RADIOLOGICAL EXPOSURE PATHWAYS REPORT

Rev. 1 **Date: 11/11/2009**

IN SUPPORT OF THE APPLICATION FOR A LICENSE FOR SOURCE MATERIAL MILLING

PIÑON RIDGE URANIUM MILL

Montrose County, Colorado

Submitted to:

Radiation Management Unit
Colorado Department of Public Health and Environment

Prepared for:

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Project No. 83088
DCN 83088.5M-ALB09RP001

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1.0 INTRODUCTION

Energy Fuels Resources Corporation (EFR) proposes to license, construct and operate a conventional acid leach uranium and vanadium mill at the Piñon Ridge Mill site (the "Site") in western Montrose County, Colorado. Site facilities will include an administration building, a 17-acre mill, tailing ponds totaling 90 acres, a 40-acre evaporation pond (expandable capacity to 80 acres), a 6-acre ore storage pad, and an access road. The mill will process ore produced from mines within a reasonable truck-hauling distance and will have a capacity of 500 tons per day, but is designed to accommodate subsequent expanded production capacity of up to 1,000 tons per day. The expected operating life of the mill is 40 years, but may be extended for 10 years or more if economic conditions warrant.

The Piñon Ridge Mill is subject to regulation by the State of Colorado, and the mill license (Radioactive Source Material License) will be issued and administered by the Colorado Department of Public Health and Environment (CDPHE). This report presents the results of the Pathways Assessment conducted by Noel Savignac, Ph.D., subcontracted to Kleinfelder West, Inc. (Kleinfelder), for EFR in support of the mill license application. The report is intended to provide a general overview of radiation exposure pathways at the Site and surrounding areas, bioaccumulation at the Site, and a toxicological assessment of the radionuclides present. More detailed information on radiation exposure is provided in "Estimates of Radiation Doses to Members of the Public from the Piñon Ridge Mill" (Little, 2009) and in Risk Assessment for Proposed Uranium and Vanadium Mill at the Piñon Ridge Property" (SENES, 2009).

The Site is located in the Paradox Valley at 16910 Highway 90, approximately 12 miles west of Naturita, in Montrose County, Colorado. The Site's legal description is the Southwest ¼ of the Southeast ¼ of Section 5, all of Section 8, the North ¼ of Section 17, and the Southeast ¼ of the Northwest ¼ of Section 17, Township 46 North, Range 17 West, of the New Mexico Principal Base and Meridian. The Site is located on both the Davis Mesa Quadrangle and Bull Canyon Quadrangle 1:24,000 United States Geological Survey (USGS) topographic/geologic maps. The Site location with respect to major topographic features is shown in Figure 1.

2.0 SOURCES OF RADIONUCLIDES

Radiological exposure pathways originate with a source of radioactive materials. The radionuclides pass through an exposure medium, such as air or water, are transmitted and produce a radiation dose to the plants, animals, and/or humans. The sources of radionuclides at the Piñon Ridge Uranium Mill are discussed below:

- Radionuclides in the uranium-238 decay series are illustrated in Figure 2. Uranium-238 is the most common isotope of uranium and forms 99.3 percent of natural uranium including uranium ores. Of the 15 radionuclides presented in the uranium-238 decay series, the following radionuclides have sufficiently long half-lives to be transferred from their source, through the exposure medium to the plants, animals, and/or humans:

    - U-238
    - U-234
    - Th-230
    - Ra-226
    - Pb-210

- U-238 and U-234 will be largely present in the mill where the uranium is separated from the ore and concentrated to create the final product, yellowcake, which consists mainly of U3O8·H2O. The yellowcake will be packaged in drums and shipped via truck from the

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mill for further processing. Yellowcake is a source of exposure to humans inside the mill from process liquids leaking and drying on equipment and the floor and during the drying and packaging process.

- U-238, Ra-226, Th-230, and Pb-210 will be present in the dust generated by ore transfer operations at the ore pad. Dust may be generated at the ore pad by truck travel on the ore pad, dumping the ore from truck onto the pad, and picking up the ore and dumping it into the grizzly. Dust is also generated from wind erosion of the ore pile. The fugitive dust is a pathway source for exposure to humans and animals. After dust is inhaled by humans or animals the particle size of the dust particle determines where the dust will be deposited in the respiratory track. Large dust particles deposit in the nose and smaller particles deposit deeper in the respiratory track. The smallest dust particle can actually be inhaled and then exhaled. In the assessment of the radiation dose from dust particles the particles size is calculated by the MILDOS-AREA computer model.

