and submit to the EPA through the responsible person (employer)
  • Advise the employer and EPA any changes required to prevent a recurrence of a similar incident.
The list of emergency contacts should be checked at least every 12 months and updated as changes occur.

Incidents Involving a Fire

In the event of a major fire in the vicinity of a fixed radiation gauge, it is possible that the radiation source housing and radioactive source encapsulation may fail. The following procedure and precautions shall be implemented:

- Immediately notify the RSO who must notify the EPA that the incident is in progress
- The area is to be cordoned off
- If possible, provide water spray over radiation gauge
- Notify fire crew / brigade, breathing apparatus to be worn to prevent ingestion of any released radioactive particles
- RSO is to monitor radiation levels for duration of incident
- RSO to check those involved in incident for radiation contamination.

Incidents involving the Loss of a Radioactive Source

If a radiation source has been lost or suspected of being stolen, the RSO shall immediately be informed and a thorough search made using a radiation monitoring instrument. If the search fails to locate the device the RSO shall notify EPA.

Reporting Requirements

A radiation incident means an incident adversely affecting, or likely to adversely affect, the health or safety of any person because of the emission of radiation. A written incident report is to be produced by the Radiation Safety Officer and submitted through the employer or responsible person to the EPA within 48 hours of the occurrence of an incident. This report is to include the following particulars:

- of the accident indicating, as far as is possible, the place where it occurred and the period during which emission of radiation was uncontrolled,
- of the area over which any radioactive substances may have been dispersed,
- of any steps taken to rectify the accident,
- of any personal injury or exposure that may have resulted,
- Of any assessment of the radiation dose to which any person may have been exposed as a result of the accident.
Security

The owner is responsible for the security of all fixed radiation gauges or sealed source devices under their care. These devices may either be installed, in storage or being transported. The ARPANSA Code of Practice: Security of Radioactive Sources 2007 rps No.11 gives details of the requirements.

The categorisation for the aggregation of radioactive sources for each Cristal site is shown in the Error! Reference source not found. Cristal sites are calculated as low isk Category 4 sources where the measures in place for safety purposes are considered adequate for compliance with the code. If additional fixed radiation gauges are acquired the categorisation for the site will be reviewed. Security measures for Category 1, 2 and 3 sources are considerable more stringent than Category 4.

Storage

When a fixed radiation gauge containing one or more radioactive sources is placed in storage:

- the gauge must be clearly labelled as containing a radioactive source;
- the gauge must be stored so that the likelihood of damage to the gauge is minimised; and
- the source control or shutter mechanism must be locked or otherwise secured in the ‘beam off’ position;
- The gauge must be monitored to ensure that the radiation beam is properly attenuated with the shutter or source control mechanism in the ‘beam off’ position.

Damage to a gauge in storage could result from a fall, collision, corrosion etc. A store used for the storage of a fixed radiation gauge containing one or more radioactive sources must:

- be of solid construction and made of durable materials; and
- be designed, located, constructed and, if necessary, shielded so that:
  - the radiation levels at any accessible place outside the store do not result in an ambient dose equivalent rate or directional dose equivalent rate, as appropriate, exceeding 10 μSv/h; and
  - no person will receive a radiation dose in excess of the appropriate limit;
the resultant radiation dose rate in any occupied area is as low as reasonably achievable;

- be under the control of a person nominated by the Responsible Person;
- be kept locked;
- be subject to strict access control;
- not be used for other purposes;
- when a radioactive source is in the store, display a conspicuous notice bearing the radiation hazard warning symbol, the letters and symbol of which must be in black on a yellow background.

A store for fixed radiation gauges must not be located:

- near to explosives, combustible or corrosive materials;
- in an area prone to flooding or other potential hazard that may damage the store and/or its contents;
- in an area that allows unrestricted access to the public;
- In close proximity to an area where persons are working constantly.

**Transport**

The transport of radioactive substances is to be in compliance with the ARPANSA Code of Practice: Safe Transport of Radioactive Material (2008) rps No.2.

