RISK ASSESSMENT FOR PROPOSED URANIUM AND VANADIUM MILL AT THE PIÑON RIDGE PROPERTY

REV 8

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RISK ASSESSMENT FOR PROPOSED URANIUM AND VANADIUM MILL AT THE PIÑON RIDGE PROPERTY

REV 8

IN SUPPORT OF THE RADIOACTIVE MATERIAL LICENSE APPLICATION

PIÑON RIDGE URANIUM MILL
Montrose County, Colorado

Submitted to:

Radiation Management Unit
Colorado Department of Public Health and Environment

Prepared for: **Energy Fuels Resources Corporation**
Lakewood, Colorado

Prepared by: **SENES Consultants Limited**
Englewood, Colorado

November 11, 2010

Approved: ______________________________
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1.0 INTRODUCTION

1.1 BACKGROUND

Energy Fuels Resources Corporation (Energy Fuels) proposes to license, construct, and operate a conventional acid leach uranium and vanadium mill at the Piñon Ridge Property in western Montrose County, Colorado. The proposed Piñon Ridge Mill Facility is located at 16910 Highway 90, approximately 7 miles east of Bedrock, Colorado and 12 miles west of Naturita, Colorado. The site location is shown in Figure 1.1. The Mill Facility includes an administration building, a 17-acre mill, tailing cells of approximately 90 acres, 40-acres of evaporation ponds (expansion capacity to 80 acres), an approximately 6-acre ore storage pad, and access roads. The mill is designed to process ore produced from mines on the Colorado Plateau located within a reasonable truck-haul distance. The mill will initially process 500 tons of ore per day and is designed for future expansion capable of accommodating a production capacity of 1,000 tons per day. The ore to be processed at the mill contains elevated concentrations of natural uranium and its decay products. The average uranium content in the blended ore is 0.23 percent U_3O_8 (647 pCi U-238/g ore).

The expected operating life of the mill is 40 years, but may be extended for 10 years or more if economic conditions warrant.

Energy Fuels is submitting a mill license application to the Colorado Department of Public Health and Environment (CDPHE) for the Piñon Ridge Mill facility. In support of this application, SENES Consultants Limited (SENES) has, in this report, characterized the radiological and non-radiological hazards and risks associated with operating the mill including associated accident analysis. Further discussion of the exposure pathways and the effects of exposure to radioactive and non-radioactive emissions described in this report is provided in the "Exposure Pathway Report" (SENES 2010) and "Estimates of Radiation Doses to Members of the Public from the Piñon Ridge Mill" (Little 2010).

1.2 SCOPE OF THE ASSIGNMENT

This report covers the following aspects of the mill operation:

- Transport of ore and reagents to the mill and transport of yellowcake and vanadium concentrates from the mill to out-of-state processing plants;
- On-site storage and use of ore, reagents, and fuels;
- Mineral processing operation including process components in the following areas:
  - Ore Handling and Grinding;
  - Leaching and CCD Thickeners;

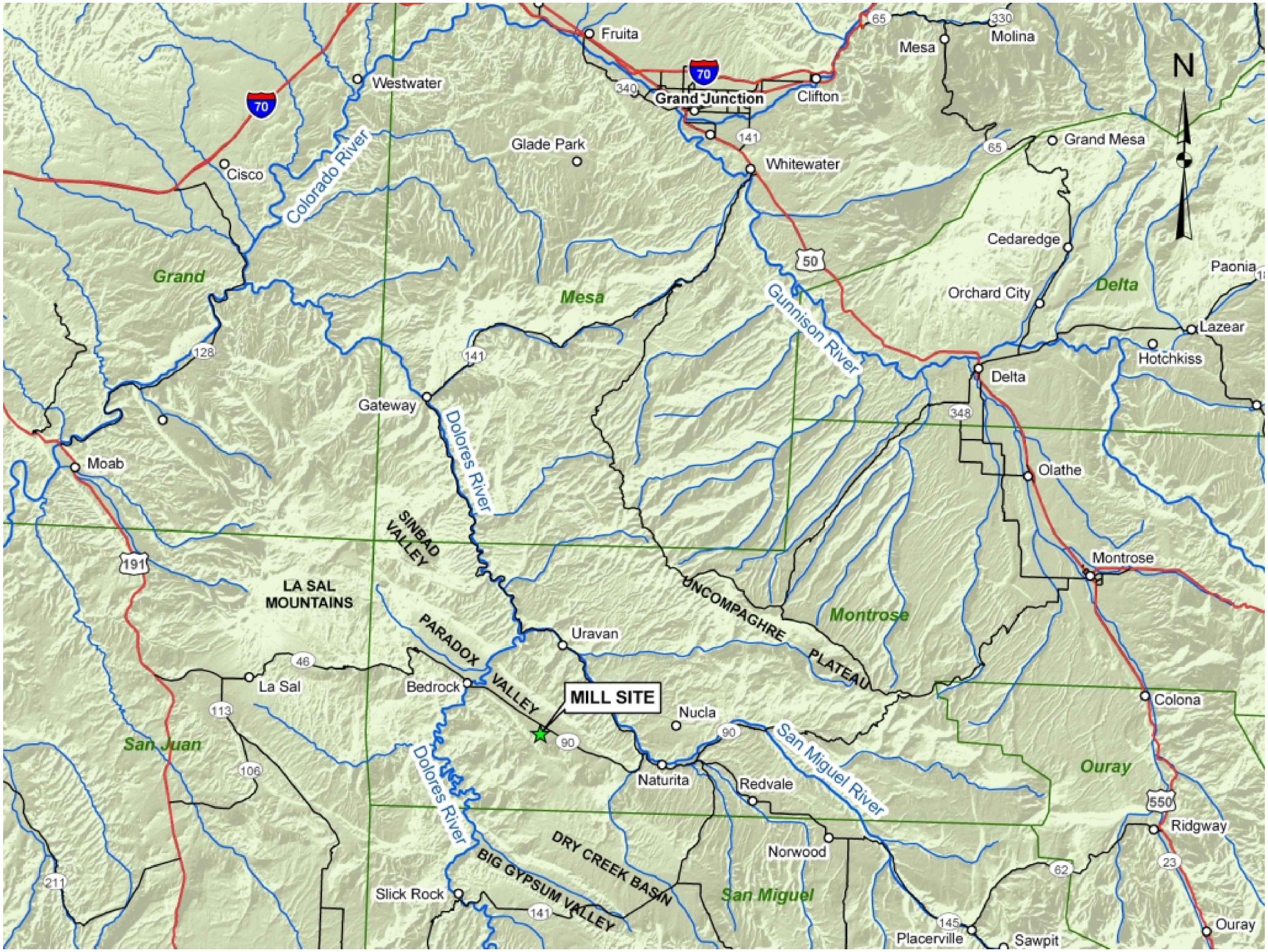
- Uranium Solvent Extraction (SX);
- Uranium Precipitation, Drying, and Packaging;
- Vanadium Oxidation and Solvent Extraction (SX);
- Vanadium Precipitation, Drying, and Packaging;
- Waste Disposal Facilities including Tailings Cells and Evaporation Ponds.

The following reagents, fuels, and process streams will be present in the mill and were considered in the analysis:

- Kerosene;
- Ammonia;
- Ammonium Sulfate;
- Sodium Hydroxide;
- Sodium Carbonate;
- Sulfuric Acid;
- Sodium Chlorate;
- Hydrogen Peroxide;
- Alamine 336;
- Isodecanol;
- Diesel Fuel and Gasoline;
- Propane;
- Uranium/Vanadium Ore and Ore Pulp;
- Water Treatment Residuals;
- Tailing Slurry;
- Raffinate;
- Yellowcake (U_3O_8);
- Black Flake (V_2O_5).

The assessment provides analysis of transportation and mill operation risks under both normal conditions and accidents including estimates of the frequencies of accidents as well as the impacts/consequences of operations and accidents on the health of workers, the public and wildlife, as applicable.

Figure 1.1 Piñon Ridge Mill Site Location



1.3 OBJECTIVES

The objective of this assessment is to characterize the radiological and non-radiological hazards and risks associated with operating the Piñon Ridge Mill including analysis of credible accidents. The report will be used in support of the mill license application submitted to the Colorado Department of Public Health and Environment (CDPHE) for the Piñon Ridge Mill. Specifically, this report supports requirements to assess the environmental impact of a new uranium mill under 6 CCR 1007-1, Part 18, RH 18.4 of the Colorado regulations as well as to demonstrate that radiological exposures and risks to workers will be maintained within established limits and as low as reasonably achievable (ALARA) in accordance with 6 CCR 1007-, Part 4, 4.6 and 4.14.

1.4 EXPOSURE PATHWAYS

The radiological and non-radiological contaminants of concerns, their sources in the mill, the human and ecological receptors, and conceptual exposure pathways model were described in a report titled “Exposure Pathways Report” (SENES 2010). The Exposure Pathways Report forms the basis for the risk assessment study presented in this report.

1.5 REPORT STRUCTURE

This report has been prepared in 6 sections:

- Section 1 includes background, scope, and objectives of this study.
- Section 2 provides preventive and mitigative measures implemented to reduce the exposure and risk to the workers, members of the public, and wildlife.
- Section 3 provides the results of the assessment of the impacts of the normal operations of the mill on members of the public and on wildlife.
- Section 4 provides the occupational impacts of normal operations.
- Sections 5 provides the results of the assessment of accidents.
- Sections 6 presents the summary and the conclusions of the study.