  Dust from mill operations is controlled with water sprays and dust suppressant chemicals applied to areas such as the roads, ore stockpiles, and tailings cells.

- Ra-226, Th-230, Pb-210 and limited amounts of U-238 and U-234 will be present in the tailings placed in the tailings cells. Sprinkling of tailings solution or raffinate on the tailings beaches will minimize dust generation, but some tailings solids may dry out on the beaches and become airborne. Radon will be produced from the beaches and, to some degree, from tailings solutions. The dust and radon are considered pathway sources for exposure to humans and animals. Liquids containing these sources will be prevented from entering pathways to plants, animals, and/or humans by the lining system under the tailings.

- Th-232 and its decay products may be present in some uranium ores. The decay chain consists of 12 elements of which radium and thorium are long-lived radionuclides. Because ore will be coming from a variety of mines in the area and thorium exists in limited quantities in a few of the ores, only limited amounts of Th-232 are anticipated in the mill feed. Th-232 passes through the mill and is discharged and contained within the lined tailing impoundment. Until such time as Th-232 is present in large quantities in ore sent to the mill, Th-232 in ore dust and/or in tailing dust is not considered a major pathway for radiation exposures.

- Uranium-235 is also an isotope or uranium but only makes up about 0.7 percent of natural uranium. Unlike the predominant isotope uranium-238, it is fissile and can sustain a fission chain reaction. The uranium concentrate that will be produced at the mill contains the same ratio of uranium-238 to uranium-235 (i.e., 99.3/0.7). This concentrate will be shipped to a converter facility where the uranium-235 content of the uranium will be enriched to three to five percent and then used to make fuel rods for nuclear power plants. Uranium-235 and its decay products in ore and/or in tailings dust are not considered a major pathway for radiation exposures due to their limited quantities.

- Uranium decay series elements will be present in low concentrations in the uranium ore processed at the mill. The Piñon Ridge Mill has three stacks that release particles of uranium and its progeny and a stack that emits uranium particles without its progeny:

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1. The feed system dust collector stack, which collects dust from the unloading of ore to the grizzly and feed conveyor (uranium and progeny).
2. The semi-autogeneous grinding (SAG) mill process vent stack from the SAG mill dust scrubber (uranium and progeny).
3. The leach train vent gas scrubber stack (uranium and progeny).
4. The vanadium dryer dust collector and packaged bed scrubber stack (uranium without progeny).

These four stacks release limited quantities of radionuclides from effluent control systems in the mill as documented in Kleinfelder (2009) and Little (2009). These stacks are considered minor pathway sources. Emissions from these stacks are presented in the Air Permit Application (Kleinfelder, 2009b). The uranium vacuum dryer is a zero-discharge system and does not emit uranium or other radionuclides.

- Rn-222 is a decay product of Ra-226 in the U-238 decay chain. It is a noble gas that has minimal chemical interaction with other elements of compounds. At the mill site radon is produced in the ore on the ore storage pad, in the ore in the mill, and in the mill tailings in the tailings cells. The radon which is released into the air from those sources is dispersed by local winds and air currents. The computer model MILDOS-AREA calculates the dispersion of radon and dust particles in the horizontal and vertical directions around the mill Site. The location of each source of radioactive materials, and the height of each source, be it a pile or a mill stack, is entered in the code. Using the annual wind speed and direction of the local winds, the code calculates the concentration of the particles, the radon concentration, and the concentration of radon decay products that have formed during transit. From those concentrations, the model calculates radiation doses that would be received by individuals at the property boundary and beyond.

3.0 RADIOLOGICAL PATHWAYS

The Office of Nuclear Materials Safety and Safeguards at the U.S. Nuclear Regulatory Commission published the “Final Generic Environmental Impact Statement (GEIS) on Uranium Milling” (NUREG-0706). The document assesses environmental emissions, pathways, and impacts of uranium mills.

