Managing naturally occurring radioactive material (NORM) in mining and mineral processing — guideline

NORM–1

Applying the system of radiation protection to mining operations

Government of **Western Australia**
Department of **Mines and Petroleum**
Resources Safety

The Chamber of Minerals & Energy Western Australia

MIAC

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1. General information

1.1. Purpose

To:

1. Summarise the system of radiation protection as recommended by the International Commission on Radiological Protection (ICRP), International Atomic Energy Agency (IAEA) and the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA); and
2. Illustrate how the system of radiation protection may be practically applied in the mining and mineral processing industry and in particular:
   - implementing best practicable technology to reduce exposure and contamination levels. For example, ensuring suitable engineering controls are used to the extent feasible;
   - classifying employees, work conditions and workplaces on the basis of measured or predicted radiation levels. For example the classification of designated employees, restricted areas, controlled areas and supervised areas; and
   - the establishment of contamination levels that trigger radiation protection responses. For example, defining special exposures and setting investigation and reporting levels.

1.2. Scope

This guideline applies to all exploration, mining and mineral processing operations in Western Australia that use or handle naturally occurring radioactive material (NORM) and come within the scope of Part 16 of the Mines Safety and Inspection Regulations 1995 [1].

The following branches of mining and mineral processing industry have been identified [3][4]as either requiring attention from the radiation protection point of view or where an additional radiological assessments may be necessary. They include:

1. Mining and processing of uranium.
2. Mining and processing of heavy mineral sands.
3. Mining and processing of rare earth elements.
4. Mining ores other than uranium and heavy mineral sands, particularly underground.
5. Production of oil and gas.
6. Manufacture of titanium dioxide pigment.
7. The phosphate industry.
8. The zircon and zirconia industry.
9. Production of tin, tantalum, copper, aluminium, iron and steel.
10. Geothermal energy generation.

1.3. Definitions

Best practicable technology *[7]* as per Regulation 16.33 [1] means the technology, from time to time relevant to a specific project, which enables radioactive waste or exposure to radiation to be managed so as to minimise radiological risks and detriment to people and the environment, having regard to:

1. The achievable levels of effluent control and the extent to which pollution and degradation of the environment is minimised or prevented in comparable exploration, mining and mineral processing operations elsewhere.
2. The cost of the application or adoption of that technology relative to the degree of radiological and environmental protection expected to be achieved by its application or adoption.
3. Evidence of detriment or lack of detriment to the environment after the commencement of exploration, mining and mineral processing operations.
4. The physical location of the mine and/or the processing plant.
5. The age of the equipment and facilities in use for mining and mineral processing purposes and their relative effectiveness in achieving radiological and environmental protection.
6. The potential long term hazards from the wastes.

Contamination level as per Regulation 16.1 [1] means an amount of radioactivity in either air, water or on a surface, the presence of which is undesirable to the extent that it could be harmful if uncontrolled or not guarded against.

Controlled area as per Regulation 16.12 [1] means an area where:

1. Access is limited to those persons who are required to work, or perform any duty in the area.
2. The boundaries of the area are clearly delineated and are made known to employees.
3. Any person entering the area has received appropriate instructions about the nature of the radiation hazards in the area.

Designated employee as per Regulation 16.14 [1] means an employee who works, or may work, under conditions such that the employee's annual effective dose equivalent might exceed 5 millisieverts (0.005 Sv).

Dose constraint means a level of dose, in relation to an employee, as determined by Regulation 16.5 [1], used to prompt investigation and (if appropriate) action if achieved or exceeded.

NORM (naturally occurring radioactive material) means material containing no significant amounts of radionuclides other than naturally occurring radionuclides, disturbed or altered from natural settings, or present in technologically enhanced concentrations above background radiation levels due to human activities that may result in a relative increase in radiation exposures and risks to the public and the environment.

Practicable means reasonably practicable having regard, where the context permits, to:

1. The severity of any potential injury or harm to health or the environment that may be involved and the degree of risk of such injury or harm occurring.
2. The state of knowledge about:
    a) the injury or harm to health or the environment referred to in paragraph (1).
    b) the risk of that injury or harm to health or the environment occurring.
    c) the means of removing or mitigating the potential injury or harm to health or the environment.
3. The availability, suitability, and cost of the means referred to in paragraph 2.(c).

Special exposure means an exposure complying with one of the following conditions:

1. An exposure to an individual or a known sub-group of individuals which arises from an unplanned non-routine or an unusual task which is unlikely to have occurred previously in the reporting period or is unlikely to occur again in the remainder of the reporting year; or
2. An exposure or exposures which arises from a planned program (e.g. maintenance operation during a shut down, non-routine housekeeping) where the exposure is abnormally high in comparison to routine operations.

Restricted area means a part of a controlled area where access is stringently controlled by virtue of the potential for significant radiation doses to be received following protracted exposure in the area.

Supervised area as per Regulation 16.12 [1] means an area where access by members of the public is supervised; and the boundaries of the area are clearly delineated and are made known to employees at the mine.

Surface contamination as per Regulation 16.1 [1] means the presence of a radioactive substance on a surface in quantities in excess of prescribed quantities.

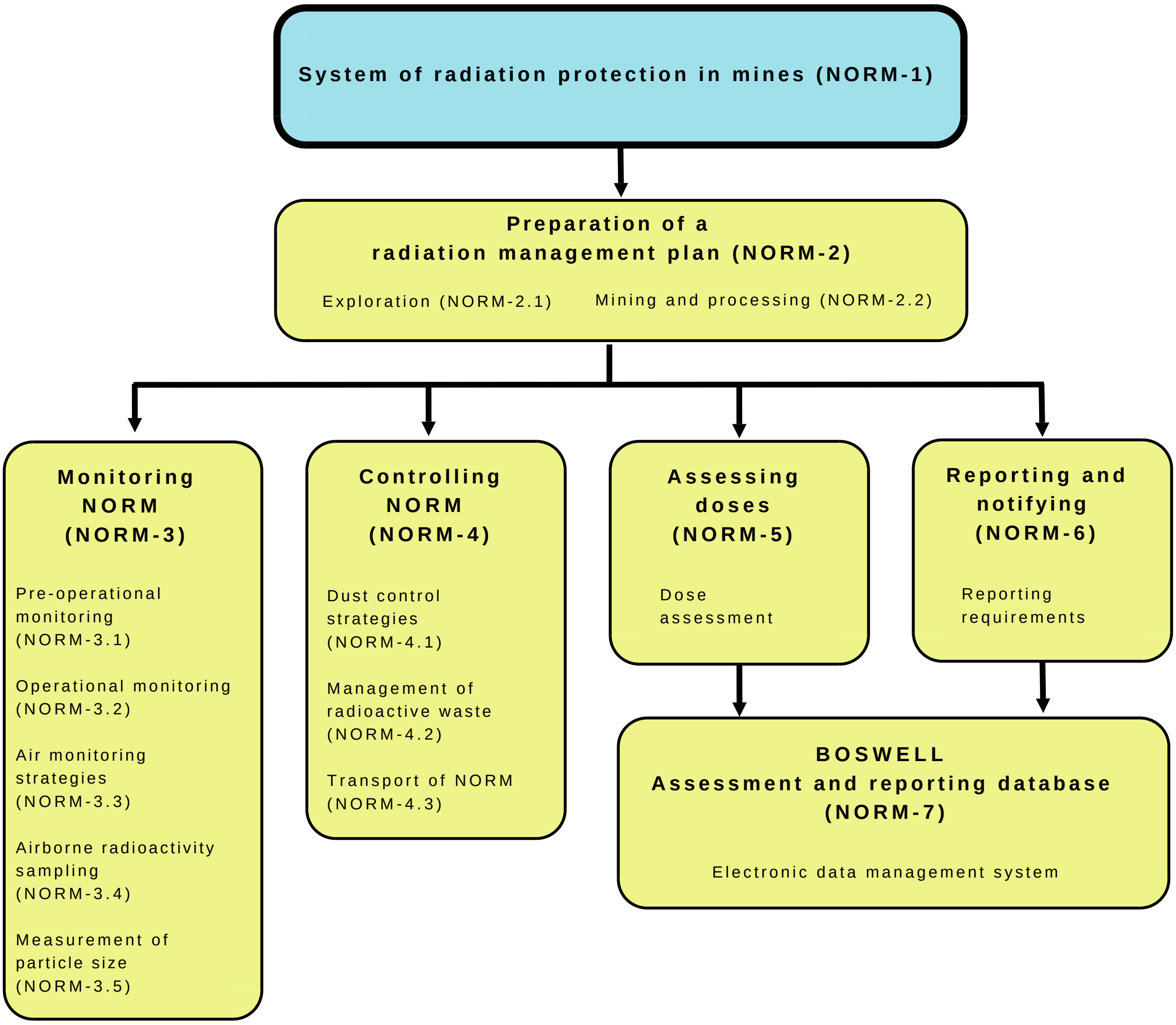
Fixed (surface) contamination means (surface) contamination other than non-fixed (surface) contamination.

