13.0 Guidelines for Radiation Protection during Exploration for Uranium

These ***e3 Plus Guidelines for Radiation Protection during Exploration for Uranium*** have been developed to assist exploration companies protect employees and others from radiation while exploring for uranium. The PDAC hopes that these Guidelines will prove useful to exploration companies in the creation or refinement of their own corporate guidelines.

The Guidelines are intended to be a living document, updated and expanded as new information becomes available. To keep these Guidelines as current as possible, the PDAC welcomes comments and suggestions, particularly regarding website resources to be added to the References and Links section. These Guidelines have been prepared in Canada and, as a result largely reflect conditions and situations found in that country. The PDAC welcomes contributions from *e3 Plus* users who can provide new content from other regions of the world.

The PDAC thanks everyone who has been of assistance in the creation of these Guidelines and would like to give particular thanks to the following:

Alex Buchnea of SCIMUS

Sally Howson and colleagues at Aurora Energy Resources

Roger Wallis of Roger Wallis & Associates

Mark Wittrup and colleagues at Cameco

Peter Wollenberg and colleagues at AREVA

13.1 Uranium and Radioactivity

13.1.2 Radiation Basics

All material is made up of atoms, which in turn are made up of a nucleus, consisting of neutrons and protons (accounting for more than 99.95% of the mass), and electrons spinning around in orbits (accounting for 99.999% of the volume). Material is radioactive when its nucleus is unstable and seeks to achieve stability by the emission of radioactive particles called gamma rays (no mass), beta particles (high energy electrons), alpha particles (two protons and two neutrons) and neutrons. These particles are very energetic and can knock electrons of atoms out of their orbit, creating ions. Thus, they are called ionizing radiation.

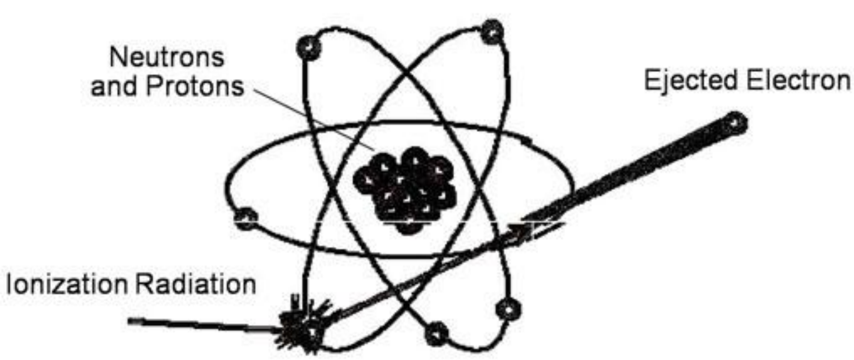

Figure 43:* Ionizing Radiation (Radiation with enough energy to remove an electron from its atom).

The following figures describe the three types of radiation – alpha, beta and gamma – which are significant in uranium exploration, and their properties.

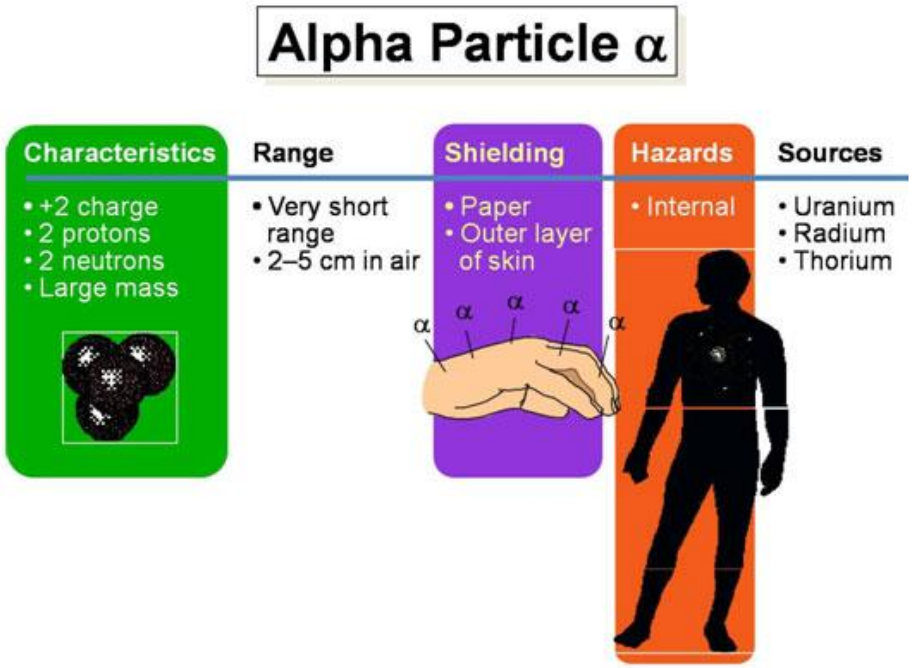

Figure 44:* Alpha Particle α.

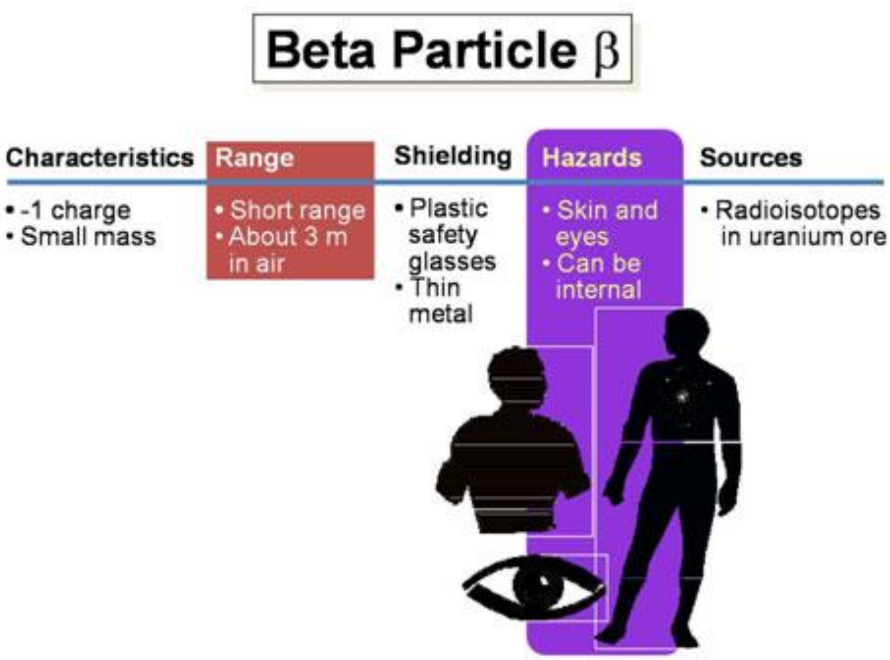

Figure 26:* Beta Particle β.

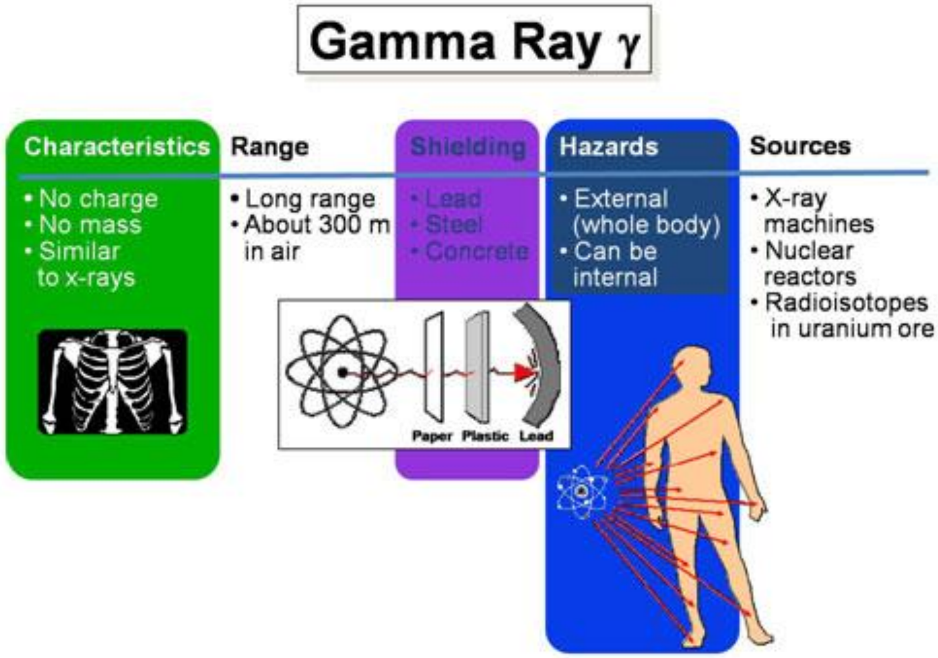

Figure 46:* Gamma Ray γ.