3.1 Applicability of the GEIS Model Mill to the Piñon Ridge Mill

Although the model mill in NUREG-0706 was an 1,800 tons per day acid leach mill and the Piñon Ridge mill is designed to be a 1,000-ton per day acid leach mill, the sources of radioactive effluents and the exposure pathways are the same (see Figure 3). Only the magnitude of the effluents and not the source or the type of effluents is different with one exception. In the 1980 GEIS, the model mill’s yellowcake dryers were assumed to release larger quantities of yellowcake into the atmosphere. Since then the dryer technology has improved to the point that the vacuum dryer that will be used in the Piñon Ridge mill will emit negligible amounts of yellowcake dust (Faillance et al., 1997; NUREG-1910). Thus, Figure 3 from the GEIS has been updated to show that the yellowcake drier is not a significant source of yellowcake emissions from the mill to the environment.

3.2 Sources of Airborne Radioactivity to Humans

The uranium recovery process for the Piñon Ridge mill is illustrated in Figure 4. It consists of four distinct processes: ore receiving/grinding, leaching, uranium recovery, and vanadium recovery. Each of these processes has a potential for generating sources of airborne radioactivity to humans. Other potential sources of radioactivity from the operations include the

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tailings disposal, dispersed ore and tailings, and truck accidents. Each potential source is discussed in more detail below. More detailed information on both radiological and nonradiological risks to mill workers may be found in Risk Assessment for Proposed Uranium and Vanadium Mill at the Piñon Ridge Property (SENES, 2009).

Ore Receiving/Grinding

The ore pad, which is located outside the mill buildings, is where the ore is unloaded from the ore trucks for temporary storage before being transferred to the mill feed and grinding circuits. Typically, the ore is delivered to the dumping platform where the trucks dump their ore without entering onto the ore pad and the restricted area of the licensed facility. However, there may be an occasion where the ore will be delivered directly to the ore pad. Should it be necessary for an ore truck to enter onto the ore pad, it will be decontaminated in the truck wash and scanned before leaving.

Upon delivery to the dumping platform or the ore pad, the ore may be moist or dry depending on its source. However, the surface of the ore can dry quickly, especially in the warmer summer months, which could result in the generation of wind-blown dust. Water sprays and/or misters will be used at the dumping platform and the ore pad to minimize fugitive dust emissions during unloading and ore handling. The dumped ore will be moved to the ore stockpile area on the ore pad or directly to the feed hopper using front end loaders. During this transfer of the ore, fugitive dust will be controlled by spraying the stockpiles and roadways with water. Radon and particulates generated from ore handling and storage on the ore pads are pathways to humans and are source terms entered into the MILDOS computer model to calculate radiation doses from the Piñon Ridge mill. The results of the MILDOS modeling for the Piñon Ridge are presented in the report entitled “Estimates of Radiation Doses to Members of the Public from the Piñon Ridge Mill” (Little, 2009).

The ore will be moved to the ore feed system via a front end loader. The loader opening into the feed hopper building will be covered with a split, heavy-duty plastic curtain to minimize fugitive dust. In addition, a series of water sprayers or misters will provide for direct dust control at the grizzly. Within the feed hopper area, the primary dust control will be provided by a dust-collecting baghouse. The mill operations personnel will operate and maintain the baghouse dust collection system in compliance with the air quality permit issued by the Air Pollution Control Division of CDPHE. Particulates and radon from the ore feed system present a potential pathway to humans and are a source term entered into the MILDOS-AREA assessment analyzed as part of the ore handling and storage operations.

The ore feed system transfers the ore to the mill where uranium and vanadium are recovered. The mill circuit consists of a series of processes as depicted in Figure 4. The ore enters the SAG mill where water is added and the ore is ground into a slurry. Particulate matter emissions are considered to be negligible since the ore is mixed with water and ground into a slurry. However, during this grinding process, radon will be released to the air inside the mill. During operations, the radon emissions will be monitored by the mill Radiation Safety Officer (RSO) and staff and will be addressed in their evaluation of radiation doses to mill personnel. Ultimately, radon is discharged to the atmosphere by the mill ventilation system or by diffusion through the ventilation system and open doors and windows to the atmosphere. This is evaluated as part of the radon source term for the ore transfer operation using the MILDOS computer model and reported in the MILDOS-AREA assessment report (Little, 2009). Particulate airborne emissions are sent to a dust collector and mill stack. Those emissions are also evaluated in the MILDOS computer model.