When a fixed radiation gauge containing one or more radioactive sources is packaged for transport, including transport within the Responsible Person’s establishment, the Responsible Person must ensure that:

- the source control or shutter mechanism in the source container is locked in the ‘beam off’ position; and
- the package is monitored to ensure that:
  - the radiation beam is properly attenuated with the shutter or source control mechanism in the ‘beam off’ position before any action is taken to remove the fixing devices that hold the container in its installed location; and
  - the radiation exposure pattern is as expected; and
the source container is:

- packed in an outer shipping container that is of strong, rigid construction; and
- effectively immobilised within the outer container; and
- the outer shipping container is labelled according to the requirements of the Transport Code and the EPA

During transport of a radioactive source in a vehicle the package must be:

- located in the vehicle so that the radiation dose received by any person travelling in the vehicle is minimised; and
- Stowed securely to prevent it from shifting under normal transport conditions.
- Transport signs in compliance with the Transport Code are to be affixed to both sides and the rear of the vehicle.
- Only persons authorised by Cristal are to transport industrial gauges.
Disposal

If a fixed radiation gauge is to be sold, lent or hired, the responsible person must ensure that the proposed new owner has a licence to possess radioactive materials and an approval to acquire the radioactive substance.

If a radioactive source is to be disposed of, application must be made to the EPA Hazardous Materials and Radiation Section for approval. The disposal must be organised by companies approved by the EPA.

The approval of the EPA is to be sought and obtained prior to the relocation of radioactive substances to a place outside New South Wales. The Director General must be notified within seven (7) days after the device has been relocated.

It is a requirement that records be kept and maintained for each fixed radiation gauge. Each gauge has its own dedicated records folder which is maintained for the life of the gauge or until it is disposed of. All records are to be kept in a legible form or in a form that can be readily reproduced into a legible form and can be made available to the request of an authorised officer.

The owner must keep a record of the fixed radiation gauge location at all times. A register of radioactive sources is maintained in compliance with the conditions of registration with the EPA. The source register is updated as the result of new installation, relocation, registration renewal, or disposal of fixed radiation gauges. A radioactive source register for each site is attached in Appendix 1.

A summary of record keeping requirements should include the following:

- all maintenance and inspection reports and summaries of QA tests undertaken on fixed radiation gauges
- copies of the radioactive source test certificates which includes the manufacturer’s recommended working life
- the owner’s licence to sell/possess radioactive materials issued under the Radiation Control Act 1990 by the EPA
- the EPA registration certificate at the radioactive source location
- the radioactive source register for each site
- a site sketch which shows the location of each fixed radiation gauge
- acknowledgment of notification to the NSW Fire Brigades
- copies of records for the fixed radiation gauge that show:
  - date received
  - name of the supplier/manufacturer
nominal activity of the radioactive source and assay date
- calibration certificates for Radiation Survey Meters
- Incident reports
- Radioactive sources in storage

Radiation Safety Officer

The OHS Manager, Occupational Hygiene Technician and other required personnel will receive training to perform the role of Radiation Safety Officer, and will then seek approval in that role from the regulatory authorities. The Radiation Consultant will be available as required for mentoring, review and advice.

The function of the RSO or responsible person is to advise and assist the employer to fulfil their responsibilities under the NSW Radiation Control Act 1990 and the Regulations 2003.

The RSO has the authority to:
- stop any unsafe operations or proposed actions that come to their attention, and
- Implement any necessary urgent actions following the occurrence of an incident.

The responsibilities of the RSO include the following:
- the preparation and maintenance of the Cristal Radiation Management Plan
- be thoroughly familiar with the relevant Act, Regulations and Codes of Practice and ensure that all registration, licence and legislative requirements are adhered to
- a detailed knowledge of working rules and emergency procedures
- Organise personal monitoring devices for those persons at risk of radiation exposure.
- preparation of dose reports
- ensure that radiation survey meters are suitable, calibrated and in good working order
- Ensure that the likely maximum radiation doses a person could receive are within the limits prescribed by the Radiation Control Regulation 2003, and are as low as reasonably achievable.
- Arrange for all employees who work with ionising radiation or radioactive substances to be provided with appropriate induction and continuing radiation safety training, and maintain records of this training.
- Organisation, maintenance and preparation of audits on fixed radiation gauges and plant processes
- Ensure that transport of fixed radiation gauges and radioactive materials complies with the relevant code of practice.
- Ensure a register of gauges at the site is maintained.
- Maintain and control a suitable radiation store at the site
- Ensure contamination levels on equipment leaving the site and bound for use outside Cristal's operations are within acceptable limits;

The Cristal Mining RSO has assistance from other suitably qualified personnel as listed below.