Non-fixed (surface) contamination means (surface) contamination that can be removed from a surface during normal handling.

1.4. Relationship to other NORM guidelines

The flowchart in Figure 1.1 shows the arrangement of the Radiation Safety Guidelines.

Figure 1.1.: Relationship to other NORM guidelines



2. Guidance

2.1. Introduction

The protection of the public and workers from the harmful effects of ionising radiation has been a concern of radiation protection professionals since the early part of the 20th century when harmful effects were first observed.

Since that time, the detrimental effects of ionising radiation have been extensively studied: from the fundamental nature of radiation's effects on cells, organs and organisms, to the epidemiological study of large populations who have been exposed to various levels of ionising radiation. Based on these studies, over time an international system of radiation protection has been built largely through the work of the International Commission on Radiological Protection (ICRP).

Radiation is currently viewed as one of the most studied of all known carcinogens. The system of radiation protection that has been built to protect the public and workers from its harmful effects is seen as extensive and robust, but is less well developed for the protection of the environment and non-human species. The system is also viewed by some as being overly demanding of resources.

Of relevance to the system of radiation protection is the increasing social desire/need to understand decisions made by governments, regulatory bodies and industry, and to participate more actively in decision-making processes involving environmental and health issues.

Nuclear Energy Agency[6]

2.1.1. History of radiation protection

Figure 2.1.: 1903 Nobel Prize–Marie Curie, Pierre Currie and Henri Becquerel

1895 Wilhelm Roentgen discovers ionizing radiation. X-rays quickly came into widespread medical use following their discovery. Although it was not immediately clear that large or repeated exposures might be harmful, mounting evidence during the first few years showed unequivocally that they could be.

1896 Frenchman Henri Becquerel discovered that uranium salts emitted rays similar to X-rays. He was able to demonstrate that this radiation was not phosphorescence, that it came spontaneously from uranium itself and it was what we know as 'radioactive'.

1896 Polish Physicist Marie Curie takes an interest in Bequerel's discovery and decides to look into uranium rays as a possible field of research for her physics thesis. She finds that the activity of the uranium compounds depended only on the amount of uranium present and the radiation came from the atom itself. This was her most important single piece of work. She studied two uranium minerals, pitchblende and torbernite and showed that these two minerals must contain small amounts of some other substance far more active than uranium itself.

1898 Marie Curie and Pierre Curie announce the existence of an element they name 'polonium', in honour of Poland.

1900 American Roentgen Ray Society (ARRS) founded.

1902 Marie Curie and Pierre Curie manage to separate one-tenth of a gram of radium chloride from a tonne of pitchblende.

1903 The Royal Swedish Academy of Sciences award Pierre Curie, Marie Curie, and Henri Becquerel the Nobel Prize in Physics, in recognition of their services rendered by their joint research into the radiation phenomena discovered by Professor Henri Becquerel.

1904 The damaging effects of ionizing radiation are unknown, and Marie Curie works in a shed without any safety measures. She carries test tubes containing radioactive isotopes in her pocket and stores them in her desk drawer, remarking on the pretty blue-green light that the substances gave off in the dark.

1906 Pierre Curies dies in traffic accident.

1910 Marie Curie, working on without her husband, isolates pure radium metal. Radium is over one million times more radioactive than the same mass of uranium.

1911 Marie Curie is awarded the Nobel Prize in Chemistry, 'in recognition of her services to the advancement of chemistry by the discovery of the elements radium and polonium, by the isolation of radium and the study of the nature and compounds of this remarkable element.'

1919 One gram of radium is valued at $100,000 and one gram of gold is valued at $586.00 (United States dollars).

1925 First International Congress of Radiology, London, establishes ICRU.

1928 ICRP established under auspices of the Second International Congress of Radiology, Stockholm.

1928 ICRU adopts the roentgen as unit of exposure.

1934 ICRP recommends daily tolerance dose.

1934 Marie Curie dies from aplastic anaemia, most certainly contracted from exposure to radiation.

1941 ACXRP recommends first permissible body burden, for radium.

1947 U.S. National Academy of Sciences establishes Atomic Bomb Casualty Commission (ABCC) to initiate long-term studies of A-bomb survivors in Hiroshima and Nagasaki.

1949 NCRP publishes recommendations and introduces risk/benefit concept.

1952 British nuclear weapon tests commence at Monte Bello Islands, Western Australia.

1955 Western Australia is the first Australian State to regulate the use of radiation through the *Radioactive Substances Act*.

1955 United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) established.

1956 International Atomic Energy Agency organized under United Nations.

1958 United Nations Scientific Committee on the Effects of Atomic Radiation publishes study of exposure sources and biological hazards.

1964 International Radiation Protection Association (IRPA) formed.

1977 ICRP Publication 26, "Recommendations of the ICRP."

1978 ICRP Publication 30, "Limits for Intakes of Radionuclides by Workers."

1991 International Atomic Energy Agency report on health effects from the April 1986 Chernobyl accident.

1991 ICRP Publication 60, "1990 Recommendations of the International Commission on Radiological Protection."

1994 ICRP Publication 66, "Human Respiratory Tract Model for Radiological Protection."

2000 UNSCEAR 2000 Report on sources of radiation exposure, radiation associated cancer, and the Chernobyl accident.

2005 ICRP proposes system of radiological protection consisting of dose constraints and dose limits, complimented by optimization.

2009 Marie Curie's papers including her cookbook from the 1890s are considered too dangerous to handle due to their levels of radioactivity. They are kept in lead-lined boxes and those who wish to consult them must wear protective clothing.