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Leaching

The slurried ore from the SAG mill is temporarily contained in two large pulp storage tanks and then fed into the solvent leaching, thickening, and clarifying units that feed the uranium and vanadium recovery circuits. Radionuclides are sent to a scrubber that is vented through a stack. Emissions from the leach train vent gas scrubber are evaluated in the MILDOS-AREA assessment (Little, 2009).

Uranium and Vanadium Recovery

Uranium and vanadium in the liquid from the leaching circuit is concentrated in the solvent extraction circuit and then precipitated and dried in the vacuum drier, which is a zero discharge operation (NUREG-1910). However, small amounts of uranium are released from the vanadium non-vacuum dryer. Those emissions are also evaluated by the MILDOS computer code and reported in the MILDOS-AREA assessment report (Little, 2009).

Tailings Disposal

The mill tailings are discharged from the milling operation and are the milling byproduct from which most of the uranium has been removed. The Th-230, Ra-226, and Pb-210 originally present in the ore are still present in the tailings after the milling process. The tailings are discharged from the mill as a sand-water slurry to the tailings cell where most of the tailings remain wet or damp. The presence of a pool of tailings liquid over a portion of the tailings cell will suppress the generation of tailings dust. However, solid tailings in the beaches above the pond water level can dry and become a source of wind-blown tailings particles, especially during the warmer summer months. EFR will minimize the generation of tailings dust by spraying tailings liquid over the solid tailings during operations. These solutions contain high concentrations of salts and are effective in forming a hard crust over the tailings. The liquid in the pond and the salt crust suppresses about 80% of the radon emissions from the tailings (NUREG-0706, Vol. 1, p 5-8, footnote b). When a tailings cell has been filled to capacity, it will be capped with a soil cover to eliminate the potential for wind-blown tailings dust and reduce radon emissions to below federal (40 CFR 61, Subpart T) and CDPHE (6 CCR 1007-1, Part 18, Appendix A) mandated limits.

Dispersed ore and Dispersed Tailings

Small amounts of dispersed ore and tailings solids can be present around the mill as windblown material and from vehicle traffic. The impact of those materials is evaluated in MILDOS model as part of the ore transfer operation (Little, 2009).

Transportation Accidents

Transportation accidents involving semi-truck transport of ore or of yellowcake packaged in 55-gallon drums are possible, but unlikely. The ore trucks will be coming from mines in the region. Given the generally low grade of the ore and the fact that the radionuclides are contained within the matrix of the rock mass, the potential transfer of radionuclides to humans from a spill of ore is negligible. The trucks transporting the yellowcake are operated by trained drivers and equipped with an emergency response kit containing equipment and supplies to minimize the spread of yellowcake that may spill from a breached drum(s). Spilled yellowcake can be spread around the accident site by vehicle traffic and human traffic and is a potential source of airborne contamination. Airborne yellowcake can be inhaled by humans at the accident scene. However, yellowcake is a heavy material, which helps to minimize its dusting potential. Air sampling at the

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accident scene, uranium in urine bioassay, and/or whole body counting of personnel who might have inhaled the yellowcake may be conducted or ordered by the accident response personnel.

Equipment Released from the Mill

Ore trucks and other equipment operating within the mill license boundary will be monitored when leaving the site to prevent the spread of contamination. Any vehicle or equipment leaving the license boundary area will be scanned for radiation by a technician. If the piece of equipment passes the radiation scan, it will be allowed to exit the site. If the truck or piece of equipment does not pass the radiation scan, it will be directed to the truck wash station for decontamination. The truck wash will be a touchless system utilizing high pressure sprays to remove any dirt or mud.