**Radiation Safety Structure**

- Joel Sulicich – Senior Safety Advisor (Lead RSO)
- Jarda Virgo – Safety Advisor (Supporting RSO)
- Clinton Chilcott – Laboratory Technician (Supporting RSO)

Other (RSO) qualified personnel able to assist if/when required:

- Murray Langley – Project Coordinator, Electrical and Instrumentation
- Paul Cameron – Electrical Supervisor
APPENDIX 1 Register of Radioactive Sources

Table 1 Broken Hill MSP Register of Radioactive Sources

<table>
<thead>
<tr>
<th>LOCATION DESCRIPTION</th>
<th>SOURCE MANUFACTURE DETAILS</th>
<th>MEASUREMENT</th>
<th>SOURCE HOUSING</th>
<th>EPA</th>
<th>ARPANSA Security Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ISO</td>
<td>ACTIVITY</td>
<td>DATE</td>
<td>ISO Class.</td>
<td>Working LIFE</td>
</tr>
<tr>
<td>PRIMARY SPIRAL FEED</td>
<td>Cs137</td>
<td>740MBq</td>
<td>09/09/05</td>
<td>C65545</td>
<td>15 years</td>
</tr>
<tr>
<td>NON-MAGNETIC CONCENTRATE</td>
<td>Cs137</td>
<td>740MBq</td>
<td>09/09/05</td>
<td>C65545</td>
<td>15 years</td>
</tr>
<tr>
<td>UNDERFLOW SPIRAL FEED</td>
<td>Cs137</td>
<td>740MBq</td>
<td>09/09/05</td>
<td>C65545</td>
<td>15 years</td>
</tr>
<tr>
<td>OVERFLOW SPIRAL FEED</td>
<td>Cs137</td>
<td>740MBq</td>
<td>09/09/05</td>
<td>C65545</td>
<td>15 years</td>
</tr>
<tr>
<td>MSP REJECTS</td>
<td>Cs137</td>
<td>740MBq</td>
<td>09/09/05</td>
<td>C65545</td>
<td>15 years</td>
</tr>
</tbody>
</table>

SUM A/D: 0.037

* D Value Table B.2
Cat 4 1+ A/D = 0.01

This document is uncontrolled if printed. Check SmartSolve for current revision.
### Table 2 Ginkgo Concentrator Register of Radioactive Sources