2.1.2. ICRP recommendations

The ICRP clearly states that the system of radiological protection applies in principle to all sources of radiation regardless of size and origin. However, it is recognised that it is inappropriate to treat all sources and exposures in the same way and with the same level of resources. The ICRP has defined two concepts to delineate the extent of radiological protection control for regulatory purposes:

1. Exclusion of certain exposure situations from legislation because they cannot be controlled by any reasonable means (for example, potassium–40 in the body or exposure to cosmic radiation at sea level).
2. Exemption from some or all radiological protection legislation for situations where such controls are felt to be unwarranted (for example, very low levels of radioactivity in building materials).

There are three categories of radiation exposure in the ICRP system:

1. Occupational
2. Public
3. Medical

An important ICRP recommendation is that 'no attempt be made to add the exposures to the same individual from the different categories of exposure for regulatory purposes'. The NORM guidelines primarily deal with the control of occupational exposures.

The basic principles of radiological protection are:

Justification 'Any decision that alters the radiation exposure situation should do more good than harm'. This principle applies to all exposure situations.

Optimisation of protection 'The likelihood of incurring exposures, the number of people exposed, and the magnitude of their individual doses should all be kept as low as reasonably achievable, taking into account economic and societal factors'. This principle applies to all exposure situations.

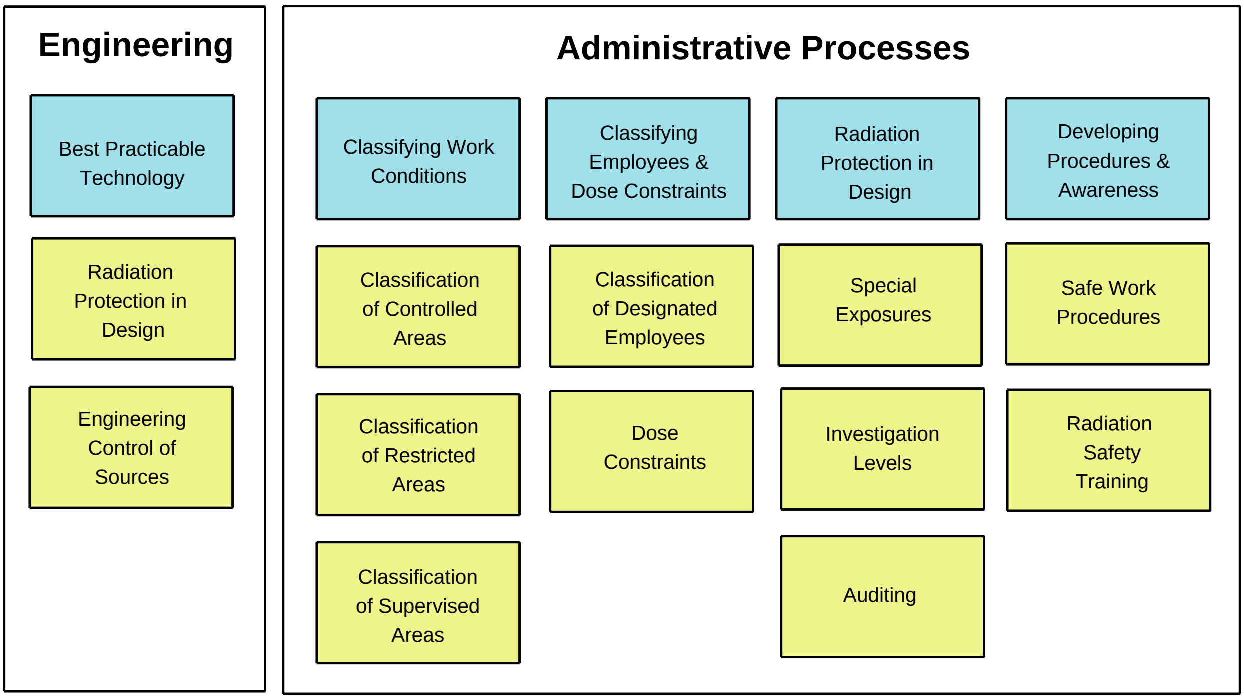
Dose limitation 'The total dose to any individual from regulated sources in planned exposure situations other than medical exposure of patients should not exceed the appropriate limits recommended by the Commission'. This principle is individual related and applies in planned exposure situations only.

The appropriate upper bound for optimising protection with regard to a particular activity or plan will vary according to a number of factors, including the overall benefit to society conferred by that activity, the cost and practicability of protection options, and the benefit received by those incurring the exposure. The ICRP recommends that the national authorities set appropriate reference levels for specific activities.

2.2. Summary

The diagram in Figure 2.2 illustrates the overall approach that is recommended to ensure that radiation doses at mines are as low as practicable.

Figure 2.2.: Application of the System of Radiation Protection in Mines



The principle of optimisation of radiation protection is a cornerstone of the international system for radiation protection and is the key driver for ensuring that radiation doses are not just maintained below standards, but are kept to the lowest feasible level throughout the life cycle of a practice involving radioactive materials. This principle is also referred to as the ALARA principle: *As Low As Reasonably Achievable* economic and social factors being taken into account.

Note: in the Mines Safety and Inspection Act 1994 ([2]), the term "as low as practicable" (ALARP)(refer Regulation 16.15 [1]*) is used and for all practical intents and purposes this is the same as ALARA.*

The use of risk management to develop a suitably detailed plan for the identification, control and monitoring of radiation exposure and the management of radioactive wastes is necessary to coordinate the system of radiation protection. This is documented in the Radiation Management Plan for an exploration, mining and/or processing operation. Details on the requirements for these are contained in the guidelines on the preparation of a Radiation Management Plan (NORM–2.1 Exploration, NORM–2.2 Mining and processing).

One of the most effective ways to control radiation risks is to engineer out radiation hazards to the extent feasible. This guideline provides a brief overview of radiation protection in design, but does not discuss engineering controls in any detail as these are covered in the other Guidelines (NORM–4.1 Dust control strategies and NORM–4.2 Management of radioactive waste).

The main focus of this guideline is on the administrative processes that are used to ensure optimisation.

2.3. Engineering

2.3.1. Best practicable technology

The responsible person at a mining operation needs to be able to demonstrate to the State Mining Engineer that the operation is employing the best practicable technology (Regulation 16.7(5) [1]) and that radiation doses to employees received as a result of that operation, are as low as practicable (Regulation 16.15 [1]).

The preparation of a formal radiation management plan (as per Regulation 16.7 [1]) is intended to document how best practicable technology has been incorporated into the design and operation of the mine and/or processing plant, and also the procedures that have been adopted to ensure the radiation exposure of persons employed at, or affected by, the mine are not just below the relevant dose limit, but are as low as practicable (refer to Guideline NORM–2.2 Preparation of a radiation management plan – Mining and processing for further information).

It is considered that if a company is able to demonstrate that they are complying with their approved radiation management plan then that should suffice as an indication that the doses received are at an acceptable level. Note that all radiation management plans are required to be reviewed within two years of commencement of each operation and subsequently at intervals designated by the State Mining Engineer (Regulation 16.7(4) [1]), typically — every two years. This review interval will be more frequent if circumstances change.

2.3.1.1. Radiation protection in design

Optimisation commences in the design stage of an exploration, mining or processing operation. At the design stage, cost-benefit analysis is required to achieve a balanced design, which is not only optimised for radiation protection, but all other health, safety and environmental requirements. Once the detailed engineering design of a process has been finalised it is often quite expensive to retrofit radiation control equipment, such as ventilation ducting for dust control and the associated infrastructure. For this reason, specification of radiation protection standards to be achieved in operations is important at the initial design stages.