3.3 Sources of Waterborne Radioactivity to Humans

The mill is located in a semi-arid environment with an absence of running streams or tributaries at the site. The dry washes that cross the site from south to north will occasionally contain running water for a short period of time after a significant rain event. Engineering controls, such as diversion channels, will be used to direct this running water away from the facility limiting the potential for this water to come in direct contact with the mill infrastructure. Runoff from the mill itself will be collected and contained on site in the storm water ponds, which will be monitored and maintained by mill personnel. Because of the lack of inhabitants near the mill and the lack of waterborne sources of radioactivity, potential contamination to humans from the surface water pathway is negligible.

Truck or vehicle accidents involving yellowcake are a potential, but unlikely, source of waterborne radioactivity to humans. If an accident involves a spill of yellowcake into a stream or river, the yellowcake would ultimately settle on the bottom of the waterway because the yellowcake is heavy compared to water and minimally soluble in water at neutral to slightly alkaline pH, which is usually the pH of water in streams or rivers. Yellowcake spilled into a waterway is expected to settle to the stream bottom where small amounts of the yellowcake may be available to enter the pathway to humans (i.e., water to fish to humans). The vast majority of orally ingested uranium in humans is excreted through the digestive track (colon and kidneys) with a very small percentage potentially deposited in the bones. A similar pathway may be expected in fish with little uranium anticipated in the muscle of fish. Fishing and the consumption of fish muscle by humans is not anticipated as a major pathway of exposure to humans from the spill of yellowcake into a waterway. If a spill to a waterway were to take place, authorities could always post the area as a “No Fishing” area if such a spill were to take place until the area can be appropriately cleaned up.

The quality of the water into which the yellowcake has spilled should change little because yellowcake is minimally soluble in water at the pH naturally occurring in streams. Therefore, subsequent use of the water for agriculture should not be a major pathway for exposure to humans or animals.

3.4 De Minimus Pathways

De Minimus pathways are those that considered too small to be of consequence. For the Piñon Ridge Uranium Mill, the De Minimus pathways include:

- Yellowcake drying and packaging area. This area has its own heating, ventilating, and air conditioning (HVAC) system, and two sets of doors (vestibules) that remain closed at the exits to provide additional containment of air-borne particles. Only authorized operations personnel are allowed within the packaging area and they are required to

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wear appropriate personal protective equipment, including air-purifying respirators, gloves, and coveralls. A viewing area is provided about the packaging area for guests and non-operations personnel. The yellowcake dryer is a rotary vacuum dryer, known as a “no emission” dryer. The moist air generated by the dryer is drawn through filter socks that are integral to the dryer. An automatic shaker shakes the sock cage and the particles fall back into the dryer. The air from the filter socks is drawn by a vacuum into a condenser where the water and any remaining particulates are removed and pumped to the uranium thickener feed box. The clean air is vented to the uranium packaging room. Negligible emissions are anticipated for this process area.

- Soil. Soil around a uranium mill can contain uranium, Ra-226, Th-230, and Pb-210 particles in the form of ore dust or tailings dust that could impact humans as a result of the ingestion or inhalation of soil or resuspended radionuclides. Those particles can be resuspended into the air by winds, vehicle traffic, or moving the soil. Resuspended radionuclides are not considered a major pathway to animals or humans because the radionuclides are diluted in the soil particles and dust. Consumption or inhalation of soil or resuspended radionuclides is considered a De Minimus pathway. NUREG-0706 does not include consumption of soil as a “principal pathway.”

- Meat, vegetable, and milk. Cattle are grazed seasonally near the mill; however, milk is not produced in the immediate area of the mill. Dust from the ore piles and dust from the tailings beaches can deposit on soils, on edible portions of vegetables, or on hay or pasture grass consumed by animals which are eaten by man. The dust contains uranium, thorium, radium, and lead. The computer model MILDOS-AREA was used to assess the transfer of those radioactive materials from vegetables and meat to man and the resulting doses. Since there are no dairy operations in the area, the transfer from milk to man was not assessed. The doses from vegetable and meat pathways were minimal (Little, 2009) and are considered De Minimus.

  Consumption of wild game is another pathway of radionuclides to humans. This pathway depends on the uptake of radionuclides by wild game (i.e., from soils to plants to animals) and on the subsequent harvesting and consumption by humans. Uptake of radionuclides should be minimal because wild game is not expected to preferentially graze on the mill property near the mill buildings and tailings area where radionuclide concentrations may be elevated. Even though a number of locals consume deer and elk meat, the very small amounts of radionuclides above background in the meat that could be from mill activities should result in this being a De Minimus pathway.