2.0 PREVENTIVE AND MITIGATIVE MEASURES

Energy Fuels is implementing numerous preventative and mitigative measures during the design, construction, and operation of the mill. These measures minimize risks and help ensure that:

1. The normal operation of the mill is safe for workers, members of the public, and is protective of the environment, and that potential impacts from radioactive and other hazardous materials will be maintained ALARA.
2. The frequency and probability of accidents and malfunctions are reduced; and
3. During a potential accident and malfunction event, the consequences and potential impact to health, safety, and environment will be minimized.

Safety and mitigative measures are classified as follows:

- Design of mill components to limit potential releases including "zero discharge" wastewater systems, low emission and "zero emission" air treatment systems, and provisions for secondary containment in the mill processing and waste disposal systems;
- Compliance with applicable regulatory requirements, such as those of the Environmental Protection Agency (EPA), Mine Safety and Health Administration (MSHA), Department of Transportation (DOT), Colorado Division of Oil and Public Safety (CDOPS), and the Colorado Department of Public Health and Environment (CDPHE);
- Implementation of comprehensive monitoring programs for workers and the environment;
- Implementation of the Health and Safety Plan (Energy Fuels 2009a), Emergency Response Plan (Energy Fuels 2009b), Materials Containment Plan (Energy Fuels 2009c), and the Spill Prevention, Control and Countermeasure (SPCC) Plan (Energy Fuels 2009d) under a formal program of work control;
- Implementation of a comprehensive training program;
- Restriction of wildlife and livestock access to the licensed area;
- Implementation of comprehensive site security.

The details of these measures are discussed as applicable in subsequent sections of this document.

3.0 IMPACTS TO PUBLIC AND WILDLIFE FROM NORMAL OPERATIONS

The effects of normal operation were assessed for the following receptors:

- Member of the Public at the Plant Boundary and Nearest Residence; and
- Wildlife and Livestock.

Table 3.1 summarizes the exposure pathways to the identified receptors.

Table 3.1 Public and Wildlife Exposure Interactions

Receptors	Exposure Pathway					
	Gamma	Yellowcake Dust	Radon and Daughter Products	Ore or Tailings Dust	Chemical Dust, Vapor, or Fume	Through Food Chain
Member of the Public	*	*	*	*	*	*
Wildlife & Livestock	*			*		*

3.1 RADIOLOGICAL IMPACTS FROM ROUTINE MILL OPERATION

3.1.1 Mill Operation

Members of the Public

Energy Fuels will implement radiological monitoring and assessment programs to protect the public and environment that comply with the following regulations and related guidance:

- CDPHE 6 CCR 1007 -1 Parts 4 – Standards for Protection Against Radiation;
- CDPHE 6 CCR 1007 -1, Part 18 - Licensing Requirements for Uranium and Thorium Processing;
- CDPHE 6 CCR 1007 -1, Part 18, Appendix A - Criteria Relating to the Operation of Uranium Mills and the Disposition of the Tailings or Wastes From These Operations;
- US EPA 40 CFR 190 – Environmental Radiation Protection Standards for Nuclear Power Operations;
- US EPA 40 CFR 192 – Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings;
- US EPA 40 CFR 61, Subpart W – National Emissions Standard for Radon Emissions from Operating Mill Tailings.

For example, radon gas and dust containing radionuclides can be released to the environment during mill facility operation. Facility design and monitoring will demonstrate that the radon concentrations at site boundaries are below the unrestricted area concentration limit for radon in Table 4B1, Part 4 of 10^{-8} µCi/ml (10 pCi/L) and that releases of any radioactive material will not result in exposure to a member of the public of a Total Effective Dose equivalent (TEDE) > 100 mrem/yr including radon.

The mill process areas, ore pad, tailings cells, and evaporation ponds are designed as “zero discharge” facilities. The uranium vacuum dryer and its off gas components is designed as a “zero-emission” system. The mill facilities with potential for release of radioactive dust or fumes (e.g. dryers, precipitation tanks) are equipped with baghouses and wet scrubbers, respectively, to minimize emissions to the atmosphere.

Inhalation is the main pathway for radionuclides from the Piñon Ridge mill to people residing 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 have the potential to produce the greatest radiation dose to people in the environment.

Dr. Craig Little of Two Lines Inc. Radiation Risk Consultants conducted an assessment of off-site radiation doses from normal operations and the results are provided under a separate report “Estimates of Radiation Doses to Members of the Public from the Piñon Ridge Mill” (Little 2010). MILDOS-AREA modeling has been used with site-specific weather information and the proposed project components 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.

MILDOS-AREA is an NRC and CDPHE accepted code for modeling of airborne radioactive exposures. MILDOS-AREA was specifically designed by the Department of Energy (Argonne National Laboratory) for the NRC to model airborne radiation doses from uranium mills. The model was run on version 2.2, not the most recent version 3.07 because of concerns about the dusting algorithm (personal communication, Craig Little). The MILDOS-AREA model allows user defined source terms.

The location of each source of radioactive materials, and the height of each source, e.g., 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. In addition, as described elsewhere (Little, 2010) the MILDOS-AREA Code also models the environmental fate of radionuclides through the environment and calculates concentrations of the radionuclides in various environmental media (such as deposition onto soil and vegetation and via consumption of beef, milk and vegetables, etc.). From those concentrations, the model estimates the radiation dose to individuals in the Paradox Valley and surrounding areas.

The MILDOS AREA modeling of off-site radiation dose indicates that the mill will have a minimal radiological impact within an 80-km radius of the mill. All of the doses are below the 100 mrem/yr dose limit for individual members of the public, including radon and its progeny, but excluding natural background radiation (Colorado Radiation Control regulations (6 CCR 1007-1- 4.14). The estimated maximum total estimated dose equivalent (TEDE) for an off-site receptor was 8.21 mrem/yr (including radon) compared to the EPA regulatory maximum limit of 25 mrem/yr (excluding radon) and the CDPHE limit of 100 mrem/yr (including radon - see Table 3.2). However, it should be noted that this “maximum” estimate was not based on the presence of an existing residence, but rather a theoretical residence located at the property boundary. This distinction is important in that it is highly unlikely in the future that a full time resident would be located at the actual boundary of the mill site (See discussion in the Exposure Pathways Report, Section 4.3, regarding future land use and the commercial/industrial exposure scenario).

Table 3.2 below shows the calculated maximum TEDE, as well as the 40 CFR 190 effective dose without contribution from radon, and doses to the lung and bone doses to a theoretical future resident at the property boundary.

Table 3.2 Maximum Doses at the Property Boundary (mrem/yr)

Location	TEDE	Effective (excluding radon)	Bone (excluding radon)	Lung (excluding radon)
Location with maximum dose	8.21 (Fence 14)	3.35 (Fence 13)	17.4 (Fence 13)	19.8 (Fence 13)

The details of the calculated dose to twelve actual offsite receptors are provided in Little, 2010. The estimated maximum TEDE as well as the 40 CFR 190 effective dose without contribution from radon, and doses to the lung and bone doses for an actual offsite receptor (i.e., the nearest resident within Paradox Valley) was estimated to be 0.50 mrem/yr (see Table 3.3).

Table 3.3 Maximum Estimated Doses to the Members of the Public (mrem/yr)

Receptor	TEDE	Effective (excluding radon)	Bone (excluding radon)	Lung (excluding radon)
Infant	5.04E-01	1.03E-01	-	7.98E-01
Child	4.73E-01	4.95E-02	1.28E-01	3.84E-01
Teen	4.62E-01	2.70E-02	1.61E-01	2.01E-01
Adult	4.61E-01	2.29E-02	1.78E-01	1.68E-01

*Infant doses do not include bone doses as the pathway is home grown vegetables, which are not typically consumed by infants

Population doses (person-rem/yr) from site releases were calculated for both total effective dose equivalent and the dose to the bronchial epithelium of receptors. Population dose results are shown in Table 3.4.

Table 3.4 Dose to Populations within 80 km of the Piñon Ridge Site (person-rem/yr)

	Population with in 80 km	Population outside 80 km	All
TEDE	2.28E-01	5.41E-01	7.68E-01
Bronchial Dose	7.41E+00	4.93E+00	1.23E+01

Since the mill is designed as a zero discharge facility, the only potential source of radionuclides in the food chain pathway is the atmospheric deposition on the soil and through agricultural products. It was indicated in the MILDOS AREA modeling report (Little, 2010) that the agricultural productivity of the land surrounding the proposed mill is modest. Therefore, the fraction of total annual livestock feed requirements to be satisfied by pasture grass or locally grown stored feed was set at 50% or 0.5. Subsequently, it was indicated that the dose to the public through food chain is very small. See Table 4.1 in the Exposure Pathways Report (SENES 2010).

Soil around a uranium mill can contain uranium, Ra-226, Th-230, Pb-210 and Po-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 in the air by winds, vehicle traffic, or other movement of the soil (e.g. excavation activities). Resuspended radionuclides are not considered a major pathway to animals or humans because the air emission levels and consequently, surface deposition are very low and the radionuclides are diluted in the soil particles and dust. Consumption or inhalation of soil or resuspended radionuclides is considered a "de minimis" pathway because deposition on soil is very small as verified by the results of the MILDOS analysis (Little 2010). See the Exposure Pathways Report (SENES 2010), Section 4.3 for the definition and discussion of de minimis radiological pathways.