***Illustrations for **Figures 1-4** are used with permission from the RadGrad course materials, available from the Michigan Section of the American Nuclear Society (MI-ANS)

[1] Sv = 1 million microsieverts (µSV); absorbed dose in tissue (J/kg) corrected for the biological effects of radiation; unit of radiation dose in International System of Units (SI)
[2] Bq = 1 disintegration per second; activity expressed in International System of Units (SI)

The two basic units of measure in radiation protection are the sievert (Sv)[1] (indicating the dose received from a radioactive material) and the becquerel (Bq)[2] (indicating the amount of radioactivity in a material, in disintegrations/second).

There are two types of radiation exposure:

1 External radiation exposure
- The radiation source is located outside the body

2 Internal radiation exposure, which results from the intake of radioactive materials through:
- Inhalation
- Ingestion
- Absorption through the skin or through wounds

13.1.2 Properties of Uranium

Uranium is a common, naturally occurring radioactive element. It is a normal part of rocks, soil, and water, and it occurs in nature in the form of minerals, never as a metal. Uranium metal is silver-coloured with a grey surface and is nearly as strong as steel. Uranium is a metal of high density (18.9 g/cm^3). The earth's crust contains an average of about 3 ppm (= 3 g/t) uranium; seawater contains approximately 3 ppb (= 3 mg/t). Natural uranium is a mixture of three types or isotopes called U-234, U-235, and U-238, together with all of its decay products (also referred to as its daughter products or progeny). In a typical sample of natural uranium, almost all the mass

(99.27%) consists of atoms of U-238. Less than 1% (about 0.72%) of the mass consists of atoms of U-235, and a very small amount (0.0054%) is U-234. All three are the same chemical, but they have different radioactive properties. U-238 and U-235 are the parent nuclides of two independent decay series, while U-234 is a decay product of the U-238 series.

Table 8: Properties of the Natural Uranium Isotopes and Isotopic Composition of Natural Uranium*

Properties of the Natural Uranium Isotopes*			
	U-234	**U-235**	**U-238**
Half-life	244,500 years	$703.8 \cdot 10^{6}$ years	$4.468 \cdot 10^{9}$ years
Specific activity	231.3 MBq/g	80,011 Bq/g	12,445 Bq/g

Isotopic Composition of Natural Uranium*				
	U-234	**U-235**	**U-238**	**Total**
Atom %	0.0054%	0.72%	99.275%	100%
Weight %	0.0053%	0.711%	99.284%	100%
Activity %	48.9%	2.2%	48.9%	100%
Activity in 1 g Unat	12,356 Bq	568 Bq	12,356 Bq	25,280 Bq

Since U-235 is such a small contributor to radiation from uranium ore, only the U-238 decay series is discussed in this section.

Table 9: Uranium-238 Decay Series*

Uranium-238 Decay Series*		
Nuclide	Half-Life	Radiation
U-238	$4.468 \cdot 10^{9}$ years	alpha
Th-234	24.1 days	beta
Pa-234m	1.17 minutes	beta
U-234	244,500 years	alpha
Th-230	77,000 years	alpha
Ra-226	1,600 years	alpha
Rn-222	3.8235 days	alpha
Po-218	3.05 minutes	alpha
Pb-214	26.8 minutes	beta
Bi-214	19.9 minutes	beta
Po-214	63.7 microseconds	alpha
Pb-210	22.26 years	beta
Bi-210	5.013 days	beta
Po-210	138.378 days	alpha
Pb-206	stable	-

***** Uranium tables used with permission of the WISE Uranium Project

Most of the radioactive decay products emit a gamma ray as well as the indicated particles. In natural uranium, these decay series generally are in secular equilibrium. This means that in 1 g of natural uranium, each nuclide of the U-238 series has an activity of 12,356 Bq. In the various processing steps of nuclear fuel production, the equilibrium is disrupted.

In a uranium ore deposit, secular equilibrium exists between U-238 and its decay products. The equilibrium may be somewhat disturbed by geochemical migration processes in the ore deposit. An ore grade of 1% U3O8 is equivalent to 0.848% uranium, and 1 million lbs U3O8 are equivalent to 385 metric tonnes of uranium. The grade of ore varies – depending on the type of deposit – with average grades of commercially viable deposits ranging between about one-tenth of one percent to over 20% U3O8 in some parts of the Athabasca basin in northern Saskatchewan.

The radiation is virtually trapped underground; exposures are only possible if contaminated groundwater circulating through the deposit migrates to a work environment. Though it can travel through underground fissures, radon from deep deposits is of no concern for surface exploration, since it decays before it can reach the surface.

The alpha radiation of the eight alpha emitting nuclides contained in the U-238 series presents a radiation hazard on ingestion or inhalation of uranium ore (dust) and radon. The gamma radiation (mainly of Pb-214 and Bi-214) together with the beta radiation of Th-234, Pa-234m, Pb-214, Bi-214, and Bi-210, presents an external radiation hazard. For ingestion and inhalation, the chemical toxicity of uranium also has to be taken into account.

15.1.3 Geological and Climatic Conditions

Depending on the region in which exploration is taking place, different geological and climatic conditions will affect the nature of the hazards during exploration and the methods used in protecting workers and the environment from these hazards. Some of the various conditions are addressed in these Guidelines; however, not all conditions are included at this stage. Further conditions may need to be addressed in future.

The hazards addressed in these Guidelines encompass the following conditions:

- Diamond drilling, usually several hundred metres deep in hard rock, requiring water cooling
- Drilling in winter conditions in northern latitudes

In progress to be included in these Guidelines in future are:

- Drilling in surficial deposits in arid climatic conditions, using rotary air blast drilling
- Drilling in wet tropical areas

These conditions delineate the various hazards that are associated with uranium drilling; other conditions likely would fall within this outline.

15.2 Exposure Limits

Exploration in Canada is governed by the provinces and the territories. The International Atomic Energy Agency (IAEA) has set radiation exposure limits for radiation workers and for members of the public that are widely used as a general guideline by regulators. These limits are adopted by the nuclear regulatory bodies in the various member countries – for example, the Canadian Nuclear Safety Commission (CNSC) and the Australian Radiation Protection and Nuclear Safety Agency. A person normally engaged in work with radiation and who has the potential of receiving exposure above the public limit is designated as a Nuclear Energy Worker (NEW)[3] by the CNSC, a special designation that requires specific controls on the worker. In Canada, such a worker on a provincial level is typically designated as an occupational worker.

Exposure (dose) is calculated by the sum of the gamma (mSv) plus RnP (radon progeny) as it impacts Working Level Months (WLM) plus LLRD (long-lived radioactive dust – internal long-lived alpha exposure):

- Effective Dose (mSv) = Gamma (mSv) + 5 (RnP WLM) + 20 (intake in becquerels/2800)
- Where 4 WLM = 20 mSv, and the LLRD ALI (annual limit of intake) = 2800 Bq

The table below gives the annual exposure limits included in the Radiation Protection Regulations of Canada's Nuclear Safety and Control Act*****. These limits represent the sum of exposure for all types of radiation – external, internal, and radon gas and its progeny.

Table 10: CNSC Whole Body Dose Limits*

CNSC Whole Body Dose Limits*		
Person	**Exposure Period**	**Effective Dose (mSv)**
Nuclear Energy Worker (NEW)	One-year dosimetry period	50
	Five-year dosimetry period	100
Pregnant NEW	Balance of pregnancy	4
General public (non-NEW)	One calendar year	1

*****The annual exposure limits cited were correct as of October 2008.

While NEW exposure levels vary by job, the average yearly radiation exposure of a monitored NEW in Canada is generally less than 1 mSv. This includes all NEWs, not only those working in exploration. A pregnant NEW has to inform the employer as soon as she is aware of the pregnancy.

Uranium exploration workers are usually classified as non-NEWs – unless the grades and conditions result in the potential for higher doses – and have the same exposure limits as members of the general public.

Exposure to radon progeny (RnP) is measured in Working Level Months (WLM) – one WLM is the exposure to 2.08×10^{-5} J of RnP for one month. The limit for exposure to radon in the absence of any other sources of radiation is four WLM in one year.

[3] A Nuclear Energy Worker (NEW) is defined as a person with "a reasonable probability that the person may receive a dose (occupational) of radiation that is greater than the prescribed limit for the general public" (i.e., 1 millisievert per year, or 1 mSv/yr; 1mSv/yr = 1,000 µSv/yr). A NEW is informed in writing of their NEW designation and a written acknowledgement is obtained from the worker and kept in central records. During radiation protection training, a NEW is informed of the risks associated with radiation to which they may be exposed in the course of their work, and the applicable dose limits. A NEW is informed of their doses at least quarterly, and their doses are recorded in the National Dose Registry.

13.3 Radiation Measurement Instrumentation

None of the human senses can detect ionizing radiation directly; thus, in order to properly implement a radiation protection strategy, radiation detection instrumentation is very important.