In design, optimisation can be facilitated by:

1. specifying radiation protection design criteria, usually in terms of contamination levels or dose rates at some fraction of derived limits;
2. specifying engineering control features, such as dust extraction or suppression equipment, shielding, layout of plant, automation of processes;
3. undertaking formal hazard assessments, such as hazard and operability (HAZOP) studies at various stages of design;
4. ensuring design engineers are aware of relevant radiation protection measures through appropriate training and instruction; and
5. applying the hierarchy of risk control principles (i.e. preference to elimination and control of hazards rather than use of operational procedures and PPE to achieve exposure control).

Although it may be possible to carry out minor modifications to plant and equipment following completion of the detailed design phase, post-design stage optimisation may be restricted to the implementation of operational procedures, including the adherence to any dose constraints that may be imposed on an operation.

The underlying principles of radiation protection have been summarised in the Table 2.1 on the facing page and should be considered in the design of new facilities.

2.4. Administrative processes for optimisation

The administrative processes used for optimisation involve:

1. Classification of working conditions and workplaces.
2. Application of dose constraints to certain work categories.
3. Implementation of investigation and reporting levels.
4. Formulation, distribution and implementation of safe work procedures for identified critical tasks and provision of awareness training to all employees.

The classification of working conditions and workplaces and the implementation of investigation and reporting levels where contamination of the workplace cannot be 'engineered out' of the operations are discussed in detail in the following sections.

2.4.1. Classifying work conditions

2.4.1.1. Classification of controlled areas

One administrative method of achieving optimisation involves identifying and delineating areas of higher contamination levels or dose rates in the workplace. There are two such areas that the ICRP and ARPANSA recommend should be invoked in premises that use or handle radioactive materials — namely, controlled and supervised areas (see definitions in Section 1.3 on page 2). Such designated areas are accompanied by suitable radiation safety rules or procedures specified by management.

Table 2.1.: Principles of radiation protection

Principle	Intent
Source barrier (shielding)	Maximise containment, minimise release
Distance	Maximise distance
Time	Minimise exposure and intake time
Source reduction	Minimise production and use of radioactive materials
Optimal technology	Choose best practicable technology
Housekeeping	Minimise spillages and surface contamination
Dilution and blending†	Minimise concentration, maximise dilution
Personal barrier	Minimise entry into the body by providing appropriate PPE and washing facilities
Education	Maximise knowledge through training
Limit other exposures	Minimise exposures to other agents

†Applicable only for mineral sands mining and separation.

The Regulations [1] require that, if there is an area in a mine in which exposure conditions are such that an employee could receive in excess of 5 mSv in a year, then that area is to be declared a *controlled area* and the provisions of Regulation 16.12 [1] should be applied to those areas.

This dose of 5 mSv may be received from one or a combination of radioactive sources; for example, either internal exposure or external exposure or both. Note that even if no employees are anticipated to work in the particular controlled area for a full twelve month period, control is still required to be established for that area if the potential for exposure exists.

Controlled area work procedures Regulation 16.12 [1] requires that each responsible person at the mine must ensure that each employee working in a controlled area has received appropriate instructions about the nature of the radiation hazard in the area. These instructions should be in the form of clearly defined written procedures which explain what is necessary for any employee working in the area to reduce, as much as practicable, any identified hazard associated with a set task.

The defined tasks would be for routine operations, as well as for tasks that are only performed at infrequent times during a year (e.g. major maintenance overhauls). It is important to describe procedures for infrequently performed tasks, as personnel may change during the period (e.g. use of contractors) and people, over time, may forget the manner in which tasks were performed to result in the lowest exposure.

Detailed work practices and procedures need to be developed to ensure that the effective control over radioactive material is established and lowest practicable exposure levels are being maintained.

Figure 2.3.: An example of a controlled area warning sign

These procedures should be reviewed periodically for their effectiveness as well as audited for their actual application in practice.

Requirements should be established for activities such as the movement, storage, processing and packaging of radioactive materials, and waste management. Work practices and, particularly, good housekeeping measures are required to prevent unnecessary exposure to, and dispersion, of radioactive materials. Procedures should be provided in relation to spillage clean up, including the control measures to be used (e.g. water, vacuuming), and the preventative maintenance of control equipment such as filters and dust collector. The procedures should also specify any personal protective clothing or apparatus that may be necessary to perform the task in a safe manner.

All written procedures for controlled areas should also be part of the radiation management plan and must be readily available to, and understood by, all personnel involved.

Controlled area work practices The practices that are adopted in controlled areas would be specific to each operation but should involve good hygiene practices as follows:

1. Areas where it is possible for designated employees to eat, drink and smoke should be clearly delineated and these areas should not ordinarily be part of a controlled area.
2. Facilities to wash personnel's hands and faces before leaving a controlled area should be provided. In certain circumstances, showering facilities may be necessary.
3. Similarly, contaminated clothing should not be allowed to leave controlled areas. It may be necessary to provide laundering facilities associated with these areas if contaminated clothing is routinely encountered. Disposable clothing, or easily cleaned clothing like waterproof garments, would be required for those tasks where clothing may become contaminated if the potential for personal contamination cannot be engineered out of a task.

2.4.1.2. Classification of restricted areas

There may be work areas in some mining and/or processing operations where the potential for exposure of employees may be a significant fraction of the annual dose limit, say, in excess of 15 mSv in a year. In these cases it may be beneficial to further categorise these areas as *restricted areas*. A restricted area would then be a part of a controlled area where access is stringently controlled; time spent in the area is minimised; and all work practices and procedures are carried out by experienced personnel possibly under supervision, either remotely or directly.

Figure 2.4.: An example of a restricted area warning sign

In the mining and processing of naturally occurring radioactive materials, restricted areas would only be anticipated where there is substantial concentration of thorium and uranium bearing materials; typically when thorium exceeds 0.3% (3,000 ppm) and uranium concentrations exceed 0.13% (1,300 ppm.).

2.4.1.3. Classification of supervised areas

In accordance with the ARPANSA definition: a Supervised Area is

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

In accordance with this recommendation, Regulation 16.12(2) [1] requires members of the public in such areas to be supervised and the dose constraint, as discussed in Subsection 2.4.1.2 on the facing page, restricts certain occupations to the same limit as members of the public.

Thus, in practice, supervised areas are all of those areas on an exploration, mining or mineral processing site where it is possible for exposure conditions, either by internal or external exposure or both, to exceed member of the public limits based on an occupancy factor of 25%, or for approximately 40 hours per week exposure.

Supervised areas should be clearly delineated so that any member of the public (e.g. a visitor) or an employee in a restricted occupation (e.g. office and administration staff), is aware that the supervised area exists and that they are required to obey a supervisors instructions whilst in these areas. The minimum constraint on these areas would require the responsible person to ensure that members of the public and relevant employees are restricted in the amount of time spent in supervised areas, assuming that access is indeed necessary.

The use of supervised areas on an exploration/mining/processing site can be used to highlight areas of marginally elevated exposure levels (e.g. stockpiles of radioactive minerals in a store producing elevated radiation levels on the other side of the store wall). As exposures to all personnel are to be kept as low as practicable then knowledge of any elevated exposure levels can eliminate unnecessary exposure.

Figure 2.5.: An example of a supervised area warning sign

Areas outside supervised areas The boundaries of supervised areas should not be confused with the site boundary, where it is required that exposure levels are such that, as a result of exploration, mining and/or processing operations, the member of the public limit should not be exceeded when based on 100% occupancy or exposure for 168 hours per week. In other words, a hypothetical person residing adjacent to the site lease will not receive in excess of 1 mSv per annum.