Cattle are grazed seasonally near the mill on some lands in Paradox Valley. Vegetables and milk are not produced in the immediate area of the mill; however, for completeness of the radiological assessment of effluents from the mill, vegetable and meat pathways were included in the computer model MILDOS-AREA. Doses from those pathways were minimal and generally less than 5% of the overall dose (Little 2010) and are considered de minimis. 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. Since wild game is not expected to preferentially graze on the mill property near the mill buildings and tailings area where radionuclide concentrations may potentially be elevated, their uptake of radionuclides should be minimal. Even though a number of locals consume deer and elk meat, the very small amounts of radionuclides above background in the meat that could result from mill activities will result in this being a de minimus pathway. The contribution to the TEDE for meat ingestion had a maximum of 3.63% contribution (fence line location). The meat pathway has a maximum of 1.71% contribution to TEDE to an actual resident (not an onsite worker or someone at the fenceline). The maximum contribution to TEDE from vegetable ingestion pathways was 20.6% at the Administration Building; however, the vegetable ingestion pathway is not a credible pathway for an onsite worker. The largest contribution to the TEDE for a hypothetical fence line resident was calculated to be 8.71% (Little 2010). As the maximum TEDE was calculated to be 0.504 mrem/yr to an actual offsite receptor and a maximum of 8.21 mrem/yr at the fence line, ingestion pathways represent a small fraction of a mrem/yr to a member of the public.

With a very low solubility in fat (and therefore very low octanol-water partition coefficient), uranium, radium, thorium, polonium, and lead typically are expected to have very poor bioaccumulation through the food chain. Uranium exhibits poor bioaccumulation or bioconcentration in aquatic environments with sorption being the main concentration mechanism rather than the uptake from the food chain. Uranium is also transported poorly from soils to plants. Greater plant uptake is expected to occur in coarser-grained soils that contain higher levels of available uranium such as sandy soil (i.e., less sorption of uranium to soil particles or formation of soluble uranium complexes). The uptake of uranium by plants, expressed as a plant/soil concentration ratio (CR), grown near a mining and milling complex was reported as 0.8 (ATSDR 1999). Additionally, this same document reports that aquatic organisms such as fish, snails, clams, and algae can bioaccumulate radium from water. The radium-226 bioconcentration factors for fish living in streams or lakes receiving uranium-processing waste effluent have ranged from 1 to 60 for flesh portions (ATSDR 1999); however, there are no perennial water streams or aquatic wildlife in the immediate vicinity of the mill. It was also shown that the radium is transported poorly from soils to plants. The soil-plant concentration ratio for radium-226 has been reported as 3×10^{-3} for fruits and 0.1 for forage and hay. As for radium-226 transfer to cattle, the mean ratio of radium-226 in milk to that in the animal's diet has been estimated to be 3.8×10^{-3}. A similar ratio for flesh was 6.8×10^{-3}. These low values indicate a poor transfer to animals from the feed.

Polonium has an affinity for proteins and can usually be found concentrated in the liver, kidney, and muscle and is also not expected to experience biomagnification in the food chain. A multi-part study of radionuclide transport through the ecosystems was recently conducted at a Canadian uranium mill, including sample collection at the mill site, tailings pile site, and a control site (Thomas 2000). This study found a range of polonium plant/soil concentration ratios (CRs) that was dependent on the site and vegetation type. The CR range for plant/soil for polonium was 0.014 - 4.0, with the majority falling in the 0.1-1.0 range. The study also found polonium CRs for soil/animal for small mammals which ranged from 0.0065-6.4. All of the CRs for soil/animal at the tailings site were an order of magnitude lower than those at the control or mill sites. Studies of moose in northern Saskatchewan showed rumen content/muscle (plant/edible tissue) CRs in the range of 0.18-0.47 indicating no biomagnifications of polonium in this species (Thomas, *et al*. 2005). A study of aquatic ecosystems found that while algae and zooplankton may act as bioaccumulators and magnifiers of polonium, no "remarkable build-up" was observed in higher trophic levels (Hoffman, *et al*. 1973).

Bioaccumulation of thorium to aquatic organisms does occur and bioconcentration factors (BCFs) can be as high 9,750,000 in algae and 20,000 in zooplankton species (dry weigh basis). High trophic level organisms have much lower BCFs; however, suggesting that there is little biomagnification of thorium in the food chain. For example, the highest recorded BCF for a rainbow trout was 465 (ATSDR, 1990). The transfer of thorium from soil to plants is generally low with soil to plant transfer coefficients in the range of 0.00006 to 0.007; however, transfer coefficients as high as 1.9-2.9 for mixed greens, grasses and sagebrush have been observed near the edges of uranium tailings impoundments (ATSDR, 1990).

As a result of lead's strong adsorption to organic soil matter, lead is generally expected to have a very low biomagnification through the food chain, though bioaccumulation may occur. The solubility of lead greatly increases with highly acidic conditions; therefore the uptake of lead into plants is dependent on the soil pH. At soil pH of >5.4, the total solubility of lead is approximately 30 µg/L in hard water and approximately 500 µg/L in soft water, with soluble lead being limited in pHs over 5.4 (ATSDR, 2007). In soils, lead is strongly adsorbed to organic matter and is not subject to leaching, and lead can also be bound electrostatically to clays, silts, and iron and manganese oxides. Soils with a pH of 6-8, which is representative of the site soils, generally form insoluble organic lead compounds. Lead generally only leaches out of soils and becomes available for plant uptake under soil pH conditions of 4-6. While bioaccumulation occurs, biomagnification is not shown in terrestrial or aquatic ecosystems. Fruits and vegetables grown in lead contaminated soils showed a much higher uptake of lead into edible shoot portions of leafy vegetables and herbs than in fruits/fruiting vegetables (Finster, *et al*. 2004). Generally bioconcentration factors (BCFs) in aquatic organisms are highest in benthic organisms and algae. BCFs for various aquatic organisms range from 42 for fish, 500 for insects, 536 for oysters, 752 for algae and 2,570 for mussels (ATSDR, 2007).

Wildlife

Radiological impacts on plant and animal receptors result from pathways such as the uptake and physical contact of plants (via foliar deposition and/or soil) with tailings and/or ore, inhalation of ore dust and tailings dust, and the consumption of vegetation by animals.

Limited airborne releases and subsequent deposition to the soil results in soil and offsite surface water concentrations which are likely to be within background levels. This is validated by the very low deposition onto soil as suggested by the very low doses from the "worst-case" MILDOS Area analyses (See Table 5-2 in Kleinfelder, 2010a).

Inhalation of radionuclides by animals near the mill site may occur, but the magnitude of these exposures is expected to be minimal due to the movement of animals in and out of the area.

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 radionuclides and birds may attempt to drink from, or land on, the ponds. Because of their elevated metal and radionuclide concentrations, the tailings and raffinate solution can be acutely and chronically toxic to wildlife; especially birds and bats that may attempt to drink from or land on the ponds. Therefore, the waste management facilities (tailings cells and evaporation ponds) represent the primary potential sources of exposure pathways to wildlife.

A screening exposure pathway assessment was conducted to estimate the radiation dose to a bird (mallard duck) landing on the tailing cells. The major exposure pathways considered was drinking the water and direct gamma exposure to the duck. A chemical analysis for the tailing solution from a conventional uranium mill, conducted in April 2003 (Energy Laboratories Inc. 2003) was used for the dose estimation. The calculations show that the total dose from Ra-226, Pb-210, Th-230, and Th-232 could be as high as 1,400 milliGrays per day (mGy/d), which exceeds the benchmark of 5 mGy/d (Garisto 2005) for birds (See appendix A1 for details of calculations). This assessment was based on wildlife having unlimited access to the tailings impoundments and evaporation ponds.

Measures will be implemented to minimize the access of wildlife and livestock to the tailings cells and evaporation ponds. These measures include:

- An eight-ft high chain-link fence topped by three strands of barbed wire will be installed around the entire perimeter of the tailings cells and evaporation ponds. The fence will be inspected daily and repaired, as necessary, to prevent access to the area by wildlife.
- Bird balls will be placed on top of the ponded portion of the tailings area to deter birds from landing on the water. The hollow balls are made of plastic and float on top of the water concealing the water surface and creating a physical barrier.
- Woven bird netting will be installed over and along the sides of the evaporation ponds.
- Mill personnel will inspect the tailings cells on a daily basis. As part of their inspection, they will identify and record any wildlife mortalities and, where possible, will implement measures to reduce or eliminate future occurrences.

Some wildlife are attracted to salt (e.g. deer) which could be a potential issue for the beach sands. The restricted area fencing is sufficient to prevent mammals from accessing the beach sands; however, birds could land on the salt-encrusted beach sands. The beach sands are acidic and constantly being deposited during operations and would not be expected to support vegetation or a large number of insects; but there is the potential for direct exposure. Generally, metals are much more soluble in acidic conditions and any tailings solution coming in contact with birds is likely to have dissolved metal cations as well as radionuclides. Birds could be exposed by directly drinking this solution or by preening wetted and encrusted feathers.