The meter generally used for measuring gamma radiation fields during drilling programs is a high volume sodium iodide (NaI) scintillometer. Workers involved in uranium exploration can use these scintillometers to make field measurements of external gamma radiation, measured in counts per second (cps), calibrated to Cesium-137. The measured value of radiation will depend on the sample size and the distance the measurement is taken from the sample.

Examples of the time required for obtaining a 10 µSv exposure by handling various grades of ore (all counts and doses at 1 m from source) are included in the following chart:

Table 11: Examples of the time required for obtaining a 10 µSv exposure

CPS	µSv/hr	Hours for 10 µSv	% U3O8	Comment
200 - 450	0.05 - 0.15	-	<0.01	Background levels
600 - 700	0.5 20	20	0.05	Maximum waste rock
1000	1*	10	0.1	Radiation protection procedure trigger
3000	3	3.3	0.3	Start of high grade ore
10000	10	1	1	High grade ore

*Some companies may use a different trigger level.

A contamination meter, such as a pancake Geiger counter with a thin mica window, measuring in counts per minute (cpm)4, is used to measure radioactive contamination of clothing, hands, and other exposed areas of the body, tools and equipment, and working areas. This detector is sensitive to beta radiation as well as gamma radiation and is primarily used to monitor personnel and equipment, in order to prevent the spread of contamination. It is considerably more sensitive to beta radiation than a gamma meter.

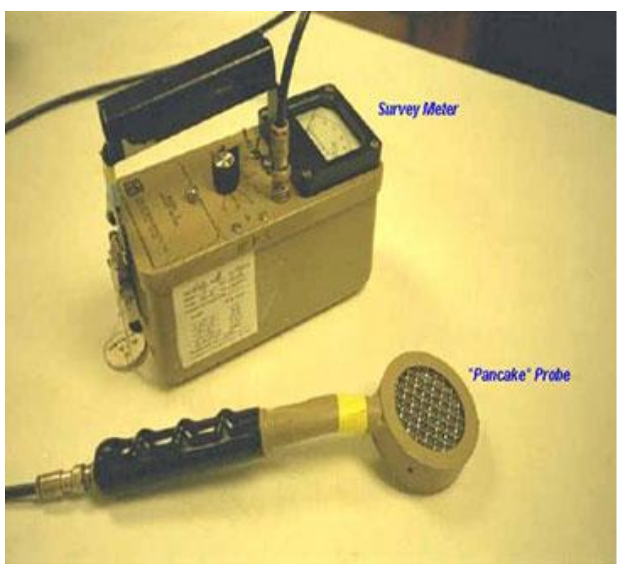

Figure 47: Contamination Meter Ludlum Model 12 Pancake G-M Detector*

* Photographs used with permission of Ludlum Measurements Inc.

RnP is also generated by uranium ore; however, the radon levels expected during exploration work in an outdoor environment should be within the range of natural background levels other than winter drilling in cold climates in enclosed spaces. If drill rig platforms and the core and splitting shacks are well ventilated, no accumulation of radon progeny above background levels is expected, except in large accumulations of the highest grade ores. In cases where significant amounts of high grade core are being examined in the core shack, or high grade ore is being stockpiled in an indoor environment, considerable amounts of radon progeny can develop. Radon monitoring should be conducted to determine whether routine monitoring is required if heated areas are enclosed and insulated during winter operations. This can be done either using a passive radon detector, such as an E-perm or PICO-RAD, Landauer RadTrak, Safety Institute of Canada radon monitor or an electronic detector (e.g., a scintillometer, ion chamber, alpha spectrometer).

Apart from winter operations, in most cases routine radon monitoring is not considered to be necessary during the exploration activities, aside from confirmation sampling and specific area monitoring to determine background with radon monitors such as E-perms. In cases in which radon measurements indicate above background levels, personal alpha dosimeters (PAD) should be worn. These are active devices which sample the air and measure both RnP and particulate alpha concentrations. In a core shack containing mineralized core, there will be RnP above background levels. As long as these working levels (WL) remain below Health Canada indoor radon guidelines (200 Bq/m3, 0.29 WL), no further action is required. If RnP levels are greater than 0.03 WL, an assessment of the working environment should be carried out to ensure that there is adequate ventilation. Reasonable efforts should be made to remove the contaminant from the working environment before employing dosimetry. Continued area monitoring of the impacted area(s) should also be conducted to assess worker exposures. In most cases, PADs would only be required if annual doses from RnP exceed 5 mSv.

If RnP levels are greater than 0.03 WL, an assessment of the working environment to ensure that there is adequate ventilation is highly recommended. Reasonable efforts should be made to remove the contaminant from the working environment before employing dosimetry. Continued area monitoring of the impacted area(s) should also be conducted to assess worker exposures. In most cases, PADs would only be required if annual doses from RnP could exceed 5 mSv.

Long-term measurement of the dose from external radiation is available from individual thermoluminescent dosimeters (TLDs) supplied by a designated dosimetry service. Workers are required to use TLDs. These are worn as a badge or ring (for extremity dose measurements) and record the cumulative external dose received. They are submitted regularly (monthly or quarterly) to the designated dosimetry service, which reports the results. The badge is typically used in the field to measure the whole body dose. TLDs do not provide real time measurement of external radiation; these badges are “passive” and must be sent to the dosimetry service for results.

Electronic personal dosimeters (EPDs), or other direct reading devices (DRDs), can also be worn by individual workers, to give a direct reading of the accumulated external gamma dose. These can also have dose and dose rate alarms.

Long-lived radioactive dust (LLRD) must also be considered in exploration activities.

3 Contamination is typically measured in counts per minute (cpm)

13.4 Radiation Hazards during Exploration

The hazards discussed in this section are those that can be expected in the conditions described in Section [Geological and Climatic Conditions]

Potential health hazards during uranium exploration come from:

- External radiation – mainly gamma and beta to the eye and hands
- Radon progeny (RnP) build-up in enclosed spaces from samples and drill-core
- LLRD particles from splitting or drilling, that can be inhaled or ingested.

During initial exploration and baseline studies, the expected radiation hazard is mainly from external gamma radiation from the uranium mineralization in the disturbed areas (e.g., waste rock piles and tailings areas associated with previous mining activities, cuttings from previous drill locations), in mineralized rock outcropping, and in specimens collected by geologists in the field. As long as normal hygiene practices are following, there is a minimal likelihood of radioactive contamination on body parts (mainly hands), clothing, and tools. The exception is when underground workings are re-evaluated for possible economic grade ore. Radon build-up in old underground workings could be a significant hazard requiring ventilation prior to entry.

During the drilling program, the possibility of contamination of equipment and personnel from the cuttings during the drilling depends on the type of drilling employed. If diamond drilling with cooling water is used, dust levels are generally low, and thus the inhalation hazard is low. The potential for contamination spread can be minimized by controlling the wet cuttings. Such control can happen through the use of a cyclone or filtration system. Radioactive cuttings should be disposed off down the hole after completion of drilling, if this is possible. Another option would be to store the radioactive cuttings in appropriate containers for later disposal or removal. Storage of such materials must be within designated areas. With rotary air blast drilling – usually employed above the water table and without water – dust can be a significant hazard and must be controlled. External gamma radiation from the drill cores or cuttings (especially where cores and cuttings are laid out for examination), or logging core is a potential hazard for both types of drilling. Stockpiles of core boxes with the greatest potential gamma hazard would generally be in the vicinity of the core shack or core storage areas.

Airborne contamination (LLRD) can also occur during the core splitting operations. A manual core splitter or a rock saw can be used in this operation – the amount of dust generated will depend on the amount of water used on the rock during splitting. Rock that is dry cut using a rock saw has the potential to generate large amounts of airborne contamination.

In most cases, hazards due to the accumulation of radon gas and its decay products are typically insignificant, since the drill sites and core stocks are expected to be in open air and the core shack facilities are expected to be well ventilated. The exception is during winter operations in northern climates in which the core shacks and drill rig platforms are heated and air exchange rates are limited. However, the use of exhaust fans to exchange the air in closed buildings even in wintertime is highly recommended. As radon is infinitely soluble in water, it may be a concern in enclosed settling tanks or if ore is intersected, in return water at a drill (especially for high grade deposits.)

Contamination controls and the use of protective clothing by workers, including gloves and respirators during core splitting, should limit the ingested and inhaled radioactivity to insignificant levels, while safety glasses provide protection against beta radiation.

13.5 Radiation Protection Principles

It is the joint responsibility of the employer and the employee to ensure that adequate radiation protection measures are in place at all times. To ensure that radiation exposure to workers is well below the dose limits noted earlier in Section Radiation Measurement Instrumentation an ALARA (as low as reasonably achievable) program is central to a Radiation Protection Program, to ensure dose levels, as well as social and economic factors, are taken into account. ALARA is implemented through the use of:

- Engineering controls (e.g., layout of drill sites, core storage and cuttings management)
- Layout of core shack area and core stockpile
- Administrative controls (e.g., personnel movement restrictions, monitoring requirements)
- Personnel protective equipment (gloves, glasses, respirators)

Certain principles outlined below are useful in controlling exposure to external gamma radiation, as well as internal beta and alpha radiation from radioactive contamination.