As all areas of potential radiation exposure should be known and classified according to the exposure conditions, there should not be any surprise exposure conditions such that persons may receive doses in excess of the member of the public limit outside of supervised or controlled areas.

Monitoring of areas outside of supervised or controlled areas could, therefore, be limited to area monitoring to determine levels of airborne radioactivity and to area gamma measurement utilising either thermoluminescent dosimeter or survey meter; it should not be necessary to conduct personal monitoring in these areas.

Note: In the assessment of the internal exposure from airborne radioactivity outside of supervised or controlled areas, unless there is evidence to the contrary, the relevant dose conversion factor for the member of the public default aerial median aerodynamic diameter (AMAD) of 1 μm should be used.

2.4.2. Classification of employees and dose constraints

2.4.2.1. Classification of designated employees

One useful operational technique used to cost-effectively target radiation protection resources is the classification of employees. This is in recognition of the fact that radiation monitoring and protective efforts need to be directed to those groups of workers who have the potential to receive a relatively higher radiation exposure in comparison to other groups of workers.

In accordance with the Mines Safety and Inspection Regulations [1], an individual is to be classified as a *"designated employee"* if there is potential for the individual to receive an occupational dose in excess of 5 mSv per year. It is required that the number of designated employees be kept to the minimum necessary for the proper conduct of the mining and/or processing operation (refer Regulation 16.14 (3) [1]).

The Regulations [1] also require that employees to be classified *'a priori'* (i.e. before operations commences) as either "designated" or "non-designated" employees. Depending on the concentrations of radionuclides and processing conditions some workers directly involved in the operation and maintenance of metallurgical plants processing radioactive materials may be classified as designated employees. Employees involved in work categories like: surface mining, concentration, transport, administration, general workshop duties and technical services are typically classified as non-designated employees, some of which have a dose constraint placed on them (see Section 2.4.2.2).

Criteria for prediction of designated employees Practical experience has indicated that the *'a priori'* assignment of an employee as a designated employee based on the previous year's work category assessments has become increasingly difficult. Complicating factors include the:

- consistent reduction, through optimisation measures, of the annual effective dose received by employees; and
- increased used of 'multi-skilling' in the mining and mineral processing industry, which means that employees spend times in several work categories throughout the reporting year.

The following criteria can be utilised for classifying designated employees for subsequent reporting years:

1. If an employee received an effective dose approaching 5 mSv in the previous year, and is likely to undertake the same work patterns in the coming year.
2. If an existing employee or a new employee is to work, in the coming year, in conditions where other employees received a dose approaching 5 mSv in the previous year.
3. Where an employee is required to work for a considerable proportion of their annual working hours in an area where the absorbed dose rate arising from gamma radiation is 2.5 microsievert per hour (µSv/h) or more.
4. Where an employee is required to work for a considerable proportion of their annual working hours in a work category that was assessed from the previous year's monitoring program, as being exposed to a mean airborne alpha activity concentration equivalent to or in excess of one quarter of the derived airborne concentration (DAC) (for more information please refer to the Guideline NORM–5 Dose assessment).
5. Any combination of the above criteria which may result in the annual effective dose approaching 5 mSv.

Note: The 'a priori' assignment of an employee as a designated employee is necessary as this group of employees requires personal monitoring which will necessitate the planning of adequate resources and possibly work activities.

2.4.2.2. Dose constraint for office and support services staff

The MSIA [2] definition of a mine includes areas where radioactive materials would not normally be encountered or handled, such as offices, warehouses and service buildings.

Under the MSIR [1], the occupational dose limit (20 mSv per year averaged over 5 years) is theoretically applicable to all employees, including contractors. However, such workers should be constrained to receive radiation doses much less than the occupational dose limit.

A dose constraint of 1 milliSievert (mSv) per year averaged over 5 years, could be applied to individuals employed in work categories where work practices do not involve the direct handling, or use, of radioactive materials. This includes employees and contractors in work categories involved in the:

- operation of any support facilities on an exploration, mining and/or processing site, including administration offices, workshops and services buildings;

- operation of residential and recreational facilities such as exploration/mining camp and the ground used for that purpose, where such facilities are located on the mine tenement and are used in connection with exploration and/or mining operations;
- operations undertaken for the environmental rehabilitation of an exploration, mining and/or processing site during production operations and after their completion; and
- operations for the care, security and maintenance of a mine and plant at the site undertaken during any period when production or development operations at the site are suspended.

2.4.3. Establishing triggers for action and control

The approved radiation management plan for the mine should contain a radiation monitoring program that requires, amongst other matters, the monitoring of personal contamination levels and external gamma doses. Due to the use of work category averages in dose assessment, any unusually high or low monitoring result may impact on the exposure estimates for all workers in the particular work category. Thus, some guidance is necessary on the treatment of non-routine measurement results.

The site radiation safety officer (RSO) is expected to have a detailed knowledge of the mean contamination levels and gamma exposures that each work category is normally exposed to. Thus, the RSO should be able to provide professional judgement to make an assessment as to whether any monitoring result appears unusual. Typically, an investigation should commence if the result is outside some pre-determined statistical bounds of the work category mean. The following sections contain guidance on this matter.

2.4.3.1. Classifying an exposure result as a special exposure

If an investigation into an unusually or unexpectedly high monitoring result reveals that an exposure to an individual resulted from a task which is non-routine, an assessment will need to be made on whether that task will be repeated frequently in the remainder of the monitoring year. This requires careful consideration as it is possible that similar circumstances or work activities may occur during the year, but, due to the nature of the sampling regime, the task may not have been monitored previously.

If it is considered that it is highly unlikely that the circumstances will occur again, then the elevated exposure should not be included in the work category average, and should be declared as a separate 'special exposure' and assigned solely to those individual(s) who incurred the exposure.

Similarly, if a known or planned task involving an unusual exposure within a work category, or across several work categories, may occur once or even several times in a monitoring period, the exposure received by those persons involved in the task could also be assigned as a personal special exposure. In this case each individual involved will be monitored each time that task is performed.

Where an exploration, mining and/or processing operation is implementing a specific campaign, where the exposure conditions are anticipated to be significantly different than usual (e.g. obtaining exploration samples with relatively high concentrations of radionuclides, re-processing radioactive tailings, cleaning of large processing vessels or pipe-work from radioactive scale and sludge), alternative arrangements for handling the monitoring data may be made. For example, a special work category sub-group may be established for the period of the campaign, rather than declaring a series of special exposures.

Consideration will also need to be given to variations in dose assessment parameters, such as particle size or different ratio of radionuclide decay series, as a result of the campaign.

Note: this method of dose assessment by declaration of special work category sub-groups is more suitable if exposures are going to occur for a large group of persons over an extended period, rather than a small group. The technique of assessment by special exposures is more useful for small groups of individuals involved in short term exposures.

Handling of special exposures If a routine monitoring program result appears unusual or, following statistical analysis, the result is significantly different from what is normally expected, then the circumstances of the particular exposure should be investigated. If the investigation confirms that the exposure circumstances comply with the conditions for a special exposure (as outlined above) then:

1. The result can be recorded in the site's radiation exposure register as a special exposure for the individual(s) concerned, along with the details of its occurrence. Note: The dose arising from this exposure is calculated separately from the individual's routine work category assessment, and is added to the dose assessment at the end of the reporting period.
2. The State Mining Engineer must be notified in writing of any special exposures including the resultant dose or exposure and the conditions under which it was received (Regulation 16.11(c) [1]). The State Mining Engineer may or may not agree that the conditions warranted a special exposure. Potential disagreement over classification may be avoided through prior discussion and agreement with a Special Inspector of Mines who deals in radiation protection matters.
3. All special exposures should be specifically highlighted in the Company's Annual Occupational Radiation Monitoring Report.