The maximum gamma exposure rate in the vicinity of a typical uranium mill tailings site is only a few mrem/yr. That rate is very low and will not impact plants significantly. The DOE for example has concluded that for a facility in compliance with the dose limits for humans, the total doses to plants and animals should be well below the recommended dose limit for animals of 0.1 rad/day and the higher limit of 1 rad/day for plants (DOE 2002). Additionally, it is generally considered that when radiological doses to humans are small, doses to biota are also small (Whicker and Schultz 1982)

3.1.2 Transportation

Transportation of radioactive materials to and from the mill can be classified into two categories:

- Shipments of yellowcake from the mill to a uranium hexafluoride conversion facility;
- Shipments of ore from mines located in the Colorado Plateau to the mill.

The yellowcake products are packed in 55-gallon, 18-gauge drums holding an average of 900 lb of yellowcake. The drums are classified by the Department of Transportation (DOT) as Type A packaging (10 CFR Part 71) and are capped with DOT-approved lid and clamping ring. The bulk ore is transported by haul trucks from the mine to the mill. The ore is covered with tarps to reduce dusting and spillage during transportation. The run-of-the-mine ore being shipped from the mines contains a significant amount of moisture and has a lower percentage of fines than ore that has been crushed. Thus, minimal dust emissions are expected during routine shipment of the ore. Any minor spillage of ore from trucks during transport would add little additional radioactivity to the mineralized natural environment of the Colorado Plateau. Therefore, the radiological impact of transportation on the members of the public and the wildlife is expected to be very small.

The US Department of Energy performed an analysis to estimate exposures of the public from transportation shipments containing uranium ore in DOE 2007. Four representative scenarios were evaluated:

1. An individual in a vehicle stopped in traffic next to a uranium ore truck. This individual would be exposed to one shipment of uranium ore for 30 minutes.

2. An individual in a vehicle who passes a uranium ore truck going the opposite direction. This individual would be exposed to one shipment of uranium ore.
3. An individual in a vehicle stopped at an intersection when a haul truck passes by. This individual would be exposed to one shipment of uranium ore.
4. A nearby resident located 33 ft from a road used by haul trucks. This individual would be exposed to all shipments of uranium ore over the course of a year.

Table 3.5 presents the radiological dose to the public from these four exposure scenarios as evaluated by DOE. The largest radiation dose would be for the nearby resident, who would receive a dose of 0.22 mrem per year from the passing haul trucks. The DOE calculated that after 10 years of having 120 to 150 shipments of ore pass per day, the resident's lifetime probability of getting cancer would increase from 220,000 in 1 million (national average) to 220,001 in 1 million.

Table 3.5 Exposure of the Public from Routine Transportation of Uranium Ore (DOE 2007)

Scenario	Estimated Public Dose
Individual in traffic jam	0.026 mrem
Individual in passing vehicle	7.4×10^{-6} mrem
Individual in vehicle intersection	1.5×10^{-5} mrem
Nearby resident	0.22 mrem / yr

3.2 NON-RADIOLOGICAL IMPACTS FROM ROUTINE MILL OPERATION

3.2.1 Mill Operation

Members of the Public

While hazardous chemicals are used at the mill facilities, the amount and variation of such chemical usage is small compared to large chemical facilities and many other industrial plants. The reagents are stored on site in pre-packaged totes, barrels, and bulk bags within weatherproof buildings and/or in closed bulk storage tanks. Containers are labeled with both the name of the product and safety placards that meet the requirements outlined in the DOT Emergency Response Guidebook (US Dept. of Transportation - ERG 2008). The containers are chemically and physically compatible with the media stored in them and meet applicable local, state and federal storage regulations, including for secondary containment as applicable.

In addition to the reagents, the heavy metals contained in the uranium ore could potentially have impact on the humans and the environment. 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 (chemotoxic impact on renal system, i.e., kidney). "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" (CDHPE, 2005).

The following processes and associated release mechanisms have a potential for generating airborne particulate matter and heavy metals (including V, As, Pb, Mo, Cd, Se, Cu, U and Zn) that could impact humans and flora and fauna.

- Transportation of ore to the mill and associated dust emissions and deposition;
- Transportation of yellowcake from the mill to out-of-state processing plants and associated dust emissions and deposition;
- Dust emissions from onsite storage and handling of ore and yellowcake;
- Dust emissions from ore handling and grinding;
- Dust emissions from uranium/vanadium recovery including drying and packaging; and
- Waste disposal facilities including erosion from dry tailings.

The mill facilities with potential for release of dust or toxic fumes (e.g. SAG mill, leach tanks, precipitation tanks, vanadium kiln and furnace) are equipped with baghouses or wet scrubbers to minimize emissions of dust or fumes to the atmosphere. The uranium dryer and its off gas system is zero-emission equipment. The following analysis of air quality impacts is based on the air modeling performed by Kleinfelder (Kleinfelder 2009b) for a 1,000 tpd processing rate. For the proposed 500 tpd processing rate, estimated concentrations would be 50% less.

It is expected that dust emissions from ore handling and grinding and resuspension and erosion of particulate matter from soil, ore stockpiles, and dry tailings will be the major sources of exposure to heavy metals. Metals in the emissions from the ore and byproduct material processes were estimated based on the modeled PM_{10} emissions for a 1,000 tpd mill (Kleinfelder 2010b) and metal concentrations in the ore and tailings. The ore and byproduct material were determined to be 30 and 8 percent of the total PM_{10} emissions, respectively. The balance of the PM_{10} emissions is from roads (61%) and combustion processes (1%). Based on the total PM_{10} emissions and concentrations of various metals in ore and byproduct material, the amount of metals emitted from the mill per year are shown in Table 3.6, below. Tables 3.7 and 3.8 show the annual estimated average metal concentrations in the atmosphere at the property line (maximum location) and at the nearest residence in Paradox Valley based on the modeled PM_{10} concentrations and concentrations of various metals in ore and byproduct material. These concentrations are in micrograms per cubic meter ($\mu g/m^3$) and represent the incremental concentrations above background levels.

Table 3.6 Total Metals Emissions
(PM_{10} = 67.26 ton/yr)

	Ore (30%) (lb/yr)	**Tailings (8%)** (lb/yr)	**Total** (lb/yr)
Arsenic	6.78	1.80	8.58
Cadmium	0.09	0.02	0.11
Copper	0.68	0.18	0.85
Lead	15.71	4.17	19.88
Molybdenum	1.28	0.34	1.61
Selenium	6.13	1.63	7.75
Uranium	142.8	1.52	144.30
Vanadium	346.6	13.81	360.45
Zinc	4.99	1.32	6.31

Table 3.7 Maximum Annual Average Concentration at Property Line (PM_{10} = µg/m³)

	Ore (30%) (µg/m³)	**Tailings (8%)** (µg/m³)	**Total** (µg/m³)
Arsenic	1.20E-03	3.18E-04	1.52E-03
Cadmium	1.56E-05	4.15E-06	1.98E-05
Copper	1.20E-04	3.17E-05	1.51E-04
Lead	2.78E-03	7.38E-04	3.52E-03
Molybdenum	2.26E-04	5.99E-05	2.86E-04
Selenium	1.08E-03	2.88E-04	1.37E-03
Uranium	2.53E-02	2.68E-04	2.55E-02
Vanadium	6.13E-02	2.44E-03	6.38E-02
Zinc	8.83E-04	2.34E-04	1.12E-03

Table 3.8 Annual Average Concentrations at the Nearest Residence (PM_{10} = 1.7 µg/m³)

Metal	**Ore (30%) (µg/m³)**	**Tailings (8%) (µg/m³)**	**Total (µg/m³)**
Arsenic	8.56E-05	2.27E-05	1.08E-04
Cadmium	1.12E-06	2.96E-07	1.41E-06
Copper	8.54E-06	2.27E-06	1.08E-05
Lead	1.99E-04	5.27E-05	2.51E-04
Molybdenum	1.61E-05	4.28E-06	2.04E-05
Selenium	7.74E-05	2.06E-05	9.80E-05
Uranium	1.80E-03	1.92E-05	1.82E-03
Vanadium	4.38E-03	1.74E-04	4.56E-03
Zinc	6.30E-05	1.67E-05	7.98E-05

Air quality guidelines for heavy metals and kerosene are provided in Table 3.9. The National Ambient Air Quality Standards (NAAQS) provides the value for Lead. Other values were selected from Texas and California.