<table>
<thead>
<tr>
<th>LOCATION DESCRIPTION</th>
<th>ISO TOPE</th>
<th>ACTIVITY</th>
<th>DATE</th>
<th>ISO Class.</th>
<th>Working LIFE</th>
<th>Source Serial No.</th>
<th>MEASUREMENT RADIATION @ 1m</th>
<th>DATE</th>
<th>MAKE</th>
<th>MODEL</th>
<th>Serial No.</th>
<th>EPA Registration No.</th>
<th>ACTIVITY (A) GBq</th>
<th><em>D</em> GBq</th>
<th>A/D (Activity Ratio)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rougher Mod 1 Pump Density</td>
<td>Cs137</td>
<td>1.85GBq</td>
<td>29/05/1999</td>
<td>C06545</td>
<td>15 years</td>
<td>7727GQ</td>
<td>0.7 µSv/h</td>
<td>15/09/05</td>
<td>SIS</td>
<td>SS200</td>
<td>2091</td>
<td>RR11582</td>
<td>1.85</td>
<td>100</td>
<td>0.0185</td>
</tr>
<tr>
<td>Rougher Mod 2 Pump Density</td>
<td>Cs137</td>
<td>1.85GBq</td>
<td>18/08/2005</td>
<td>C065445</td>
<td>15 years</td>
<td>0442/05</td>
<td>0.7 µSv/h</td>
<td>15/09/05</td>
<td>SIS</td>
<td>SS200</td>
<td>2092</td>
<td>RR11578</td>
<td>1.85</td>
<td>100</td>
<td>0.0185</td>
</tr>
<tr>
<td>Cleaner Spirals Pump Density</td>
<td>Cs137</td>
<td>1.85GBq</td>
<td>18/08/2005</td>
<td>C065445</td>
<td>15 years</td>
<td>0443/05</td>
<td>0.7 µSv/h</td>
<td>15/09/05</td>
<td>SIS</td>
<td>SS200</td>
<td>2093</td>
<td>RR11577</td>
<td>1.85</td>
<td>100</td>
<td>0.0185</td>
</tr>
<tr>
<td>Mids Spirals Pump Density</td>
<td>Cs137</td>
<td>1.85GBq</td>
<td>18/08/2005</td>
<td>C065445</td>
<td>15 years</td>
<td>0444/05</td>
<td>0.7 µSv/h</td>
<td>15/09/05</td>
<td>SIS</td>
<td>SS200</td>
<td>2094</td>
<td>RR11576</td>
<td>1.85</td>
<td>100</td>
<td>0.0185</td>
</tr>
<tr>
<td>Re-Cleaner Spirals Pump Density</td>
<td>Cs137</td>
<td>0.74GBq</td>
<td>3/09/2000</td>
<td>C065445</td>
<td>15 years</td>
<td>0024/00</td>
<td>0.3 µSv/h</td>
<td>15/09/05</td>
<td>SIS</td>
<td>SS200</td>
<td>2068</td>
<td>RR11573</td>
<td>0.74</td>
<td>100</td>
<td>0.0074</td>
</tr>
<tr>
<td>Finisher Spirals Pump Density</td>
<td>Cs137</td>
<td>0.74GBq</td>
<td>4/09/2001</td>
<td>C065445</td>
<td>15 years</td>
<td>0742CX</td>
<td>0.3 µSv/h</td>
<td>15/09/05</td>
<td>SIS</td>
<td>SS200</td>
<td>2009</td>
<td>RR11572</td>
<td>0.74</td>
<td>100</td>
<td>0.0074</td>
</tr>
<tr>
<td>HMC Stage 2 Pump Density</td>
<td>Cs137</td>
<td>0.74GBq</td>
<td>21/01/2005</td>
<td>C065445</td>
<td>15 years</td>
<td>0041/05</td>
<td>0.3 µSv/h</td>
<td>15/09/05</td>
<td>SIS</td>
<td>SS200</td>
<td>2090</td>
<td>RR11599</td>
<td>0.74</td>
<td>100</td>
<td>0.0074</td>
</tr>
<tr>
<td>Tailings Stage 1 Pump Density</td>
<td>Cs137</td>
<td>3.7GBq</td>
<td>2/08/2006</td>
<td>C065445</td>
<td>15 years</td>
<td>0242/05</td>
<td>1.4 µSv/h</td>
<td>15/09/05</td>
<td>SIS</td>
<td>SS200</td>
<td>2095</td>
<td>RR11588</td>
<td>3.7</td>
<td>100</td>
<td>0.037</td>
</tr>
<tr>
<td>Dredge Slurry Discharge</td>
<td>Cs137</td>
<td>11.1GBq</td>
<td>30/03/06</td>
<td>C065445</td>
<td>15 years</td>
<td>0105/06</td>
<td>4.0 µSv/h</td>
<td>24/04/06</td>
<td>SIS</td>
<td>SS200</td>
<td>2113</td>
<td>RR11916</td>
<td>1.1</td>
<td>100</td>
<td>0.111</td>
</tr>
</tbody>
</table>

| SUM A/D                          |          |          |                  |            |              |                   |                            |        |      |       |            |                      |                  |         |                    |

* D Value Table B.2

Cot 4: A/D > 0.01
Table 3 Ginkgo WHIMS Register of Radioactive Sources

<table>
<thead>
<tr>
<th>LOCATION DESCRIPTION</th>
<th>SOURCE MANUFACTURE DETAILS</th>
<th>MEASUREMENT</th>
<th>SOURCE HOUSING</th>
<th>EPA</th>
<th>ARPA/MISA Security Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ISO</td>
<td>ACTIVITY</td>
<td>DATE</td>
<td>ISO Class.</td>
<td>Working LIFE</td>
</tr>
<tr>
<td>PRIMARY WASHING CYCLONE</td>
<td>Cs137</td>
<td>740MBq</td>
<td>09/09/05</td>
<td>C65545</td>
<td>15 years</td>
</tr>
<tr>
<td>SECONDARY WHIMS NON-MAG 1</td>
<td>Cs137</td>
<td>740MBq</td>
<td>09/09/05</td>
<td>C65545</td>
<td>15 years</td>
</tr>
<tr>
<td>PRIMARY WHIMS MAG 1</td>
<td>Cs137</td>
<td>740MBq</td>
<td>09/09/05</td>
<td>C65545</td>
<td>15 years</td>
</tr>
<tr>
<td>SECONDARY WHIMS NON-MAG 2</td>
<td>Cs137</td>
<td>740MBq</td>
<td>09/09/05</td>
<td>C65545</td>
<td>15 years</td>
</tr>
<tr>
<td>PRIMARY WHIMS MAG 2</td>
<td>Cs137</td>
<td>740MBq</td>
<td>09/09/05</td>
<td>C65545</td>
<td>15 years</td>
</tr>
</tbody>
</table>