13.5.1 Protection from External Exposure to Gamma Radiation

There are powerful methods that are simple to implement and can result in drastic reductions in worker exposure. Four main principles are employed to reduce dose from external gamma radiation:

1. Time – restrict time in contact with radioactive material; dose received is proportional to time spent
2. Distance – dose is reduced by square of distance (i.e., dose at 2 m is ¼ dose at 1 m)
3. Shielding – use core with low radiation fields to shield core with high fields, or place appropriate shielding material between oneself and the source of radiation, to lower the radiation dose received
4. Source reduction – remove radioactive core from high occupancy areas as soon as possible

13.5.2 Protection from Internal Radiation (Contamination Control)

The single most important thing to do is to ensure that the contaminated area is separated from clean areas. Protective gear should be kept in the contaminated area and personnel should clean up before moving to a clean area, eating or smoking.

Controlling the spread of contamination is the most effective way of controlling doses from internal beta and alpha radiation. Simple protective equipment (e.g., coveralls, gloves, safety glasses, lead aprons, respirators), work practices, and procedural controls (e.g., no eating, no smoking) can be used in areas where there is known radioactive material. Monitoring can be used to prevent the spread of contamination from these areas. Establish areas known as contamination control zones and monitor procedures to restrict movement of personnel and equipment from these areas. This system is described in detail 13.6 Radiation Protection Program

Principles of radiation protection from internal exposure to radiation:

1. Wear appropriate protective clothing
2. Wear approved and properly fitted respiratory protection
3. Follow radiation safety procedures
4. Practice good hygiene
5. Monitor for contamination when leaving a restricted area
6. Appropriately dispose of contaminated clothing, equipment, and materials
7. Take appropriate steps to minimize the spread of contamination

13.6 Radiation Protection Program

In order to adequately protect the workers from radiation during the exploration and drilling programs, a Radiation Protection Program (RPP) must be designed and implemented and should be in place at all times. However, the program's success can only be achieved through the full cooperation of all workers. As a result, all workers should receive RPP training, to ensure they understand all information in the program. In Canada exploration activities (with the exception of some advanced exploration) are not regulated by the CNSC but rather by the provinces and territories. Exploration is considered a NORM (naturally occurring radioactive materials) related activity, except during the transport of mineralized core where CNSC and Transport regulations apply. The Radiation Protection Regulations of Canada's Nuclear Safety and Control Act specify the following for a licensed facility (other jurisdictions have similar regulations):

"Every licensee shall implement a radiation protection program and shall, as part of that program…keep the amount of exposure to radon progeny and the effective dose and equivalent dose received by and committed to persons as low as is reasonably achievable, social and economic factors being taken into account, through the implementation of

1. management control over work practices,
2. personnel qualification and training
3. control of occupational and public exposure to radiation, and
4. planning for unusual situations."

Although an exploration and drilling program is not a licensed activity, the above RPP is deemed a minimum requirement. For a progressive approach, see the Canadian Guidelines in NORM. A program to be implemented during the exploration and drilling phases should include:

- •Training of all field personnel
- Adequate supervision to ensure radiation protection (RP) procedures are developed and implemented, including workplace monitoring (e.g., RnP and LLRD)
- Personnel dosimetry
- External gamma radiation monitoring and protection
- Contamination control
- Environmental controls

In addition, appropriate records of the above elements must be kept as indicated further below.
Note: As RP requirements depend on the grade of the mineralization being drilled, typically implementation of RP controls has been needed only when the drilled core exceeds a certain radiation field. Below this level, no controls are necessary other than periodic monitoring.

The action level* recommended for the initiation of RP controls is 1 µSv/hr at 1 m distance/height or 10 µSv/hr on contact from an accumulation of freshly drilled core, as indicated on a gamma meter.

*Action level is a guideline to all project personnel, based on previous field experience.

13.6.1 Responsibilities

It is recommended that a Radiation Safety Officer (RSO) be placed in charge of the RPP. The RSO must be qualified in radiation protection and is responsible for developing the RPP procedures, work instructions, and forms, and ensuring that they are properly implemented. In addition, the RSO ensures that workers receive training. Any modifications to the program are made by the RSO. The RSO may report to either the Project Manager or the person in charge of overseeing the day-to-day Environmental, Health, and Safety (EHS) activities (i.e., overseeing the implementation of the RPP in the field). The EHS Manager delegates someone to be in charge of issuing and collecting all dosimeters and radiation detection instrumentation and ensuring any necessary daily briefings are conducted. Implementation at drill sites and core shacks (e.g., routine radiation measurements) is the responsibility of the Project Geologist on duty. The people mentioned above form the Radiation Protection (RP) Management Team. The RP Management

Team's responsibilities include:

- Creating corporate RP guidelines* regarding uranium exploration and EHS protection
- Requiring all workers involved in handling mineralized materials use the protective devices, measures, and procedures outlined in corporation's RP guidelines, to minimize radiation exposure, and requiring that all necessary RP procedures are routinely applied
- Directing all workers so that all government regulations with regard to safe work practices are strictly adhered to
- Providing education and training to all personnel with respect to RP guidelines requirements
- Advising personnel of potential hazards associated with site operations
- Providing for routine radiological monitoring of the exploration facilities, specifically sites where radioactive materials (e.g., drill core, rock samples etc.) are being handled and where actions are required
- Requiring the proper use of appropriate personal protective equipment by all on-site personnel
- Requiring that any work practices or conditions that may result in injury or unnecessary radiation exposure are corrected immediately following identification
- Overseeing the processes for the transportation of mineralized core or rock samples

All workers involved in exploration and drilling programs (including regular staff, contractors, and visitors) are required to:

- Attend all necessary training and pre-job safety briefing sessions
- Be familiar with and adhere to RP guidelines, and report any deviations from anticipated conditions affecting worker safety to the EHS Manager or equivalent for action
- Perform only those tasks that they believe they can do safely, and immediately report any accidents and/or unsafe conditions to management

Some examples of possible routine daily RP tasks are noted below; daily RP tasks would also include monitoring of potentially contaminated surfaces such as the tops of core logging tables.

Table 12: Routine daily Radiation Protection (RP) Tasks and responsibility

ROUTINE DAILY RADIATION PROTECTION (RP) TASKS AND RESPONSIBILITY		
RP Tasks	**Description**	**RP Responsibility**
Start of the Day		
Get TLDs	Each worker is required to take his/her TLD from the designated rack.	Company to provide TLD; worker to wear it
Use protective clothing as necessary	Normal working clothes and gloves necessary for most days. If certain tasks require additional PPE, EHS Manager or designate will specify.	EHS Manager or designate and worker
Pre-job briefing	RP considerations for planned work reviewed, radiation field levels reviewed, RP responsibilities assigned if different from previous day.	EHS Manager or designate and worker

Initial survey	Survey of work area, as required.	EHS Manager or designate
	During the Day	
Personal hygiene for breaks, lunch	Workers are required to remove gloves and wash hands prior to eating and smoking; workers to eat and smoke in designated areas only.	Workers, EHS Manager or designate, Project Geologist
	End of the Day	
Change clothing at change facilities	Workers are required to remove work clothes, boots, and gloves at change facilities. If persistent contamination detected, workers must monitor themselves prior to entering change facilities.	EHS Manager or designate
Return TLDs	TLDs from each worker are replaced on designated rack.	Worker, Foreman/Logistics Coordinator

*****RP Management Teams can refer to the PDAC ***Guidelines for Radiation Protection during Exploration for Uranium*** document as a resource when creating their own corporate RP guidelines

13.6.2 Personnel Training Requirements

Prior to the commencement of the exploration and drilling programs, all field personnel involved in the handling of radioactive materials should be required to receive training in basic principles of radiation associated with uranium mineralization and the basic principles of radiation protection.

In addition, workers should be given radiation protection training specific to the exploration and drilling program, including the following:

- Thorough review of the RP guidelines created by the company, and walk-through of specific procedures
- Project tasks and the radiation hazards associated with each task
- RP activities ongoing during the tasks
- Responsibilities of the various personnel implementing the RPP during the exploration and drilling program
- Review of the radiation instrumentation to be used on the project
- Review of the routine daily RP procedures

13.6.3 Personnel Dosimetry Requirements

TLD badges should be kept in an area with low background radiation levels, removed from the area of active work. All workers engaged in exploration activities should be supplied with a personal TLD badge that clearly identifies them (i.e., with the person's name) and are required to wear these daily. In Canada, personnel information and a Social Insurance Number is required for everyone issued a TLD. The personnel information disclosed is collected and used to report radiation doses to the National Dose Registry. Workers must pick up their TLDs from the designated rack at the beginning of each day and wear it at all times while at work. At the end of each day, workers must return their badges to the designated rack.