Table 3.9 Air Quality Guidelines

COPC	NAAQS[1]	California[2]	Texas[3]
Arsenic		0.015 µg/m^3 Chronic REL[6]	0.1 µg/m^3 short-term[4] 0.01 µg/m^3 long-term[5]
Cadmium		0.02 µg/m^3 Chronic REL	0.1 µg/m^3 short-term 0.01 µg/m^3 long-term
Copper			10 µg/m^3 short-term 1 µg/m^3 long-term
Lead	0.15 µg/m^3 3-months 1.5 µg/m^3 quarterly	1.5 µg/m^3 30-day	NAAQS
Molybdenum			30 PM[7] µg/m^3 short-term 3 µg/m^3 long-term
Selenium		20 µg/m^3 Chronic REL	2 µg/m^3 short-term 0.2 µg/m^3 long-term
Uranium			Soluble: 0.5 µg/m^3 short-term 0.05 µg/m^3 long-term Insoluble: 2 µg/m^3 short-term 0.2 µg/m^3 long-term
Vanadium			0.5 µg/m^3 short-term 0.05 µg/m^3 long-term
Zinc			20 PM µg/m^3 short-term 2 µg/m^3 long-term
Kerosene			1000 µg/m^3 short-term 100 µg/m^3 long-term

1 - http://www.epa.gov/air/criteria.html
2 - http://www.arb.ca.gov/research/aaqs/caaqs/caaqs.htm
3 - http://www.tceq.state.tx.us/assets/public/implementation/tox/esl/list/june2010.pdf
4 - in Particulate Matter
5 - generally 1-hour
6 - generally annual
7 - Recommended Exposure Limit

The following processes have a potential for generating sources of airborne acid mists and fumes and organic vapors that could impact humans and flora and fauna.

- Acid mists and fumes emissions from the leach and CCD circuits;
- Organic vapor emissions from SX circuits.

The process vessels in the leach, CCD, and SX circuits are closed to minimize the emissions of the acid mists and fumes and organic vapors. However, offsite receptors may also be exposed to very low concentrations of organic vapors emitted from the SX circuits and evaporation ponds.

The organic reagents used in the uranium and vanadium SX circuits include kerosene (“$C_{14}H_{30}$”), amine (“Alamine 336 (R_3N)”) and isodecanol (“Exxal 13($C_{10}H_{22}O$)”). The organic mixture is nominally 96% kerosene, 3% isodecanol, and 1% Alamine. For a 1,000 tpd processing rate, it is estimated that 36.4 tons/year (1.06 g/s) of VOCs are emitted from the SX system and 162 tons/year (4.7 g/s) of VOC's are emitted from the tailings and evaporation facilities. Based on these emission rates and the dilution factors presented in Kleinfelder 2010a, the atmospheric concentration of organic vapors was calculated. The average concentrations of organic vapor (mostly kerosene) at the nearest residence and at the site boundary were 3.4 $\mu g/m^3$ and 48.8 $\mu g/m^3$, respectively. These are very conservative estimates since it is assumed that all kerosene in the tailings slurry and raffinate solutions evaporates to the atmosphere.

Based on the modeled concentrations for the proposed facility, the metal concentrations are well below the regulatory guidelines presented in Table 3.9. Kerosene levels are also below long-term limits even when 100 percent evaporation is assumed. Therefore, impacts to air quality in the area of the proposed facility would be less than levels deemed to be protective of human health and the environment and would not degrade the existing air quality.

The mill process areas, ore pad, tailings cells, and evaporation ponds are designed as "zero discharge" facilities in terms of surface and groundwater. Process solution is routed from the mill to lined tailings cells and lined evaporation ponds for evaporation (See Piñon Ridge Facility Operating Plan). No liquids are released from those structures to runoff channels near or on the property. Without perennial surface water in the area, bioaccumulation of uranium, thorium, radium, and lead and other heavy metals cannot occur in the runoff channels.

Wildlife

Exposure to waterborne non-radiological COPC is unlikely due to incomplete pathways such as the lack of permanent surface water bodies in the vicinity of the site, and deep groundwater levels. Surface water channels near the mill will contain water after local rains but not for a long enough period of time for aquatic organisms to live in the channels and take up uranium, thorium, radium, or lead from dust generated from mill operations. Aquatic organisms that may be present within the tailings cells and evaporation ponds can take up uranium, thorium, radium, or lead but those organisms will remain in those structures. At the end of the mill life those organisms will be buried under a tailings cover and will not be available to transfer these elements to human or animals as a part of the food chain.

Screening level risk calculations indicated that the waste management facilities (tailings cells and evaporation ponds) represent the primary potential sources of exposure pathways to wildlife (Kleinfelder 2008). Because of their elevated metal concentrations, the tailings and raffinate solution can be acutely and chronically toxic to wildlife; especially birds and bats that may attempt to drink from or land on the ponds.

A screening exposure pathway assessment was conducted to estimate the hazard quotients (HQ) for a bird (mallard duck) landing on the tailing cells. The major exposure pathways considered was drinking the water. The chemical analysis for the tailing solution conducted in April 2003 for International Uranium (USA) Corp (Energy Laboratories Inc. 2003) was used for the HQ estimation. The calculations show that the Screening Index (SI) varies between 1.24 x 10^{-4} and 2.67 x 10^{4} for various metals showing adverse effects from unlikely exposure of birds to some heavy metals (See appendix A2 for details of calculations).

The protective measures described in Section 3.1.1 will be implemented to eliminate the access of wildlife to the tailings cells and evaporation ponds. However, birds could land on the salt-encrusted beach sands and could be exposed by directly drinking this solution or by preening wetted and encrusted feathers. It is also important to consider that there will be a lack of suitable habitat and food sources to attract birds to those areas. The noise and movements associated with mill activity at the site may also act as a deterrent for some species. The inventory of bird species at the site did not indicate the presence of waterfowl; this is assumed to be due to the lack of suitable habitat on the site for these species.

3.2.2 Transportation

Shipments of hazardous material will follow U.S. Department of Transportation hazardous materials shipping regulations and requirements (49 CFR Parts 171, 172, 173, 177, 178, and 179). Most of the reagents are transported to the mill site in prepackaged totes, barrels, and bulk bags. The bulk materials are typically transported by closed tanker trucks. Any bulk material transported in open trucks is covered with tarps to reduce dusting and spillage during transportation.

No significant dust or fume emissions are expected during routine shipment of the ore. Therefore, the non-radiological impact of transportation on the members of the public and the wildlife is very small.

4.0 IMPACTS TO OCCUPATIONAL HEALTH AND SAFETY FROM NORMAL OPERATIONS

The effects of normal operation on the following receptors were assessed:

- Operational Worker at the Mill and Waste Management Area;
- Office Worker at the Administration Building;
- Transportation Truck Driver

Table 4.1 summarizes the exposure pathways to the identified receptors.

Table 4.1 Worker Exposure Interactions

Receptors	Exposure Pathway				
	Gamma	Yellowcake Dust	Radon and Daughter Products	Ore Or Tailings Dust	Chemical Dust, Vapor, or Fume
Office Worker at the Mill			*	*	
Operational Worker at the Mill and Waste Management Area	*	*	*	*	*
Transportation Truck Driver	*	*		*	*

With consideration of the above exposure pathways, the impacts on the receptors are discussed in the following sections.

4.1 RADIOLOGICAL IMP ACTS FROM ROUTINE MILL OPERATION

4.1.1 Radiological Exposure during Routine Mill Operation

The modern state-of-the-art design of the Piñon Ridge mill (monitoring systems, containment and control of radioactive materials, process controls, etc) combined with the implementation of the health and safety plan, extensive training program, availability of personal protection equipment, and implementation of Federal (e.g., MSHA, USNRC) and Colorado (CDPHE) regulations and guidance will ensure that occupational health and safety limits are not exceeded and that a safe workplace is maintained at all times.. Examples of applicable regulations and guidance that will be followed to ensure low risk of radiological exposures of workers include:

- CDPHE 6 CCR 1007 -1, Part 4 – Standards for Protection Against Radiation;

- CDPHE 6 CCR 1007 -1, Part 18 - Licensing Requirements for Uranium and Thorium Processing;
- CDPHE 6 CCR 1007 -1, Part 18, Appendix A - Criteria Relating to the Operation of Uranium Mills and the Disposition of the Tailings or Wastes From These Operations;
- American National Standards Institute Practices for Respiratory Protection, ANSI Z88.2;
- US Nuclear Regulatory Commission Regulatory Guide 8.30 - Health Physics Surveys at Uranium Recovery Facilities;
- US Nuclear Regulatory Commission Regulatory Guide 8.31 – ALARA Programs at Uranium Recovery Facilities;
- US Nuclear Regulatory Commission Regulatory Guide 8.22 – Bioassay at Uranium Mills;
- MSHA 30 CFR 57.5037 to 57.5047 – Radiation Protection Standards (as may be applicable to surface operations). However, it should be noted that the MSHA standards may not be as protective of workers as CDPHE and NRC regulations in that MSHA does not require the summing of internal and external doses and MSHA regulations are based on older dosimetry models.

Workers are potentially exposed to radiation and/or radioactive materials above background in a uranium mill, either from external sources (direct gamma exposure from sources outside the human body – in ore handling, tailings and yellowcake areas) or from internal sources as result of inhalation and/or ingestion of radioactive materials in the work place.

Numerous radiation exposure monitoring systems are utilized at the Piñon Ridge Mill Facility to identify potential radiation sources and measure and document exposure of workers to ensure that radiation exposures received by workers above background are maintained ALARA. The radiation monitoring program and procedures are directed by the facility's Radiation Safety Officer (RSO) whose qualifications must be approved by the CDPHE and are documented in the mill's Health and Safety Manual. Routine work in the mill is performed in accordance with the approved Radiation Health ("RH") procedures which are identified in Table 4.2 below.

Non-routine work tasks (i.e., activities for which established procedures may not exist) require a Radiation Work Permit, administered by the RSO, that outlines special radiological monitoring and assessments, PPE and other health / safety related measures required while doing the work (Health and Safety Procedure RH 060).