- Rainwater, surface water, or groundwater. Consumption of locally-occurring water is not anticipated by humans in the mill area because of the scarcity of these commodities in the area. Animals may drink rainwater when available, but that activity is limited at the Site because of the lack of available water collection areas and low rainfall and should not be a significant pathway of radionuclides to animals. Bird balls will be used to cover the water surfaces in the tailings cells and bird netting will be used to cover the evaporation pond area. These measures will block access by waterfowl and birds that might attempt to drink from the tailing cells or evaporation ponds. Releases of radionuclides to groundwater are not anticipated at the Site in part due to the lining system under the tailings cells, evaporation ponds, stormwater ponds, and ore pad (Golder, 2008a, 2008b, and 2008c). Even if a leak were to occur, the depth to groundwater beneath the site of 400 feet or more combined with the lack of down gradient potable water wells in the area (Golder, 2009), would rule out the potential for

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consumption by the public. Monitoring wells will be installed at the Site to monitor for potential releases to the subsurface. In addition, should a release be detected, remedial measures are available to limit the spread of contamination.

- Ore trucks. Transportation accidents or spills involving transporting uranium ore from the mines to the mill are also possible, but unlikely (NUREG-0706, NUREG-1508). Ore spills will be cleaned up immediately. The workers involved in responding to spills or accidents of this type will have specific training in how to respond to the incident and recover the spilled materials to prevent personnel contamination and further spread of the materials. The pathway of the radionuclides to humans could exist, but the low concentration of radionuclides in the ore and the fact that people are not usually near ore spills, makes those pathways De Minimus.

- Sprinklers. Sprinklers are often used to assist in the evaporation of tailings liquid from the evaporation pond. Winds can carry the spray beyond the edges of the evaporation pond. Animals are expected to avoid the liquids and spray due to its acidic taste. This pathway is considered De Minimus.

3.5 Toxicological Assessment

Toxicology is the study of the adverse effects of chemicals on living organisms. Of all the radioactive materials in the uranium-238 and uranium-235 decay chains, uranium is singled out in the State of Colorado radiation control regulations as important to regulate based on chemical toxicity. “Notwithstanding the annual dose limits, the licensee shall limit the soluble uranium intake by an individual to 10 milligrams in a week in consideration of chemical toxicity” (CDPHE, 2005). Another reason for addressing the chemical toxicity of uranium is that it is a heavy metal that can concentrate in the bones of mill workers. At the Piñon Ridge Uranium Mill, uranium will be monitored using a uranium-in-urine bioassay program that monitors the levels of uranium in the human body. In addition uranium will be monitored in the mill using breathing-zone-air samplers that sample uranium in air while workers conduct specific high-uranium-concentrations tasks. Area air samplers also will also be used to monitor uranium concentrations in specific work areas of the mill. In the environment around the tailings cells and evaporation ponds, air monitoring stations monitor uranium concentrations in the air.

4.0 DISPERSION OF RADIONUCLIDES IN AIR

Radionuclides released into the atmosphere from the Piñon Ridge mill, as particulates or as radon, are dispersed by the local winds. Although the predominant wind direction shifts diurnally between east and west, dispersion occurs in all directions. Meteorological data from two towers on-site have been collected for a year and have been entered into the MILDOS computer code for evaluation of the radiation doses to people within an 80-km radius of the Site. MILDOS uses a Gaussian dispersion of gases and particulates in both horizontal and vertical directions. The results of the MILDOS evaluation of radiation dose are presented in (Little, 2009).

5.0 RADIOLOGICAL IMPACTS ON HUMANS

Inhalation is the main pathway of radionuclides from the Piñon Ridge mill to people in the vicinity of the mill. Radon progeny, Th-230, and Ra-226, in inhaled dust particles from the tailings impoundments and the milling operations, produce the greatest radiation dose to people in the environment. MILDOS has been used to assess the magnitude of that impact in units of millirem per year (mrem/yr) to the general public within an 80-km radius of the mill.

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Comparisons of the modeled radiation doses to the regulatory maximums and to the annual background radiation doses are presented in (Little, 2009).