updated 25 February 2013: J Slechtta - Hunter Valley Radiation Services

* D Value Table 8.2
**Cat 4**

This document is uncontrolled if printed. Check SmartSolve for current revision.
### Table 4 Snapper Register of Radioactive Sources

<table>
<thead>
<tr>
<th>UNIT</th>
<th>LOCATION</th>
<th>ISOTOPE</th>
<th>ACTIVITY</th>
<th>DATE</th>
<th>Serial No.</th>
<th>Dose Rate @ 1m, μSv/h</th>
<th>DATE</th>
<th>MAKE</th>
<th>MODEL</th>
<th>Serial No.</th>
<th>EPA Registration No.</th>
<th>ACTIVITY (A) GBq</th>
<th>D GBq</th>
<th>A/D (Activity Ratio)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIT 2017</td>
<td>DESLIME CYCLONE FEED</td>
<td>Cs137</td>
<td>3700 MBq</td>
<td>01/2010</td>
<td>SG284</td>
<td>1.0</td>
<td>04/2010</td>
<td>Endress &amp; Hauser</td>
<td>QG20 YR2C</td>
<td>CB0022010E1</td>
<td>RR22420</td>
<td>3.7</td>
<td>100</td>
<td>0.037</td>
</tr>
<tr>
<td>DIT 2046</td>
<td>ROUGHER FEED</td>
<td>Cs137</td>
<td>1100 MBq</td>
<td>01/2010</td>
<td>SH843</td>
<td>0.3</td>
<td>11/2009</td>
<td>Endress &amp; Hauser</td>
<td>QG20 YR2C</td>
<td>CB0022010E1</td>
<td>RR22421</td>
<td>1.1</td>
<td>100</td>
<td>0.011</td>
</tr>
<tr>
<td>DIT 2062</td>
<td>MID SPIRAL FEED</td>
<td>Cs137</td>
<td>370 MBq</td>
<td>01/2010</td>
<td>SH840</td>
<td>0.1</td>
<td>11/2009</td>
<td>Endress &amp; Hauser</td>
<td>QG20 YR2C</td>
<td>CB0022010E1</td>
<td>RR22422</td>
<td>0.37</td>
<td>100</td>
<td>0.0037</td>
</tr>
<tr>
<td>DIT 2066</td>
<td>TAILS CYCLONE FEED</td>
<td>Cs137</td>
<td>1850 MBq</td>
<td>01/2010</td>
<td>SH842</td>
<td>0.4</td>
<td>11/2009</td>
<td>Endress &amp; Hauser</td>
<td>QG20 YR2C</td>
<td>CB0022010E1</td>
<td>RR22423</td>
<td>1.85</td>
<td>100</td>
<td>0.0185</td>
</tr>
<tr>
<td>DIT 2091</td>
<td>CLEANER SPIRAL FEED</td>
<td>Cs137</td>
<td>370 MBq</td>
<td>01/2010</td>
<td>SH841</td>
<td>0.1</td>
<td>11/2009</td>
<td>Endress &amp; Hauser</td>
<td>QG20 YR2C</td>
<td>CB00224010E1</td>
<td>RR22424</td>
<td>0.37</td>
<td>100</td>
<td>0.0037</td>
</tr>
<tr>
<td>DIT 2121</td>
<td>RECLEANER SPIRAL FEED</td>
<td>Cs137</td>
<td>370 MBq</td>
<td>01/2010</td>
<td>SH839</td>
<td>0.1</td>
<td>11/2009</td>
<td>Endress &amp; Hauser</td>
<td>QG20 YR2C</td>
<td>CB00224010E1</td>
<td>RR22420</td>
<td>0.37</td>
<td>100</td>
<td>0.0037</td>
</tr>
<tr>
<td>DIT 2161</td>
<td>FINISHER SPIRAL FEED</td>
<td>Cs137</td>
<td>185 MBq</td>
<td>01/2010</td>
<td>SH836</td>
<td>0.1</td>
<td>11/2009</td>
<td>Endress &amp; Hauser</td>