Stationary and portable air monitors are used throughout the mill to monitor the concentrations of radioactivity in the air. Workers involved in operations at locations where airborne radioactivity can occur wear breathing-zone air monitors to measure the radioactivity in the air that they breathe. They may also wear canister-type respirators that are provided for use in these areas. For those workers potentially exposed to higher concentrations of airborne radioactivity, bioassays are conducted to determine the amount of uranium that has been inhaled and/or ingested.

Table 4.2 Radiological Control Procedures

RH No.	Title	RH No.	Title
010	Radiological Health and Safety Training	150	Occupational Breathing Zone Monitoring
020	Decontamination	151	Calibration of Air Samplers Using the Bubble Method
030	Posting	160	Source Leak Test, Shutter Test, and Inventory
040	Radiation Exposure Action Levels	170	Nuclear Density Gauges
050	Uranium Bioassay	200	Personnel Release Surveys
060	Radiation Work Permits	210	Personal Radiation Monitors
070	Release of Equipment to Unrestricted Areas	300	Radiation Dose Calculations
100	Shipment of Yellowcake, Ore or Contaminated Equipment by Truck	301	Worker Exposure to Long-lived Radionuclides in Airborne Particulate Matter
110	Beta and/or Gamma Exposure Rate Surveys	302	Radionuclide Concentrations in Air Samples
120	Alpha and Beta-Gamma Contamination Surveys	303	Dose Calculation Spreadsheets
130	Occupational General Air Particulate Survey	310	Declared Pregnant Worker
140	Radon -222 Decay Product Surveys		

Workers exposed to large quantities of ore and/or milling products wear dosimeters ("TLD badges") which measure gamma exposure. Other protections to reduce radiation exposure include regular power washing of equipment and vehicles, monitoring (and if necessary controlling) the amount of time workers are in areas where they are potentially exposed to radiation, and implementation of good housekeeping and personal hygiene measures.

The yellowcake packaging area has its own heating, ventilating, and air conditioning ("HVAC") system, and two sets of doors (vestibules) remain closed at the exits to provide additional containment of air-borne particles. Only required operations personnel are allowed within the packaging area and they are required to wear appropriate PPE including air-purifying respirators, gloves, and coveralls.

Expected Radiation Doses to Workers from Normal Operations

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 and tailings dust, and radon progeny.

It is Energy Fuels policy to take all practical steps to ensure exposure to workers from radiation and/or radioactive materials will be maintained as low as reasonably achievable (ALARA). It is Energy Fuels objective to limit exposures of workers to ≤ 100 mrem / year above background. Although external exposure associated with uranium mills is typically expected to be low, the potential exists for internal exposure as a result of inhalation of airborne radioactivity in ore and tailings handling and yellowcake processing areas.

Engineering controls include process containments and HVAC systems; administrative processes include formal work control programs underpinned by rigorous radiological control procedures (see above). Comprehensive radiation safety training programs are designed to minimize risks of significant radiological exposure of workers at the mill. 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 and the CDPHE. 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)" and to institute corrective actions if necessary.

Office workers at the Administration building that do not routinely enter the restricted area of the mill will be exposed to relatively low levels of radiation. Table 4.3 shows the MILDOS AREA modeling results for the annual dose to workers in the Administration Building. The majority of these doses are the result of the inhalation of tailings dust. The estimates are conservative as the model assumes that a receptor is present 24 hours per day and 7 days per week (168 hours per week), while an office worker would normally be present on-site for 40 to 50 hours per week.

Table 4.3 Annual Doses to Workers Located in the Administration Buildings (mrem/yr)

TEDE	Effective (excluding radon)	Bone (excluding radon)	Lung (excluding radon)
4.81E+00	1.52E+00	1.61E+01	5.21E+00

Table 4.4 provides a summary of radiation doses received by uranium mill workers at the Cotter Corporation uranium mill near Canyon City, Colorado for the year 2005 (Cotter Corporation, Annual Report for the Year 2005). Employee doses were calculated for 167 employees during that calendar year. There were 47 employees who worked under 500 hours (average 237 hours), 31 employees who worked from 500 to 999 hours (average 704 hours) and 89 employees who worked 1,000 hours or more (average 2061 hours).

Table 4.4 Summary of Annual Radiation Doses to Workers at the Canyon City Uranium Mill for the Calendar Year 2005

Total Effective Dose Equivalent, mrem	<500 Hours	500 to 999 Hours	>999 Hours
Average	30	110	261
Standard Deviation	25	49	96
Median	30	107	247
Maximum	107	254	577

Health Canada presents in its *2007 Report on Occupational Radiation Exposures in Canada*, occupational radiological exposure data for the year 2005 from numerous industries and job categories in the Canadian nuclear industry. For the category "uranium mine mill workers", the report indicates in its Table 4 (Dose distribution by job category as of the end of 2005) that 87% of the workers in this category received < 200 mrem in 2005 (< 2mSv) and zero workers received > 500 mrem (> 5 mSv)

For workers at the White Mesa Mill, the average individual radiation dose was 110 mrem in 1999 (IUC 2003).

For the reasons described above, typical worker exposures at the Piñon Ridge mill from routine operations are expected to be a few hundred mrem/yr committed effective dose equivalent (CEDE) or less. The Piñon Ridge mill is designed with state-of-the-art controls and programs (i.e., containment and isolation of radioactive materials, HVAC systems, formal work control and training program, etc) to achieve ALARA exposure levels. Relative to typical natural radiation background in the region of the mill of 400 - 450 mrem / yr., no significant radiological risks and/or health related impacts to workers are expected from the routine operation of the Piñon Ridge uranium mill.

4.1.2 Transportation

Transportation of radioactive materials to and from the mill can be classified into two categories:

- Shipments of yellowcake from the mill to a uranium hexafluoride conversion facility;
- Shipments of ore from mines located in the Colorado Plateau to the mill.

The yellowcake products are packed in 55-gallon, 18-gauge drums holding an average of 900 lb of yellowcake. The yellowcake drums are classified by the Department of Transportation (DOT) as Type A packaging (10 CFR Part 71) and are capped with DOT-approved lid and clamping ring. The bulk ore is transported by haul trucks from the mine to the mill. The ore is covered with tarps to reduce dusting and spillage during transportation.

Yellowcake characteristics and the average ore grade (0.23% U_3O_8) were used to estimate the radiation dose to a forklift operator and a truck driver transporting the yellowcake and ore.

For this assessment, it was assumed that a truck driver is expected to make 15 deliveries per year from the mill site to a conversion facility. Two options were considered: Metropolis Illinois and Port Hope Ontario, Canada. Since the trip to Port Hope is longer, the conservative estimate of the dose to the driver, was based on the trip to Port Hope. The 26-ton truck contains approximately 60 drums (55 gallons each) of yellowcake. The estimated exposure time while driving or resting in the cabin is approximately 31 hours per delivery. In addition, the truck driver will perform a load inspection prior to departure and upon arrival at the destination; each inspection was assumed to take 30 minutes.

It was assumed that the forklift operator moves 60 drums from each truck. The conservative estimated exposure time for the forklift driver is 5 minutes per drum. It was conservatively assumed that one worker operates the forklift to move all the drums for each delivery for all 15 deliveries each year. Therefore, the exposure time is approximately 5 hours (300 minutes) per delivery and 75 hours per year (i.e., 5 hours per delivery x 15 deliveries per year).

The assumed exposure time for the truck driver transporting uranium ore was 3 hours per day and 200 days per year. Therefore, total exposure time was assumed to be 600 hours per year.

The dose assessment was performed using Microshield Version 8.02 (Grove Software 2009). The details of the calculations are provided in Appendix A3 and the summary of the results is shown in Table 4.5. Refer to Appendix A6 for printouts of the Microshield runs.

Table 4.5 Annual Effective Doses for Receptors during the Routine Transportation of Radioactive Materials

Receptor	Effective Dose (mrem/y)
Truck Driver - Transporting Yellowcake	46.7
Forklift Driver - Moving Drums Containing Yellowcake	7
Truck Driver – Transporting Ore	48

The MicroShield modeling of operator and driver radiation dose described above as well as the independent analysis performed for White Mesa Mill indicate that the transportation will have a minimal radiological impact on drivers and forklift operators. Doses are projected to be well below the annual public dose limit of 100 mrem/yr (6 CCR 1007-1, Part 4, 4.14). Relative to typical natural radiation background in the region of the mill of 400 - 450 mrem / yr., no significant radiological risks and/or health related impacts to workers are expected from the transportation of yellowcake and ore.