The pathways that result in radiological impact to mill employees and visitors are exposure to gamma rays from radionuclides in the mill and exposures from the inhalation of yellowcake dust, ore dust, and radon progeny. The ongoing radiological impact of mill operations to the mill employees and visitors will be assessed by the mill Radiation Safety Officer and staff. Doses are determined from mill area air samples, breathing zone air samples, uranium in urine bioassay samples, and by direct measurement of radiation in the mill. Procedures for collecting those samples and making the measurements are presented in the Piñon Ridge Mill Health and Safety Plan (EFR, 2009). Radiation doses to workers must be limited to 5,000 mrem/yr per CDPHE by regulations, but EFR's goal is to limit exposure for employees to 100 mrem/yr or less. Radiation doses will be evaluated regularly, including on a daily basis for some operations. Employee dose reports from the Radiation Safety Officer will be sent to employees. Additionally, copies will be sent to mill management and to the Safety Committee to determine if the doses are "as low as reasonably achievable (ALARA)."

6.0 RADIOLOGICAL IMPACTS ON PLANTS AND ANIMALS

The radiological impact on plants and animals results from pathways such as inhalation of ore dust and tailings dust, consumption of vegetation by animals, and the uptake and physical contact of plants with tailings and/or ore. Inhalation of radionuclides by animals near the mill site may occur, but the magnitude of exposures should be minimal due to the movement of animals in and out of the area. The radiation doses to animals can be approximated by the radiation doses to humans as calculated by MILDOS, e.g., <10 mrem/yr. That compares to 43,000 mrem/yr to 70,000 mrem/yr where animals show some morphological and physiological effects (Maslov et al., 1967).

The liquids that will be contained in the evaporation ponds and tailings cells have attracted birds, including ducks and geese, at some mill sites. The liquids will have a low pH and elevated concentrations of metals and birds may attempt to drink from, or land on, the ponds. To prevent this from occurring, bird balls will be placed over the tailings water pool and bird netting will be installed over the evaporation ponds. Bird balls are floating plastic balls that are placed on the surface of the tailings liquid. In the unlikely event that birds do drink the solution, Ra-226 and Th-230 could be present in the edible meat of the birds, which could enter the human food chain through consumption of the meat. However, this pathway is considered De Minimus because the ponds will be covered to prevent access and the liquids in the pond are acidic and would probably taste bad to the birds to the extent that they would not drink the liquid. In addition, a chain link fence will be installed around the perimeter of the evaporation ponds to prevent access to the area by terrestrial wildlife.

The maximum gamma exposure rate in the vicinity of a typical uranium mill tailing site is only a few mrem/yr. That exposure rate could approximate the maximum exposure rate to plants. That rate is very low and will not impact plants significantly. For comparison, studies have shown that a dose rate to plants that does produce a significant impact is 1,000,000 mrem/yr to pine trees where decreased growth was observed (Maslov et al., 1967).

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7.0 CONCLUSIONS

De Minimus exposure pathways, or those that are negligible, trivial, or small enough to be ignored or not taken seriously, include exposures from:

- Yellowcake drying and packaging
- Consumption or inhalation of soil or resuspended radionuclides
- Consumption of meat, vegetables, and milk produced locally
- Consumption of wild game
- Consumption of rainwater, surface water, or groundwater
- Transportation accident involving ore trucks
- Sprinklers around the tailings impoundment.

The main radiological exposure pathway from the Piñon Ridge Uranium Mill to people in the vicinity of the mill is inhalation of radon progeny and particulates containing Th-230 and Ra-226. Sources of particulates and radon progeny include:

- The ore haulage, storage, and handling at the ore pad
- Grinding of the ore in the mill
- Mill tailings
- Transportation accidents involving the release of yellowcake.

For personnel working in the mill, the main radiological exposure pathway is from inhalation of yellowcake dust, ore dust, and radon progeny, and from exposure to gamma radiation from radionuclides outside their bodies.

The results of potential radiation doses to the public from the Piñon Ridge Mill operations are presented in a report entitled “Estimates of Radiation Doses to Members of the Public from the Piñon Ridge Mill” (Little, 2009).

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