It is important that workers understand that the purpose of the TLD is to monitor radiation doses at the work site. TLDs continually monitor radiation doses – the data collected can give false readings if workers do not return the badges to the designated location at the end of their shift. Two badges are designated as controls and several non-labelled badges should be made available for visitors and additional personnel. Any badge used on a continuing basis by a worker should be labelled with their name. Badges should never be shared or tampered with. A lost or damaged badge should immediately be brought to the attention of the supervisor your supervisor so that a replacement badge can be assigned.

The reporting period for the TLDs is quarterly. Each quarter, the TLDs are replaced with new ones and those that have been worn, the control TLDs, and any unused TLDs are returned to the designated dosimetry service for measurement by management. In Canada, the company is required to notify workers of their accumulated doses, once the results have been received from the designated dosimetry service.

Electronic personal dosimeters (EPDs) can also be worn, but are not normally required unless the primary criterion of 1 µSv/hr at 1 m distance/height is exceeded. If DRDs are being assigned, log sheets should be completed daily, so that worker exposures can be tracked and if necessary used to estimate worker doses to gamma radiation.

13.6.4 External Gamma Radiation

A potentially significant hazard can be presented by external gamma radiation exposure from uranium mineralization (depending on the grade of ore) and radioactive sources in exploration equipment. Adequate monitoring of sites with above-background level of radiation is essential.

Prior to conducting any work such as drilling and core handling, a gamma survey should be conducted and the areas with gamma fields greater than 1 µSv/hr on a gamma meter at a distance of 1 m should be identified to workers. Areas with significant radiation levels that are adjacent to work locations in which workers may be routinely present (e.g., the core storage areas, any areas where radioactive samples are stored, trenches and waste rock dumps with elevated radiation levels), must be clearly identified to workers (e.g., signs posted at core shack and storage areas). Workers should conduct gamma surveys in each work area prior to commencement of work and whenever conditions change substantially (i.e., as mineralized core accumulates in the core stocks). Gamma surveys should also be conducted at the completion of drilling. Mitigation measures should be taken during drilling to ensure that dose levels are below 1 µSv/hr when measurable contamination is present.

As noted in Section 13.5.1 Protection from External Exposure to Gamma Radiation in order to apply the ALARA principle and minimize the dose, the four strategies of time, distance, shielding, and source reduction are used.

The action level recommended for the initiation of the contamination control procedures is 1 µSv/h at 1 m distance/height

13.6.5 Contamination Control Procedures

Contamination control is achieved by maintaining a separation between areas that have radioactive contamination and those that do not. It is also achieved by careful contamination monitoring and the use of protective clothing (e.g., gloves, coveralls).

During the preliminary exploration phase, the risk of contamination is expected to be small and only present during the handling of mineralized material. Workers must wear cotton or equivalent gloves when handling radioactive materials. If the mineralization is above the action level, workers must monitor themselves and tools prior to leaving the work area, using the procedures described in Section Contamination Monitoring of Contamination Control Zones below. If mineralized material is handled, monitoring of workers should also be done prior to breaks or lunch. Contamination control procedures should also include routine monitoring of work surfaces and floors; core shacks should be thoroughly cleaned daily. Contamination can build up slowly over time. Good housekeeping will also help minimize the buildup and spread of contamination.

During the drilling program, the potential for contamination on the drill rig platform is small, as diamond drilling utilizes water and there is no build-up of dust, regardless of the grade of ore being recovered. The main potential sources of contamination are the wet cuttings collecting under the platform and rock chips that may fall on the platform during the extraction of core from the core tube.

Poly tanks are metal tanks with removable plastic “wiffles” which separate the coarse cuttings from the drill water. Poly tanks are often used to collect cuttings when drilling on the ice. If these tanks are not available a mud tank or lined sump can be used to collect drill cuttings. The purpose of collecting the cuttings from the mineralized zones is to monitor them and based on results dispose of the cuttings in an appropriate manner as outlined in these Guidelines. As a conservative measure and to control environmental emissions, the wet cuttings should be routed to a sump from the poly tanks when drilling in the mineralized zone. The use of a dual filtration system, allowing the routing of radioactive cuttings into one containment and the routing of non-radioactive cuttings into a separate system is encouraged. Radioactive cuttings may be disposed of down the drill hole at the termination of the drilling if feasible, or stored in appropriate containers until proper disposal or removal from the work site.

The drill rig platform is constantly being washed to prevent the accumulation of cuttings for conventional safety reasons, which ensures that the potential is low for contamination of workers and equipment in the work area. The workers use coveralls and gloves, which are generally left at the change facilities. There is typically no need to designate the drill rig platform as a contamination control zone during wet drilling, unless periodic measurements so indicate (especially when the action level is exceeded).

The presence of radioactive cuttings has to be checked after the removal of the drill platform. Proper disposal of any such cuttings is required, as per previous descriptions.

During rotary air blast (RAB) drilling however, considerable dust can be generated – cuttings are dry and the potential for contamination spread is large. This is particularly true in arid climates. Active RAB sites should be designated as contamination control zones, until monitoring and any decontamination, if necessary, has been completed.

In the core shack area – whenever radioactive core is being handled – the core logging tables, floor, and the core splitting facility have the greatest potential for contamination. Other potential sources of radioactive contamination are spills that may occur when emptying the drip pan under the core-cutting saw. Core logging and splitting facilities should be designated contamination control zones. The use of a respirator during core splitting or cutting is recommended. It would be good practice, even during wet cutting, that the worker wears at least an N95 filter mask.

Workers must keep the change facilities free from contamination by following the procedures in these Guidelines. These are also designated contamination control zones. In order to control the spread of potential contamination, contamination monitoring should be conducted periodically in these contamination control zones, in the manner described and as required, on all workers and equipment in these zones. In addition, workers are required to wear proper personal protective equipment (PPE) in the work area.

13.6.5.1 Contamination Monitoring of Contamination Control Zones

When the mineralization grade is below action level in the contamination control zones identified above, the drill platforms (only under certain conditions), the core logging and core splitting facilities, and the change facilities should be monitored periodically. Designated “Clean Areas”, such as work bunkhouses and the dining area, should also be checked routinely.

If contamination is detected, the monitoring frequency should be adjusted to weekly or daily, until the source of the contamination is identified or there is no contamination for three successive weeks. When the mineralization grade is above the action level, these areas should be monitored on a weekly basis, or daily if contamination is routinely detected. The monitoring should be conducted as follows:

- Ensure that the contamination meter is turned on, that the battery is charged, and that the reading is not sensitive to movement of the cable attached to the probe. Observe the background reading for 20 seconds using the slow response time and record average reading. This should be performed in a low background area away from potential sources of contamination.
- Switch to the fast response time, and slowly move the contamination meter 1 cm above surface area of floors and tables, particularly along floor cracks, and along the edges and corners of the room, and any other areas that may have a potential for the accumulation of contaminated material.
- If the meter reads 100 cpm above background level, clean the area and repeat the measurement until the level is acceptable; if the reading remains high or if the background in the area is above 300 cpm, take a swipe[5] of an area of at least 300 cm^2 and monitor the swipe in an area with a background level count of less than 100 cpm
- Occasional wash water and fines or sweepings, if generated, will be minimal and will not cause increased background level radiation; if contamination levels are high (above 1000 cpm), the wash water and fines or sweepings can be temporarily collected in a sump or other small containment area located near the monitored zones, until they are transferred to the secure containment areas where elevated cuttings are safely disposed.

[5] To swipe, use a clean cloth to remove any surface material from an area of at least 300 cm^2, take it to an area of low background, and take a count with a beta and/or alpha sensitive contamination meter.

Examples of Monitoring and Control of Workspace Contamination Associated with Exploration Activities

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Weekly Monitoring Tasks by Geologists and Geotechnicians During Core Examination and Logging

Conduct a source check of the pancake Geiger probe and count rate meter. Replace probe and meter unit if there is no response or low response to the check source. Document results:

1. Swipe all tabletops and walkways between tables in the core logging facilities for removable contamination.
2. Place the swipes in a plastic bag, take a count, and record results.
3. If removable contamination levels exceed 5.0 Bq/cm2 (beta) or 0.5 Bq/cm^2 (alpha) on a 300 cm^2 surface, the tables will have to be cleaned as described in Step 5 under Daily

Monitoring Tasks above. Note: Surface should be cleaned if any contamination 100 cpm or more above background is detected.

4. Conduct swipe checks again following cleaning and record results.
5. If removable contamination persists at levels above the values stated in Step 6 under Daily Monitoring Tasks above, dispose of tabletops and walkway floorboards, and replace with clean material.
6. Until the time of removal from the exploration activity, store the ashes and other contaminated materials in a designated and marked area.