4.2 NON-RADIOLOGICAL IMPACTS FROM ROUTINE MILL OPERATION

4.2.1 Mill Operation

The modern state-of-the-art design of the Piñon Ridge mill (monitoring; containment and control of hazardous materials, dust and fume emissions; HVAC systems; process control; etc) combined with the implementation of the health and safety plan, extensive training program, availability of personal protection equipment, and compliance with Federal (e.g., MSHA, EPA) and Colorado (CDPHE, CDOPS) regulations will ensure that occupational health and safety limits are not exceeded and that a safe workplace is maintained at all times. Examples of applicable regulations and guidance that will be followed to ensure low risk of chemical exposures of workers include:

- 30 CFR Subpart C, Fire Prevention and Control;
- 30 CFR Subpart D, Air Quality and Physical Agents;
- 30 CFR Subpart O, Materials Storage and Handling;
- 30 CFR 56.20014, Prohibited Areas for Food and Beverages;
- Mine Improvement and *New Emergency Response Act* of 2006 (*MINER Act*);
- 40 CFR Part 68, Chemical Accident Prevention Provisions;
- 40 CFR Part 355, Emergency Planning and Notification;
- 40 CFR Part 302, Designation, Reportable Quantities, and Notification;
- 7 CCR 1101-5 Boiler and Pressure Vessel Regulations;
- 7 CCR 1101-14, Storage Tanks Regulations;
- 49 CFR Parts 130. 171, 172, 173, 177, and 178, Various DOT Regulations;

- 2 CCR 601-8, Traffic Regulations Governing the Use of the Tunnels on the State Highway System;
- 8 CCR 1507-25, Rules and Regulations Concerning the Permitting, Routing & Transportation of Hazardous and Nuclear Materials and the Intrastate Transportation of Agricultural Products in the State of Colorado;
- American Conference of Governmental Industrial Hygienists – Threshold Limit Values and Biological Exposure Indices.

For example, airborne concentrations of potentially hazardous materials to which workers could be exposed at the mill will be controlled to the Threshold Limit Values (TLV) as recommended in ACGIH 2009. Examples are provided in Table 4.6 below.

Table 4.6 Examples of Applicable ACGIH TLV Values

Substance	TLV (mg/m^3)
Ammonia	18
Sulfuric Acid	1
Sodium Hydroxide	2
Propane	Asphyxiant – maintain Oxygen content > 18 %
Hydrogen Peroxide	1.5
Kerosene	100 ppm

In addition to the workplace safety measures, uranium exposure of workers will also be monitored using a uranium-in-urine bioassay program, which monitors the levels of uranium in the human body. Uranium will be monitored in the mill using breathing-zone air samples that sample uranium in the air while workers conduct tasks potentially generating uranium dusts. Area air samplers will also be used to monitor uranium concentrations in specific work areas of the mill. In addition to uranium, concentrations of other heavy metals, ammonia, sodium hydroxide, and sulfuric acid will be controlled to comply with the Mine Safety and Health Administration (MSHA) regulations and the Threshold Limit Values (TLVs) recommended by the American Conference of Governmental Industrial Hygienists (ACGIH). Control of acid and caustics is important as these chemicals are corrosive and can cause burns upon contact with skin.

Based on the occupational health and safety measures and other control measures in place at the mill, it is expected that the worker exposure to elevated levels of non-radiological COPC is unlikely. In addition, the exposure to acid fumes and organic solvent vapors will also be reduced by process control measures (i.e., closed systems equipped with scrubbers or baghouses) implemented in the acid storage areas and the leach, CCD, and SX circuits. Therefore, no significant non-radiological risks and/or health related impacts to workers are expected from the routine operation of the mill.

4.2.2 Transportation

Hazardous material shipments will comply with U.S. Department of Transportation hazardous materials shipping regulations and requirements (49 CFR Parts 171, 172, 173, 177, 178, and 179). Most of the reagents are transported to the mill site in pre-packaged totes, barrels, and bulk bags. The bulk materials are typically transported by closed tanker trucks. Any bulk material transported in open trucks is covered with tarps to reduce dusting and spillage during transportation.

No significant dust or fume emissions are expected during routine shipment of the ore, chemical reagents and other hazardous materials. Therefore, no significant non-radiological risks and/or health related impacts to the driver are expected from the routine transportation of the reagents and hazardous materials.

5.0 IMPACTS TO PUBLIC AND OCCUPATIONAL HEALTH AND SAFETY FROM ACCIDENTS

The environmental effects of accidents involving the release of radioactive materials or hazardous chemicals that could occur at the mill site are described in this section.

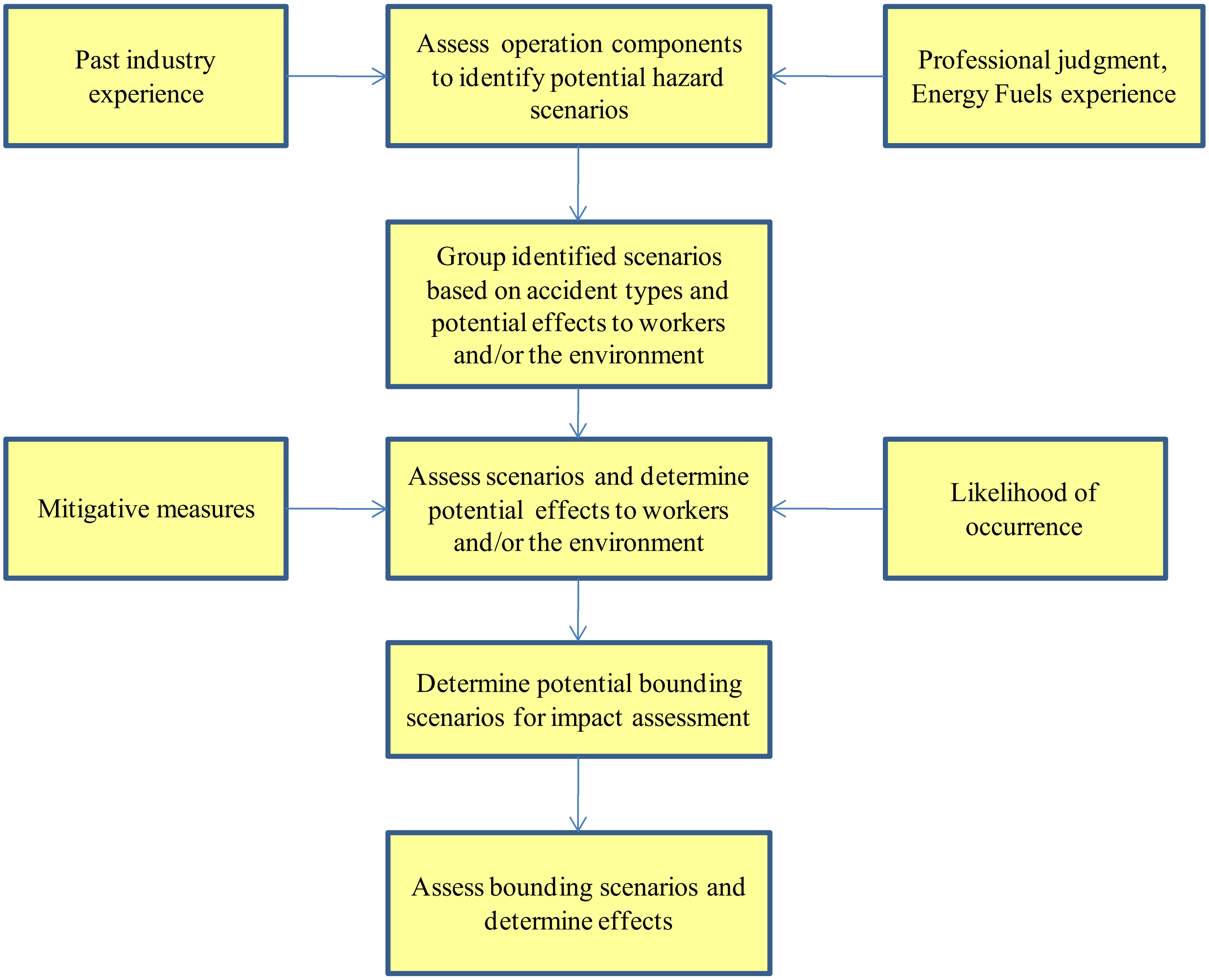
During over four decades of commercial nuclear facility operation in the US, the frequency and severity of accidents have been markedly lower than those in related industrial operations (construction, chemical and petrochemical, farming, manufacturing, etc). This can be attributed to the rigorous regulatory framework and well-developed plans and procedures for safe operation of nuclear facilities including uranium mining and milling operations. The experience gained from the few accidents that have occurred has resulted in improved engineered safety features and operating procedures, and the probability that similar accidents might occur in the future is considered low.

The radioactive materials handled at a uranium mill have relatively low specific activities (amount of radioactivity per unit mass, e.g., μCi/g). The low specific activities require the release of exceedingly large quantities of material in order to be of concern; driving forces (energy sources - initiating events for accidents) for such releases are generally lacking or extremely unlikely in the milling operation. In light of past experience, it is believed that even if major accidents did occur, radiation exposures would be too small to cause any measurable deleterious effect on the health of the human population. A well-trained workforce operating under rigorous emergency response procedures will minimize occupational impacts from occurrence of accidents and unplanned events.

5.1 METHODOLOGY FOR ACCIDENT RISK ASSESSMENT

A consistent methodology was applied to evaluate the potential accident scenarios for the facility operations. This methodology is shown in Figure 5.1 below.

Figure 5.1 Methodology for the Assessment of Malfunctions and Accidents



5.2 HAZARD IDENTIFICATION

The mill facility components and activities were reviewed to determine the potential accident scenarios. For this assessment, the process description provided in the Facility Operating Plan (Energy Fuels 2009e) was used to identify the specific major components of the mill facility. Professional judgment, industry experience, and particularly Energy Fuels' experience were used to identify the potential radiological and conventional (non-radiological) accident sequences that were determined to be credible.