<td>QG20 YR2C</td>
<td>CB00225010E1</td>
<td>RR22429</td>
<td>0.186</td>
<td>100</td>
<td>0.00185</td>
</tr>
<tr>
<td>DIT 2191</td>
<td>TAILS BOOM FEED</td>
<td>Cs137</td>
<td>740 MBq</td>
<td>01/2010</td>
<td>SH837</td>
<td>0.2</td>
<td>11/2009</td>
<td>Endress &amp; Hauser</td>
<td>QG20 YR2C</td>
<td>CB00227010E1</td>
<td>RR22428</td>
<td>0.74</td>
<td>100</td>
<td>0.0074</td>
</tr>
<tr>
<td>DIT 2139</td>
<td>TAILS STACKER FEED</td>
<td>Cs137</td>
<td>740 MBq</td>
<td>01/2010</td>
<td>SH838</td>
<td>0.2</td>
<td>11/2009</td>
<td>Endress &amp; Hauser</td>
<td>QG20 YR2C</td>
<td>CB00228010E1</td>
<td>RR22427</td>
<td>0.74</td>
<td>100</td>
<td>0.0074</td>
</tr>
<tr>
<td>DIT 2222</td>
<td>HMC TRANSFER PUMP</td>
<td>Cs137</td>
<td>110 MBq</td>
<td>01/2010</td>
<td>SH835</td>
<td>&lt;0.1</td>
<td>11/2009</td>
<td>Endress &amp; Hauser</td>
<td>QG20 YR2C</td>
<td>CB00225010E1</td>
<td>RR22426</td>
<td>0.11</td>
<td>100</td>
<td>0.0011</td>
</tr>
<tr>
<td>DREDGE</td>
<td>WET CONCENTRATOR FEED</td>
<td>Cs137</td>
<td>1100 MBq</td>
<td>07/2010</td>
<td>SN652</td>
<td>0.3</td>
<td>05/2010</td>
<td>Endress &amp; Hauser</td>
<td>QG20 YR2C</td>
<td>DS0012010E1</td>
<td>RR22425</td>
<td>1.1</td>
<td>100</td>
<td>0.011</td>
</tr>
<tr>
<td>DMU</td>
<td>DMU SLURRY DISCHARGE</td>
<td>Cs137</td>
<td>370 MBq</td>
<td>02/2012</td>
<td>TY994</td>
<td>0.1</td>
<td>02/2012</td>
<td>Endress &amp; Hauser</td>
<td>FQG61</td>
<td>EC00010115F</td>
<td>RR23418</td>
<td>0.37</td>
<td>100</td>
<td>0.0037</td>
</tr>
</tbody>
</table>

**Note:** Updated 15 March 2013: J. Sietckle - Hunter Valley Radiation Services

Cat 4

1. Activity > 0.01
# REVISION INFORMATION

## Revision History

<table>
<thead>
<tr>
<th>Rev. #</th>
<th>Date</th>
<th>Owner / Reviewer</th>
<th>Detail of Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
<td>Original Document</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>19/11/2014</td>
<td>A. Carter</td>
<td>Updated Bemax to Cristal Mining. No other changes were made within document. Document number changed from AP_ME_4.4.20001 AP_ME_4.4.04010</td>
</tr>
<tr>
<td></td>
<td>10/12/2014</td>
<td>J. Sulicich</td>
<td>Rejected document and asked for numbering to remain the same.</td>
</tr>
<tr>
<td></td>
<td>28/04/2015</td>
<td>C. Reynolds</td>
<td>Deletion of M. Priest from document context.</td>
</tr>
<tr>
<td>3</td>
<td>4/08/2015</td>
<td>J. Sulicich</td>
<td>Added Paul Cameron as qualified RSO.</td>
</tr>
</tbody>
</table>