Daily Monitoring Tasks by Geologists and Geotechnicians
During Core Examination and Logging

Drill core is often examined on plywood trestle tables inside or, weather permitting, just outside the core logging facility:

1. Monitor tabletops and the walkway floors between tables for radioactivity, as core boxes are removed, and prior to bringing in new core for examination. This is done by direct check with the pancake Geiger probe and count rate meter (Ludlum 12).
2. To perform a direct check, first move the range switch of the rate meter to the “Battery” position and ensure that the battery voltage levels are within the acceptable range.
3. Move the range switch to the lowest range. The meter should register a background level count rate of 30 to 120 counts per minute (cpm)*. No mineralized core should be in the area when contamination monitoring is being conducted.
4. Move the Geiger probe over the plywood surface being monitored and note areas of elevated contamination above background levels.
5. Clean any tabletop surface with levels greater than 1000 cpm on direct check by damp wiping, to reduce levels below 1000 cpm.
6. If levels cannot be reduced below the 1000 cpm levels, replace the tabletops with new plywood. (Note: Tabletops can be lined with sheets of easily decontaminated material to facilitate clean up).

* Measurement of contamination levels is typically done in counts per minute (cpm)

15.6.5.2 Personnel Monitoring in Work Areas

If contamination is detected in any of the change facilities on a routine basis, an investigation should be conducted to determine the source of the contamination. If the source can be identified, personnel contamination monitoring should be established in a designated monitoring area, either adjacent to the source (e.g., the core splitting shack, the drill platform), in an area free of radioactive contamination and with low radiation fields. The radiation field should be recorded, as well as the background level reading on the contamination survey meter. If possible, the background level reading on the contamination meter should be less than 300 cpm. Note: If the source cannot be readily identified, worker monitoring should be conducted prior to entry into the change facilities.

The monitoring areas and the change areas must be kept free of radioactive contamination. When personnel monitoring is necessary, workers are required to perform the following checks with the contamination meter:

- Ensure that the meter is turned on, that the battery is charged, and that the reading is not sensitive to movement of the cable attached to the probe
- Observe the background level reading for 20 seconds, using the slow response time
- Switch to the fast response time and pass the survey meter – at a distance of about 1 cm – over the soles of shoes and hands (without gloves) Note: If the work area is particularly dusty, use the meter to monitor coveralls as well.
- Ensure that the reading is less than 100 cpm above background level. If it is higher, identify the area and wash with water to decontaminate. Repeat the process until the reading is within acceptable limits. Report any issues to the EHS Manager or designate.

The change facilities are areas where workers change from their work clothes into clean clothes and vice versa. The floors and benches of change facilities should be monitored on a regular basis (at least once a month) to ensure they are free of contamination. The work clothes should also be monitored periodically (as determined by the EHS Manager) to ensure there is no build-up of contamination. If there is a persistent need to decontaminate the floors, bench, and/or personnel, the monitoring frequencies should be increased and the clothes monitored and, if necessary, decontaminated by washing in water. Safely dispose wash water in a secure containment area.

Periodic monitoring of dining areas should also be carried out, to ensure no contamination is present.

Personnel decontamination can be done by cleansing with a cloth or, if necessary, washing. Contaminated clothing can also be washed in water.

13.6.5.3 Personal Protective Equipment

Personal Protective Equipment (PPE) required for RP during the exploration program when handling of mineralized material consists mainly of gloves (i.e., cotton); in the case of rock cuttings, PPE consists of respirators (or dust masks) and coveralls. During the drilling program, in addition to required PPE – coveralls, gloves, as well as safety boots and hard hats (on drill rigs) – the use of safety glasses is recommended during the examination of mineralized rock and drill core, in order to protect the eyes from rock shards, as well as beta and alpha radiation. A respirator should be worn during the core splitting. The Radiation Safety Officer (RSO) can provide further guidance on PPE and make adjustments, as required. A lead apron is also provided to the Geologists and technicians who examine high grade cores.

13.6.6 General Radiation Safety Guidelines

The most important considerations in handling mineralized materials are personal hygiene and the prevention of contamination leaving the control zones on one’s person or clothing. Good personal hygiene is the best way to prevent ingestion of any radioactive material.

All personnel are required to apply the following safety measures when working on an uranium exploration project:

- Wear gloves (i.e., cotton) when handling soil, silt; wear a dust mask as well as gloves when collecting rock, or when taking chip samples

- Wash hands and hair daily, and wash clothes regularly
- Do not bring any rock or drill core into contact with lips or mouth
- Avoid drinking water from open drill holes
- Keep any open wounds bandaged
- Wash hands after handling rock or drill core, and before eating or smoking, to prevent ingestion of radioactive materials
- Do not eat, drink, or smoke in the vicinity of areas with elevated radiation levels
- Gloves and safety glasses must be worn, when working with mineralized drill core
- Safety glasses are mandatory when examining drill core, to protect the eyes from beta radiation
- A respirator must be used when splitting core
- Reduce dust by wetting the area with water whenever necessary and available; in arid regions, use other dust suppression methods
- If the 1 µSv/hr action level has been exceeded in the drill core, periodically check field clothes with contamination meter; if the reading is greater than 100 cpm above background level, bag clothes on-site for laundering
- Ensure that there is proper ventilation in the core logging facility, to avoid inhalation of radioactive materials (e.g., radon gas, dust); taking seasonal conditions into account, always take steps to maximize ventilation (e.g., opening doors and windows, turning on exhaust fans to circulate the air)
- Always work in well-ventilated environment or monitor periodically for radon build-up; if the 1 µSv/hr action level has been exceeded in the drill core, monitor work areas on a regular basis with contamination meters
- Control the spread of contamination at all times by following field protocols as outlined in these Guidelines
- All workers are required to wear their thermoluminescent dosimeters (TLDs)
- If levels above the criterion are encountered, exploration workers examining and logging mineralized cores must wear a direct reading dosimeter (DRD) in addition to their TLD; drill contractors who handle and box the core are required to wear a TLD alone
- Distance is the best way to reduce exposure to radioactivity; store any radioactive core well away from the main camp area (i.e., >30 m away) and downwind from the main wind direction
- Mineralized core should also be stored at least 30 m away from any body of water
- Store only a minimum amount of core boxes inside an enclosed core logging facility while logging the core
- Ensure that the core storage area is well posted with appropriate signs to indicate the presence of radioactive material
- Long-term core storage areas should be secured with appropriate radiation warning signs

13.6.7 Action Levels*

The following action levels are recommended for an exploration and drill program:

Table 13: Recommended action levels for an exploration and drill program

Monitored Parameter	Action Level	Action
Radiation dose rate at 1 m	1 µSv/hr (10 µSv/hr on contact)	Initiate RP controls
	10 µSv/hr	Restrict time
Daily dose as measured with EPD	10 µSv	Review, restrict time
Quarterly TLD dose rate	100 µSv	Investigate, restrict time
Contamination meter reading	>300 cpm	Swipe
	100 cpm above background level	Decontaminate

***** Action levels are guidelines to all project personnel, based on previous field experience.

The investigation will review:

- The type of work being done and work practices
- The grade percentage of the core
- Exposure time
- Conditions of work area

13.7 Field Protocols

The field protocols are examples of possible daily routines for application of the Radiation Exploration Guidelines when dealing with radioactive uranium samples in an exploration field program and during a drilling program.

Field protocols should be reviewed with all field crews and contractors before anyone begins working in the field. Project Geologists should be responsible for ensuring that their field crews, as well as the drilling crews, follow all protocols and safety measures. Protocols should be reviewed regularly to ensure that they are adequate for the type of work undertaken, or on a more timely basis if workplace investigations call for a change to field protocol(s).

13.7.1 Exploration Field Protocol

Exploration field protocol applies when the work involves soil, silt, rock, and chip sampling.

All field workers shall:

- Pick up their personal TLDs from the designated rack at the start of their shift, wear them inside their jacket or cruiser vest during work, and return them to the rack at the end of their shift
- Wear gloves when collecting rock, soil, or chip samples
- Wear safety glasses and a dust mask, if chip sampling or channel sampling with a rock saw

- Remove work gloves before eating or smoking
- Ensure that sample storage areas, or previously contaminated areas with mineralized core, and/or rock, and other high gamma areas (>1 μSv/hr at 1 m) are clearly identified to personnel

Before entering a vehicle, aircraft, or helicopter at the end of the day, workers shall:

- Place all samples in plastic sample bags
- If action level of 1 μSv/hr at 1 m distance/height has been exceeded, monitor hands, soles of shoes, and clothing with a contamination meter prior to boarding; if the monitoring indicates contamination, then decontaminate
- Store sample bags in a baggage compartment that is removed by personnel by 1 m at a minimum

At the base camp, workers shall:

- Store samples in designated area – the area should be well ventilated and marked and be a minimum of 30 m away from any work area
- Remove and store field clothes and gear in change facilities
- Return TLDs to designated rack
- Not store any field clothing or samples in the office or living quarters
- • Wash and dry field clothing only in designated washing machines

13.7.1.1 Change Facilities and Camp Dining Area Monitoring Program

The following monitoring program should be conducted in change facilities and in the camp dining area:

• The change facilities and dining area should be monitored with a contamination meter at least once every month and at the end of the program with a contamination meter
• If contamination is found in any of the areas, the contaminated areas should be cleaned and the contamination monitoring frequency increased in the field
• The field protocols should be reviewed by the EHS Committee
• The monitoring and decontamination protocols in Section Contamination Control Procedures should be followed

13.7.2 Drill Personnel Protocol

Drill protocols will be reviewed with the drill crew. The drill foreman is responsible for ensuring that drill crews follow all protocols and safety measures. Drillers should use the normal safety equipment (e.g., coveralls, boots, gloves) when dealing with mineralized drill core.