2.4.3.2. Investigation levels

The numerical value of a monitoring result determines whether an investigation into the exposure is necessary. Investigation and reporting levels have been identified for such radiation parameters as:

1. Area Gamma Dose Rate
2. Personal External Dose
3. Personal Internal Dose
4. Airborne Radioactivity
5. Airborne Dust
6. Radon/Thoron in Air
7. Radionuclides in Water
8. Stack Emissions
9. Surface Contamination

These are outlined in further detail in NORM–6 Reporting requirements.

2.4.3.3. Auditing

Regulation 16.38 [1] requires that an audit of all sealed radiation sources and of their location within the operation should be carried out on an annual basis. Further information can be obtained from the guidelines issued by the Radiological Council of Western Australia.

2.4.4. Developing procedures and awareness

2.4.4.1. Safe work procedures

Safe work procedures should be written work procedures and reviewed periodically for their effectiveness as well as audited for their actual application in practice. These written work procedures should be referenced in the radiation management plan (see NORM–2.1 and NORM–2.2), and must be readily available to, and understood by, all personnel involved.

Requirements should be established for activities such as the movement, storage, processing and packaging of radioactive materials, and waste management. Work practices and particularly good housekeeping measures are necessary to prevent unnecessary exposure to, and dispersion, of radioactive materials. Procedures should be provided in relation to spillage clean up, including the control measures to be used (e.g. water, vacuuming), and the preventative maintenance of control equipment such as filters and dust collectors.

2.4.4.2. Radiation safety training

All employees who may be exposed to radiation should be provided with information on the risks associated with radiation exposure, detailed description of sources and pathways of radiation exposure, and safe working methods. The detailed information for a particular mining/processing site should be included in the education and training program.

One of the outcomes of the Uranium Industry Framework (UIF)[5] was the need for the development of a course on mining-related radiation safety and protection to meet the needs of mining operators and regulators, including accreditation of course work and related industrial experience. These units are part of a national certification process for radiation safety officers.

Recently, the Federal Government funded Government Skills Australia to develop units of competency for those working in fields which involve Radiation Protection and Safety. Several units of competency are available from the Government Skills Australia web site www.governmentskills.com.au that can be used to create training programs for radiation workers. The units available at time of writing were:

1. Work safely in a radiation environment
2. Work safely with radioactive ores and minerals
3. Consign radioactive material
4. Handle and transport radioactive material
5. Work safely with radiation sealed source equipment
6. Monitor radiation
7. Coordinate radiation safety
8. Select, commission and maintain radiation measuring instruments
9. Lead a quality audit
10. Participate as a member of a workplace emergency initial response team
11. Lead a workplace emergency initial response team
12. Apply a specialised knowledge of radiation protection and safety to develop and implement an ionising
13. radiation management plan

14. Work safely with radioactive ores and minerals
15. Consign radioactive material
16. Handle and transport radioactive material
17. Work safely with radiation sealed source equipment
18. Monitor radiation
19. Coordinate radiation safety
20. Select, commission and maintain radiation measuring instruments
21. Lead a quality audit
22. Participate as a member of a workplace emergency initial response team
23. Lead a workplace emergency initial response team
24. Apply a specialised knowledge of radiation protection and safety to develop and implement an ionising radiation management plan.

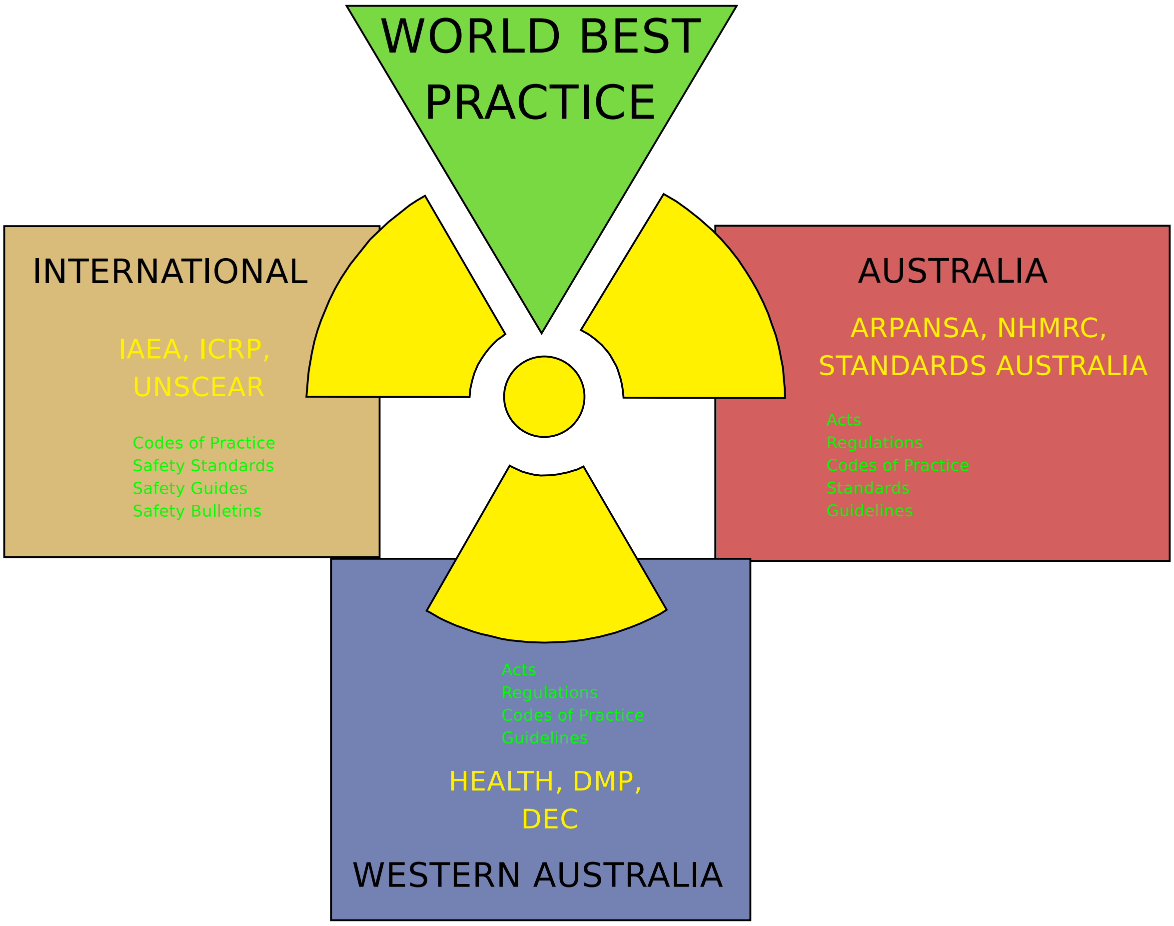
Further guidance on the nature and extent of employee training is provided in NORM–2.2.

A. Appendix listing referenced organisations and documents

A.1. Australian radiation protection bodies

Figure A.1 shows the interaction of world radiation protection practice with the WA Mining Industry.

Figure A.1.: Radiation protection knowledge and control



Radiation protection in Western Australia is based on International and National standards.

A.1.1. Western Australia

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www.radiologicalcouncil.wa.gov.au

Department of Mines and Petroleum, Resources Safety Division – Mines Safety and Inspection Regulations — Approvals.
www.dmp.wa.gov.au

Department of Mines and Petroleum, Environment Division – *Mining Act*, Program of Work (POW) — Exploration, abandonment of sites.
www.dmp.wa.gov.au

Department of Environment and Conservation, Contaminated Sites Section – *Contaminated Sites Act 2003 (Act)* — Control of radioactive wastes.
www.environment.wa.gov.au

A.1.2. National

Department of the Environment, Water, Heritage and the Arts - under the *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act) control matters of national environmental significance including nuclear actions. Regulation of uranium exploration, mining, milling, and uranium mine rehabilitation. www.environment.gov.au

Department of Industry, Tourism and Resources Uranium Industry Section - Customs (Prohibited Exports) Regulations 1958 — Export of Uranium and Thorium.
www.industry.gov.au

Australian Nuclear Safeguards and Non-Proliferation Office - *Nuclear Non-Proliferation (Safeguards) Act* — Application to Transfer Uranium Ore Concentrates (UOC) Internationally. www.asno.dfat.gov.au

Australian Radiation Protection and Nuclear Science Agency (ARPANSA).
www.arpansa.gov.au

Australian Customswww.customs.gov.au — Export / Import of radioactive material. Export/Import

A.2. Western Australia specific Acts and Regulations

Copies of the WA Acts and Regulations are available for download free from the State Law Publisher. www.slp.wa.gov.au

Radiation Safety Act, 1975. link

Radiation Safety (General) Regulations, 1983. link

Radiation Safety (Qualifications) Regulations, 1980. link

Radiation Safety (Transport Radioactive Substances) Regulations, 2002. link

Mines Safety & Inspection Act, 1994. link

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www.arpansa.gov.au

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National Directory for Radiation Protection – Edition 1.0, Radiation Protection Series Publication No. 6, Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), 2004.

Code of Practice and Safety Guide: Radiation Protection and Radioactive Waste Management in Mining and Minerals Processing, Radiation Protection Series Publication No.9, Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), 2005.

Code of Practice for the Security of Radioactive Sources, Radiation Protection Series Publication No.11, Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), 2007.

Code of Practice and Safety Guide for the Safe Use of Fixed Radiation Gauges, Radiation Protection Series Publication No.13, Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), 2007.

Safety Guide: Management of Naturally Occurring Radioactive Material (NORM), Radiation Protection Series Publication No.15, Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), 2008.

Safety Guide: Pre-disposal Management of Radioactive Waste, Radiation Protection series Publication No.16, Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), 2008.

A.3.2. National Health and Medical Research Council

www.nhmrc.gov.au

Australian Drinking Water Guidelines (ADWG) EH19 National Health and Medical Research Council (NHMRC), 2004.

A.3.3. Standards Australia

www.saiglobal.com/shop/ — these documents may be purchased from Australian Standards.

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AS 3580.9.3:2003. Methods for sampling and analysis of ambient air Method 9.3: Determination of suspended particulate matter—Total suspended particulate matter (TSP)—High volume sampler gravimetric method, 2003.

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AS 1716: 2003. Respiratory protective devices, 2003.

AS/NZS 4801:2001 Occupational Health and Safety Management Systems – Specifications with guidance for use, 2001.

AS/NZS 4804:2001 Occupational Health and Safety Management Systems – General guidelines on principles, systems and supporting techniques, 2001.

AS 4360: 2004 Risk Management, 2004.

HB 158–2006 Delivering assurance based on AS/NZS 4360:2004 Risk Management, 2006.

HB 205–2004 OHS Risk Management Handbook, 2004.

HB 436:2004 Risk Management Guidelines, 2004.

AS/NZS ISO 14001:2004 Environmental Management Systems – Requirements with guidance for use, 2004.

AS/NZS ISO 14031:2000 Environmental Management – Environmental performance evaluation – Guidelines, 2000.

AS/NZS 3931: 1998 Risk analysis of technological systems – Application guide, 1998.

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www.icrp.org

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A.3.4.2. International Atomic Energy Agency (IAEA)

www.iaea.org

Safety requirements:

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Fundamental Safety Principles, Safety Standards Series No.SF-1, International Atomic Energy Agency (IAEA), Vienna, 2006.

Regulations for the Safe Transport of Radioactive Material: 2009 Edition, Safety Requirements No.TS-R-1, International Atomic Energy Agency (IAEA), Vienna, 2009.

Near Surface Disposal of Radioactive Waste, Safety Requirements No.WS-R-1, International Atomic Energy Agency (IAEA), Vienna, 1999.

Pre-disposal Management of Radioactive Waste, Including Decommissioning, Safety Requirements No.WS-R-2, International Atomic Energy Agency (IAEA), Vienna, 2000.

Remediation of Areas Contaminated by Past Activities and Accidents, Safety Requirements No. WS-R-3, International Atomic Energy Agency (IAEA), Vienna, 2003.

Safety guides:

Regulatory Control of Radiation Sources, Safety Guide No.GS-G-1.5, International Atomic Energy Agency (IAEA), Vienna, 2004

Occupational Radiation Protection, Safety Guide No.RS-G-1.1, International Atomic Energy Agency (IAEA), Vienna, 1999.

Assessment of Occupational Exposure due to Intakes of Radionuclides, Safety Guide No.RS-G-1.2, International Atomic Energy Agency (IAEA), Vienna, 1999.

Assessment of Occupational Exposure due to External Sources of Radiation, Safety Guide No.RS-G-1.3, International Atomic Energy Agency (IAEA), Vienna, 1999.

Building Competence in Radiation Protections and the Safe Use of Radiation Sources, Safety Guide No.RS-G-1.4, International Atomic Energy Agency (IAEA), Vienna, 2001.

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Decommissioning Strategies for Facilities Using Radioactive Materials, Safety Report No.50, International Atomic Energy Agency (IAEA), Vienna, 2007.

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Current Practices for the Management and Confinement of Uranium Mill Tailings, Technical Report No.335, International Atomic Energy Agency (IAEA), 1992.

Decommissioning of Facilities for Mining and Milling of Radioactive Ores ans Closeout of Residues, Technical Report No.362, International Atomic Energy Agency (IAEA), 1994.

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Radiation Protection 135, Effluent and Dose Control from European Union NORM Industries: Assessment of Current Situation and Proposal for a Harmonised Community Approach, European Commission, Directorate–General for Energy and Transport, Unit H.4 – Radiation protection, 2003.

A.3.4.4. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)

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A.3.4.6. United Kingdom

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Systematic Radiological Assessment of Exemptions for Source and By-product Materials, NUREG-1717, U.S. Nuclear Regulatory Commission, 1999.
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B. Appendix on Radiation Safety Officer requirements

B.1. Mining and mineral processing – qualifications and experience

B.1.1. Qualifications

A pre-requisite to formal approval as a Radiation Safety Officer for an exploration, mining and/or minerals processing operation in Western Australia that use or handle NORM (naturally occurring radioactive material — (Regulation 16.9 [1]), must be that the individual as a minimum has successfully completed a Bachelor of Science degree — preferably in a technical discipline (physics, chemistry or engineering). The main reason is that it is essential for the Radiation Safety Officer (RSO) to have a firm grasp of advanced mathematical principles.