All drill workers shall:

- Pick up their personal TLDs from the designated rack in the morning and wear them inside their jacket or cruiser vest at all times during their shift, and return their TLDs to the designated rack at the end of their shift
- Ensure that no field clothing or samples are stored in the living quarters or office
- Wash and dry field clothing only in a designated washing machine

Drill Crew Contamination Monitoring Program:

- The Project Geologist and EHS Manager or designate will be responsible for monitoring the core shacks, the camp change facilities, checking the monitoring area for contamination, and ensuring that the drill crew are following proper protocols as indicated in Section Contamination Control Procedures, whenever implementation is necessary

13.7.2.1 Drill Site Environmental Protection Protocol

Prior to drilling, the Project Geologist or EHS Manager will fill in the Drill Site Check List, documenting pre-drilling site conditions. Background levels of radiation will be recorded with a gamma meter. Background radiation levels should be measured on a close grid pattern at the drill location and potentially impacted surrounding areas (e.g., low or runoff areas). If possible, field measurements should be linked to a GPS coordinate.

The following actions also are necessary to ensure appropriate on-site environmental protection:

- Once mineralization has been intersected, the mineralized core will be stored 10-20 m from the drill platform or behind large boulders, prior to transporting to the core shack
- When diamond drilling through mineralized zones, a closed circuit facility (i.e., poly tanks) should be used to recycle water through settling tanks or drums
- When RAB drilling is employed in mineralized zone in dry soil above the water table, appropriate dust suppression techniques should be employed
- In wet drilling, once the cuttings settle out, the water can be recycled and drained into a sump or soak-away pit, located down slope from the drill and 50 m from streams or lakes, in accordance with applicable government guidelines
- After a drill hole is completed, monitor the residues (e.g., drill mud, cuttings, soils) using a gamma meter; when monitoring a site the gamma meter should be held 1 m away from the cuttings; any residues with a gamma reading greater than 1 µSv/hr at 1 m distance/height should be either covered with soil in a pit, or returned down the drill hole
- If no further investigations in the drill hole are necessary, the upper 30 m of bedrock or the entire depth of the hole – whichever is less – should be grouted; grouting of mineralized sections is highly recommended
- If significant ore is encountered, consider grouting the entire hole, so that if there is subsequent underground activity, there isn't an open hole into the workings; certain jurisdictions (e.g., Saskatchewan) require grouting above and below the mineralized intersection

13.7.3 Core Shack Facilities Protocol

In the handling and storage of core, it is recommended that core with greater mineralization (i.e., with gamma fields greater than 1 µSv/hr at 1 m distance/height) be separated physically from core with lower gamma fields. This will serve to clearly identify the core with the potential radiological hazards, so that:

- Core may be appropriately stored to limit worker exposure
- Appropriate RP protocols can be applied during splitting and handling
- Appropriate shipping protocols can be used, as identified in Section 13.8 Handling and Transportation of Radioactive Samples

All personnel working in the core facility shall:

- Pick up their personal TLDs from the designated rack in the morning and return them to the rack at the end of shift
- Wear their TLDs at all times during the work shift
- Wear gloves, coveralls, and safety glasses when handling radioactive core
- Log core in the core shack, and ensure that the core shack is well ventilated
- Allow mineralized core to remain in the core shack for only 48 hours
- Ensure that a sign warning of radiation is placed on the core shack, core splitting facility door, and the core storage facilities
- Wear gloves when handling mineralized core and remove them before eating or smoking
- Ensure there is no eating, drinking, or smoking in the core facility
- On an as-needed basis, sweep the core shack and splitting facility to remove dust
- Practice dust control during cleanup to minimize the suspension of dust

Core Facility Monitoring Program:

- The EHS Manager or the Project Geologist will be responsible for checking the site, to ensure the work areas are kept clean and as free of dust as possible
- The EHS Manager or the Project Geologist will routinely monitor mineralized core and arrange storage, so that gamma fields are less than 1 µSv/hr at 1 m distance/height at any work area
- The facilities should be checked with a contamination meter, as indicated in Section Contamination Control Procedures

13.7.4 Core Logging and Splitting Protocol

The core can be split with either a manual core splitter or with a rock saw. Manual splitting keeps dust at a minimum. Once the core is split, workers can remove samples and core boxes from the shack and store them at a distance, so that gamma fields are less than 1 µSv/hr at 1 m distance/height at any work area.

All workers logging or splitting core shall:

- Pick up their TLDs in the morning from the rack and return them after their shift
- Wear their TLDs at all times during their work shift
- Wear safety glasses, gloves, and coveralls
- Wear a respirator when splitting mineralized core
- If necessary, monitor themselves, as indicated in Section Personnel Monitoring in Work Areas
- Remove gloves before eating or smoking
- Refrain from eating, drinking, or smoking in the core splitting facility
- If removing field clothing from the field for washing, place the field clothing in a plastic bag for transportation
- Use only designated washing machines for the cleaning of contaminated clothing
- Thoroughly clean up after cutting

The use of a rock saw is recommended only once a dedicated effluent collection system is in place and available. Proper disposal of any radioactive rock chips or grinds from the sawing is mandatory.

13.8 Handling and Transportation of Radioactive Samples

Any person who handles, offers for transport or transports dangerous goods must either:

- Be trained
- Be issued a training certificate by their employer in accordance with the TDG Regulations for Class 7 radioactive materials; certificates are valid for 36 months

  Or:
- Perform these activities in the presence and under the direct supervision of a person who is trained

13.8.1 Handling Samples

At the exploration site soil, rock, and drill samples for storage on-site or to be readied for shipment for analyses/assay off-site are generally separated by their relative radioactivity, as indicated by hand-held or down-hole measurements.

Each exploration group will develop their own guidelines relevant to each particular project in compliance with local jurisdictional regulations; however, an example of a typical procedure is as follows:

- Samples with a uranium content of <0.01% eU308 or <100pm U (these samples are "effectively" unmineralized) or samples between 0.01% and 0.1% eU3O8, are below the recommended action level; these are stored in the general core rack facility or in chip storage plastic bags, but with no extra-special precautions.
- Samples with a uranium content >0.1% eU308 to 1% eU308 are also stored in the general core rack facility, but the core boxes usually have their lids nailed closed; as well, the area of the core rack is marked by a fluorescent yellow radioactive warning sign.
- Samples with uranium content of >1.0% eU308 are stored in a totally separate, protected area, very clearly marked with fluorescent yellow radioactive warning signs. The site is usually in the open so that it is well ventilated; core boxes are nailed closed.
- The disposition of all samples must be thoroughly documented in a systematic, up-to-date manner.
- Any material taken for analyses/assay must be clearly indicated in the original core boxes, rock or core chip sample bags, or soil sample bags. This information also must be clearly indicated on the drill logs or the chip sample records and on all duplicate shipping tags.

Who took what, and when, and where it was stored or sent to must be meticulously recorded and duplicates kept at the exploration site and in the exploration office. All jurisdictions have the right to ask for this information at any time and accurate records need to be easily available.

13.8.2 Shipping Requirements

The Internal Atomic Energy Agency (IAEA) has made recommendations and given guidelines for the transportation of radioactive materials. While the IAEA is the accepted guiding document, Transport Canada and the CNSC Packaging and Transport of Nuclear Substances regulations are the law in Canada.

When shipping radioactive samples, it is the responsibility of the exploration company to determine which category should be assigned to the shipment. Each country's regulations for the transportation of radioactive material are typically based on the International Atomic Energy Agency (IAEA) Regulations for the Safe Transport of Radioactive Materials. Radioactive material is defined as material with radioactivity that is greater than 70 kBq/kg[6]. Packages containing radioactive material must be correctly labelled with shipping information and United Nations (UN) number.

In some jurisdictions, radioactive samples can only be analysed at labs that are licensed by the regulator to receive radioactive samples.1) Requirements for Shipping Excepted Packages

If the radiation fields are <5 µSv/hr on contact with the outer surface of the package, then the shipment may be considered an "Excepted Package" under IAEA regulations. Therefore, if the dose rate on the exterior of the package is <5 µSv/hr, it can be considered non-dangerous goods, and shipped under routine conditions of transportation.

The following procedures must be followed when shipping an Excepted Package:

- A label marked "Radioactive Samples" must be placed inside the package so that the label is visible to the person opening the package
- Removable radioactive contamination on the outside of the package must not exceed 0.4 Bq/cm^2 averaged over 300 cm^2 or must not be detectable above background, using the swipe protocol described in Section Contamination Monitoring of Contamination Control Zones
- The UN number "UN2910" must be attached to one vertical side of the shipping container
- Both the consignor and consignee addresses must be displayed on exterior of the package
- If the weight exceeds 50 kilograms, the weight must be shown on exterior of the package
- If transported by air, the package must be able to withstand a temperature range of -40 °C to -55 °C and withstand without leakage a reduction of ambient pressure to 5 kPa
- The way bill requires the shipping name (Radioactive Material, Excepted Package – Limited Quality of Material) and the UN number
- Three copies of the documentation are required – one each for the shipper, the carrier, and the receiver

Requirements for Shipping Low Specific Activity-I (LSA-I) Packages:

If the dose rate on the exterior of the package is >5 µSv/hr, then the package will be shipped as a Low Specific Activity-I (LSA-I) shipment.

The following procedures must be followed when shipping any Low Specific Activity-I package:

- Both the consignor and consignee addresses are to be displayed on the exterior of the package
- If it exceeds 50 kilograms, the weight must be shown on the exterior of the package
- The shipping name (Radioactive Material, Low Specific Activity) and the UN Number "UN2912" must be attached to two vertical and opposite sides of the shipping container
- Three copies of the documentation are required; one each for the shipper, the carrier and the receiver
- Radioactive Yellow II labels are attached next to the shipping name and UN number labels

On the Radioactive Yellow II labels the following must be written:

- “LSA-I” in Radioactive Contents section
- The activity level in the package, estimated in Bq
- The Transport Index. This index is the gamma radiation field in mSv/hr at a distance of 1 m from the exterior of the package multiplied by 100 – or the field in µSv/hr/10. For example, the Transport Index for 4.5 µSv/hr will be 0.5.

The package for an LSA-I Shipment must satisfy the IAEA Requirements for Type 1 Industrial Packages (Type IP-1), which are the same as for an Excepted Package, plus:

- The smallest external dimension of the package cannot be less than 10 cm
- The container must be durable and legally marked on the outside “Type IP-1”

[6] For uranium ore, a pail of core pieces would have a radiation field >5 µSv/hr at 1 m distance/height from the surface of the pail.

13.8.3 Packaging Samples for Shipment Protocol

All personnel handling radioactive material shall:

- Be properly trained in the handling and shipping of radioactive material.
- Follow same RP procedures as core facility personnel
- Store and package samples for shipment at a designated site (core facility)
- Move packaged material to a low background level area, and take gamma measurements – on contact and at 1m – on as many sides of the package as possible
- Record the maximum contact and 1 m reading in µSv/hr
- Take gamma measurements for each package, if there is more than one package (e.g., pail, drum)
- Move away from the samples when filling out shipment forms
- Fill in the proper forms and labels based on the gamma measurements

13.8.4 Transportation of Samples

Soil, rock, and silt samples will be placed in plastic bags before shipping from the exploration site For shipment to the lab:

- Packages will be packed so as not to exceed the limits for a Low Specific Activity-I (LSA-I) packages
- Samples will be packaged so as not to exceed 5 µSv/hr, whenever possible
- Proper containers (i.e., IP3 type – metal) will be used
- Samples will be shipped by the appropriate transportation means to the lab

13.8.5 Emergency Measures

Emergency response measures need to be in place in case an accident or spill occurs. These measures can be in form of a stand-alone emergency response plan (e.g., a manual) or may be in the form of a contract with commercial emergency response service providers. Personnel undertaking shipping of radioactive materials need to be trained in emergency procedures.

As a first response the following actions are recommended:

- If an accident or spill occurs, cover the material with plastic sheeting and secure it
- Contain the spill to prevent the potential contamination of wider areas or nearby water sources
- Minimize the time spent in close proximity to the material, as well as potential ingestion or inhalation of the material
- Contact health and safety services immediately, depending on the size and nature of the spill/accident
- After responding, ensure that any contaminated clothing and equipment is properly cleaned up

13.9 Glossary of Acronyms

ALARA As low as reasonably achievable (social and economic factors taken into account)

ALI Annual limit of intake

Bq Becquerel – unit of radioactive material, one distintegration per second

CNSC Canadian Nuclear Safety Commission

cpm Counts per minute

cps Counts per second

DRD Direct reading dosimeter

EHS Environment, Health, and Safety

EPD Electronic personal detector

IAEA International Atomic Energy Agency

LLRD Long-lived radioactive dust

LSA Low specific activity

NEW Nuclear energy worker

NORM Normally occurring radioactive materials

PAD Personal alpha dosimeter

PPE Personal protective equipment

R Roentgen – unit of measurement for ionizing radiation; 1 R/hr = approximately 10,000 µSv/hr (see µSv below)

RAB Rotary air blast (drilling)

RnP Radon progeny

RP Radiation protection

RPP Radiation Protection Program

RSO Radiation Safety Officer

Sv Sievert – unit of measurement for radiation dose; 1Sv = 1 million microsieverts (µSv)

TDG Transportation of Dangerous Goods (regulations)

TLD Thermoluminescent detector

UN United Nations

µSv Microsieverts; 1 million µSv = 1 Sv (see Sv above)

WL/WLM Working level/Working level months

13.10 References and Links*

Canadian Government
Canadian Council of Ministers of the Environment – Canadian Water Quality Guidelines,
www.ccme.ca/publications/can_guidelines.html

Canada's Nuclear Safety and Control Act – Radiation Protection Regulations,
http://laws.justice.gc.ca/en/n-28.3/sor-2000-203/154458.html

Canadian Nuclear Safety Commission (CNSC),
www.nuclearsafety.gc.ca/eng/index.cfm

Canadian Nuclear Safety Commission (CNSC) – Packaging and Transport of Nuclear Substances,
http://laws.justice.gc.ca/en/n-28.3/sor-2000-208/154290.html

Health Canada – Canadian Guidelines for the Management of Naturally Occurring Radioactive Materials (NORM),
http://www.hc-sc.gc.ca/ewh-semt/pubs/contaminants/norm-mrn/concern-probleme-eng.php

Health Canada – Environmental & Workplace Health, National Dose Registry,
National Dose Registry

Health Canada – Occupational Exposure to Radiation,
It's Your Health - Occupational Exposure to Radiation

Transport Canada – Transportation of Dangerous Goods,
http://www.tc.gc.ca/tdg/

Canadian Provincial Governments
Newfoundland and Labrador – Environmental Guidelines for Construction and Mineral Exploration Companies,
www.gov.nl.ca/mines&en/mgrights/environment.pdf
Newfoundland and Labrador – Mines and Energy Legislation,
www.gov.nl.ca/mines&en/legislation/#mines

Saskatchewan – The Radiation Health and Safety Regulations 2005,
http://www.qp.gov.sk.ca/documents/English/Regulations/Regulations/R1-1r2.pdf

Environment – Mineral Exploration Guidelines for Saskatchewan,
http://www.publications.gov.sk.ca/details.cfm?p=10611

Saskatchewan Labour – Radiation Protection Guidelines for Uranium Exploration,
http://www.labour.gov.sk.ca/Default.aspx?DN=25dcdf65-129a-4928-9f72-9431733643da

Worksafe Saskatchewan – Radiation,
http://www.worksafesask.ca/topics/specific_hazards/physical/radiation.html

Other
American Nuclear Society, Michigan Section – Radiation Protection Training,
http://local.ans.org/mi/Teacher_CD/Teacher%20Guides/RADGRADcourse.ppt

Queensland Government, Department of Minerals and Energy – Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland,

http://www.epa.qld.gov.au/ecoaccess/mining/Technical_Guidelines

Queensland Government, Department of Mines and Energy – Guidance note QGN12: Radiation protection from naturally occurring radioactive materials (NORM) during exploration,
http://www.minerals.org.au/__data/assets/pdf_file/0008/26882/guidance_notes12.pdf

International Atomic Energy Agency (IAEA) – Safety Standards, Regulations for the Safe Transport of Radioactive Material, 2005 Edition, Safety Requirements,
http://www-pub.iaea.org/MTCD/publications/PDF/Pub1225_web.pdf

International Atomic Energy Agency (IAEA) – Transport of radioactive material, Published Safety Standards,
http://www-ns.iaea.org/standards/documents/default.asp

Radiation Measurement Units – International (SI) System,
Radiation Units Conversion Table

***** PDAC welcomes contributions of other website resources of interest.