Where the monitoring of radioactivity concentrations in air is expected to be required, it is necessary that the individual successfully completes the course of 'Surface Ventilation Officer' — to be eligible for the appointment as a Ventilation Officer for an exploration, mining and/or minerals processing operation (Regulation 9.4.(2) [1]).

It is advisable that the individual attends and successfully completes the 'Radiation Officer for Static Gauges' course and become 'RSO for Static Gauges' initially. Subsequently, a more advanced course should be completed, as advised by the appropriate authority.

Ideally, qualifications and experience of the individual should be sufficient for the full membership in the Australasian Radiation Protection Society, which are as follows:

"Every applicant shall:

- *Have graduated from a minimum three year, full time equivalent, degree or diploma course (preferably in radiation protection field), which is recognised by the Australian Council on Tertiary Awards, or in exceptional circumstances present such evidence of equivalent study and/or experience as shall satisfy the Committee, and*
- *Have been regularly and substantially engaged in one or more appropriate aspects of radiation protection for at least one year at a level of competence and responsibility which will satisfy the Committee, and*
- *Be so engaged at the time of such application."*

B.1.2. Experience

There are two principal aspects of experience, which an RSO must possess. These are technical experience and relevant background:

1. Technical experience: An RSO must be thoroughly conversant with the various radiation monitoring and recording techniques approved by the appropriate authority, as well as the appropriate reporting protocols. It is unlikely that the required level of proficiency will be acquired by an individual with less than 12 months practical experience in these activities under the

general direction of an approved RSO as a Radiation Safety 'Technician' or 'Specialist'. In accordance with the 'gradual approach' principle, the period of 12 months may be modified (to 6–18 months) for the specific situation — depending on the qualifications and the experience of the individual and on the levels of radiation exposure that are likely to be encountered at the particular operation.

2. Relevant background: Protection of workers, public and the environment from potentially harmful effects of ionising radiation requires an understanding of many disciplines, such as: physics, mathematics, biology, biophysics, engineering (mechanical, chemical, and electrical), chemistry, genetics, ecology and other environmental sciences, metallurgy, medicine, and toxicology. Also, as the RSO operates in a mining and/or processing environment, the individual should have an employment history in this industry and a clear understanding of mining and processing principles, particularly those that are applied at the particular operation.

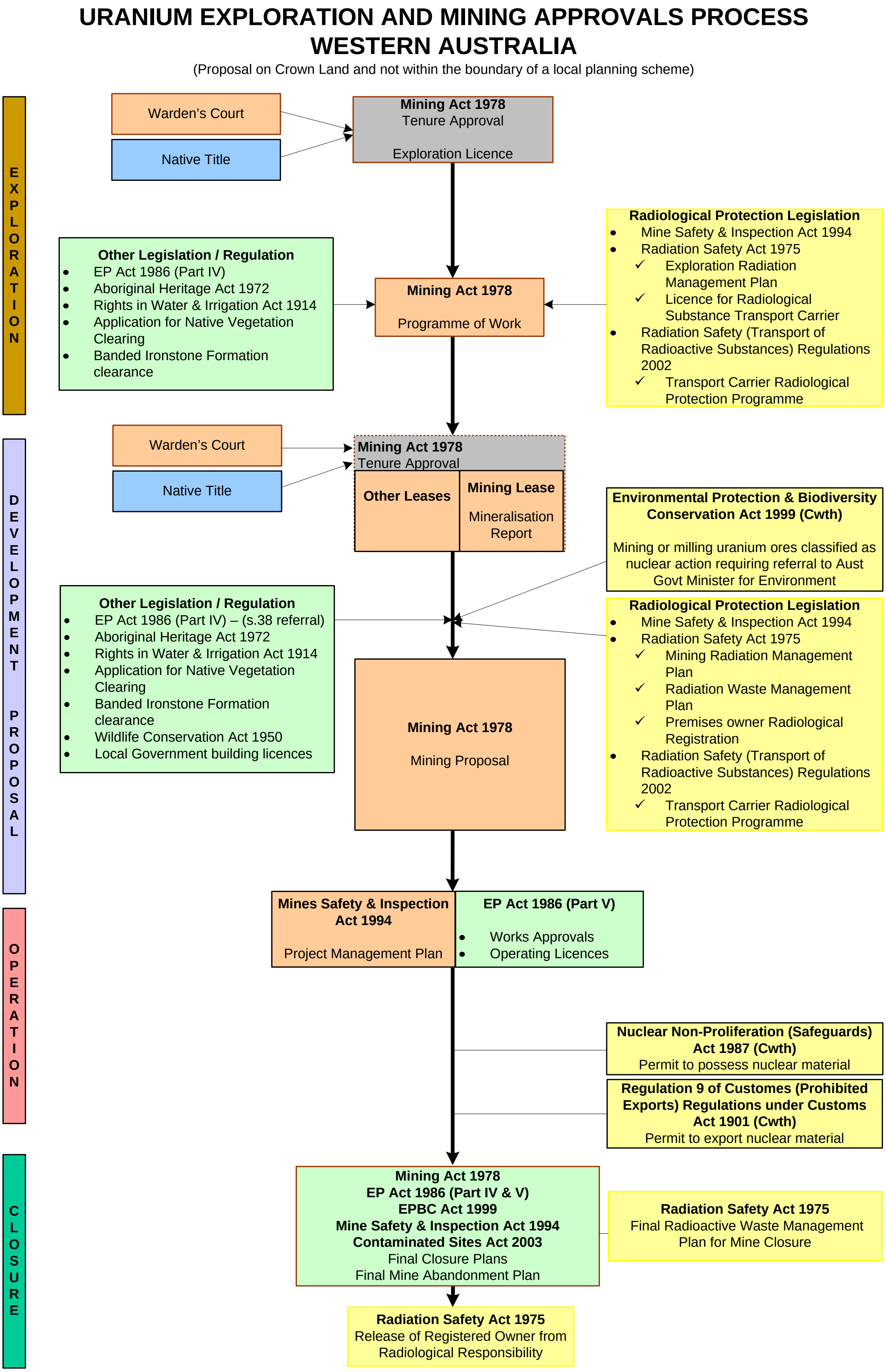
C. Appendix on uranium mining approval process

The State Government will ensure the highest standards for environmental, occupational health and safety and transportation to mine and export uranium in this state. It will be a requirement for any proposal.

Protection of the environment is of paramount importance. Any proposed uranium mining project will be subject to detailed mining proposals and environmental scrutiny, including referral under the State *Environmental Protection Act 1986* and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

The State Government does not support the export of uranium through any ports surrounded by residential development. Legislation is already in place to prevent nuclear waste being brought into WA and the State Government will not support the construction or operation of a nuclear power facility in the State.

Figure C.1.: Simple flowchart showing mining approvals process



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[2] *Mines Safety & Inspection Act, 1994.*

[3] Radiation Protection and Radioactive Waste Management in Mining and Minerals Processing, ARPANSA, 2005

[4] Management of Naturally Occurring Radioactive Material (NORM), ARPANSA, 2008.

[5] Uranium Industry Framework - Report of the uranium industry framework steering group, Resources Division of the Department of Industry, Tourism and Resources, 2006.

[6] A Critical Review of the System of Radiation Protection – First Reflections of the OECD Nuclear Energy Agency's Committee on Radiation Protection and Public Health (CRPPH) Nuclear Energy Agency Organisation for Economic Co-operation and Development, 2000.

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