It was determined that sources of hazards were attributed to the following:

- Radioactive materials;
- Flammable materials;

- Toxic / corrosive materials;
- Power outage / electrical.

The list of materials, stored, handled, or transported in the mill facility is provided in Section 1.2. Table 5.1 below lists the identified potential accidents for each process component and activity.

Table 5.1 Summary of the Identified Accident Scenarios

Component	Accident Scenarios
Construction	Conventional accidents and personnel injury due to typical project activities such as working at heights, working with heavy equipment, power tools, high voltage, etc Potential injuries include falls, trips, strains, electrocution, crushing, pinching, etc.
	Spill of construction materials, e.g. cement
	Spill of fuel from mobile and stationary storage during refueling and maintenance
	Spill of engine fluids on-site from heavy equipment
	Collapse of soil during excavation
Ore Handling and Grinding	Personnel injury due to working with heavy equipment
	Spill of wash water
	Failure of baghouse and dust release
	Failure of Venturi scrubber and dust release
	Spill of pulp from pulp storage tanks, piles, and pumps
Leaching and CCD Thickeners	Failure of Venturi scrubber and release of acidic fumes from pre-leach tanks, leach tanks, or CCD thickeners
	Failure of the tanks, pipes, and pumps and release of acidic leach solution
	Overflow of the tanks or thickeners and release of acidic leach solution
	Worker injuries due to contact with acid
Waste Disposal	Failure of the tailings pipes and pumps and release of tailings
	Failure of the raffinate pipes and pumps and release of raffinate and wastewater
	Failure of tailings embankment and release of tailings
Solvent Extraction	Failure of the, pipes, filters, and pumps and release of pregnant solution or raffinate
	Failure of the, pipes, filters, and pumps and release of kerosene and amine extractant
	Overflow of the tanks and release of pregnant solution
	Overflow of the tanks and release of kerosene and amine extractant
	Accidental release of caustic/sodium carbonate solution from tanks, pipes, and pumps
	Accidental release of sodium chlorate from tanks, pipes, and pumps
	Accidental release of ammonia from transfer line
	Fire involving organic solvents

Component	Accident Scenarios
Uranium Precipitation and Drying	Accidental release of hydrogen peroxide from tanks, pipes, and pumps
	Accidental release of uranium precipitate form pipes, filter, and process tanks
	Propane explosion in uranium dryer
	Failure of the air cleaning system (baghouse) and release of yellowcake dust
Vanadium Precipitation and Drying	Accidental release of ammonium sulfate from tanks, pipes, and pumps
	Accidental release of ammonia from transfer line
	Failure of wet scrubber and release of ammonia fumes
	Propane explosion in the kiln
	Propane explosion in the fusion furnace
	Failure of the air cleaning system (baghouse and scrubbers) and release of vanadium oxide dust
Chemical Storage	Spill of liquid chemicals during offloading of trucks
	Release of ammonia during transfer from truck to the storage tanks
	Overflow of storage tanks and chemical release
	Failure of pumps, pipes, valves and release of chemicals
	Release of solid chemicals during on-site transfer and handing
	Fire involving organic chemicals in the storage area
	Release of diesel or gasoline during off loading and refueling
	Fire involving fuels
External Events	Airplane crash and catastrophic failure of all containments
	Tornado and high wind and dispersion of contaminants from stockpiles
	Flood and dispersion of contaminants from stockpiles
	Earthquake
	Building fire
	Wildfire
Transportation Accidents	Transportation accident resulting in potential release of radioactive materials to the environment (surface)
	Transportation accident resulting in potential release of non-radioactive materials to the environment (stream)
	Transportation accident resulting in a fire and release to air
	Transportation accident and release of ammonia to air
Power and Emergency Generator	Electrical hazards; power outage and loss of control systems

5.2.1 Classification of Accidents

Identified accident scenarios were classified based on the type of the accidents and their potential health and environmental impacts. The grouping process reduced duplication between different process components. This was done in order to facilitate the identification of potential bounding scenarios for assessment of health, safety and/or environmental effects.

5.2.2 Identified Bounding Scenarios

A bounding accident scenario for each group was selected that encompasses the impact of all accident scenarios in each group. Following are the selected bounding case scenarios:

1. Conventional accidents and personnel injury due to typical project activities such as working at heights, working with heavy or processing equipment during construction or plant operation;
2. Spill of radioactive materials from storage tanks, transfer lines, valves, pumps, and other process equipment as well as during offloading;
3. Spill of non-radioactive materials and fuel from storage tanks, transfer lines, valves, pumps, and other process equipment as well as during offloading;
4. Failure of air cleaning systems and release of toxic fumes and/or radioactive dust;
5. Spill of tailings slurry from transfer line, pumps, or due to tailings cell embankment failure;
6. Fire involving flammable liquids in the storage area and SX circuit;
7. Propane explosion in boilers, kiln, dryer, and fusion furnace;
8. Airplane crash and catastrophic failure of all containments;
9. Tornado and high wind and dispersion of contaminants from stockpiles;
10. Flood and dispersion of contaminants from stockpiles;
11. Building fire or wildfire;
12. Transportation accident resulting in potential release of materials to the environment (streams);
13. Transportation accident resulting in a fire and release to air;
14. Transportation accident and release of ammonia to air.

5.3 METHODOLOGY FOR ASSESSMENT OF BOUNDING SCENARIOS

The risk of bounding scenarios was assessed qualitatively and/or semi-quantitatively, as applicable to the scenario, to determine the potential effect to mill workers, the public and/or the environment that would result from each type of accident. Risk may be defined as the multiplication of the frequency of occurrence and the severity of the consequence of a hazardous event:

*Risk = Frequency * Severity of the Impact*

A simple and effective way of mapping the risk for identified hazard scenarios is using a risk matrix such as that shown in Figure 5.2.

Figure 5.2 A Typical Risk Ranking Matrix

IMPACT RANKING	***Large***	*3*	**3**	**6**	**9**
	Moderate	*2*	**2**	**4**	**6**
	Small	*1*	**1**	**2**	**3**
			1	*2*	*3*
			Low	***Medium***	***High***
			FREQUENCY RANKING		

5.3.1 Likelihood Assessment

The frequency of the occurrence of any accident scenario is a combination of the frequency of the initiating events and the conditional probabilities of the hazard scenario occurring.

*Frequency of Hazard Scenario = Frequency of the Initiating Event * Conditional Probabilities*

The conditional probabilities are dependent on mill operating conditions. For example the frequency of a spill reaching the environment is the product of frequency of tank overflow (or a tank failure) and the conditional probability of failure of secondary containment during the original release (other features, as designed or natural, that minimize the probability that the spill can reach an unrestricted area). Provisions of secondary containment and comprehensive monitoring dramatically reduce the frequency of a spill reaching the environment.

5.3.2 Impact Analysis

The assessment of the impact of the identified bounding scenarios was consistent with the following sections of NUREG-1910 (NRC 2009) and NUREG-0706 (NRC 1980).

- Radiological Impacts to Public and Occupational Health and Safety from Accidents;
- Non-radiological Impacts to Public and Occupational Health and Safety from Accidents.

In the above documents, accident risk assessment included processes, storage, and transportation activities. The Nuclear Regulatory Commission (NRC) Generic Environmental Impact Statement for In Situ Leach Uranium Facilities (NUREG 1910) categorized the potential environmental impacts using significance levels. According to the Council on Environmental Quality, the significance of impacts is determined by examining both context and intensity. Context is related to the affected region, the affected interests, and the locality, while intensity refers to the severity of the impact, which is based on a number of considerations. NUREG 1910 used the significance levels identified in NUREG–1748 (NRC 2009). These significance levels are simply:

- SMALL Impact: The environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource considered.
- MODERATE Impact: The environmental effects are sufficient to alter noticeably, but not destabilize, important attributes of the resource considered.
- LARGE Impact: The environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource considered.

The assessment of impacts was consistent with the above classification.

5.4 ASSESSMENT OF BOUNDING SCENARIOS

Extensive health and safety procedures and training programs will be in place to minimize the occurrence of, and reduce the potential extent of, personnel injuries. Hazards to construction personnel and operators will be controlled or minimized through the implementation of MSHA and CDPHE compliance programs and through the use and implementation of appropriate personal protective equipment, signage, training, standard work procedures, and controlled access where applicable

In addition, to minimize the probability of personnel injuries from accidents, Energy Fuels has prepared the following plans, which will be implemented throughout the operating life of the Mill Facility.

- Health and Safety Plan: This plan is designed to inform mill personnel of the rules, procedures, and work practices that are in place to protect them from injury (Energy Fuels Resources Corporation, 2009a).
- Emergency Response Plan: This plan identifies possible emergency incidents that may occur and provides identification and response procedures for those incidents (Energy Fuels Resources Corporation, 2009b).
- Material Containment Plan: This plan identifies the hazardous materials on site, their location, quantities, use and hazardous characteristics. It also provides instructions for

containment and cleanup in the event of a spill or release (Energy Fuels Resources Corporation, 2009c).

- Spill Prevention Control and Countermeasure (SPCC) Plan: This plan identifies fuels, oils, and other petroleum products on site, their location, quantities, inspections, spill response, and spill reporting procedures (Energy Fuels Resources Corporation, 2009d).

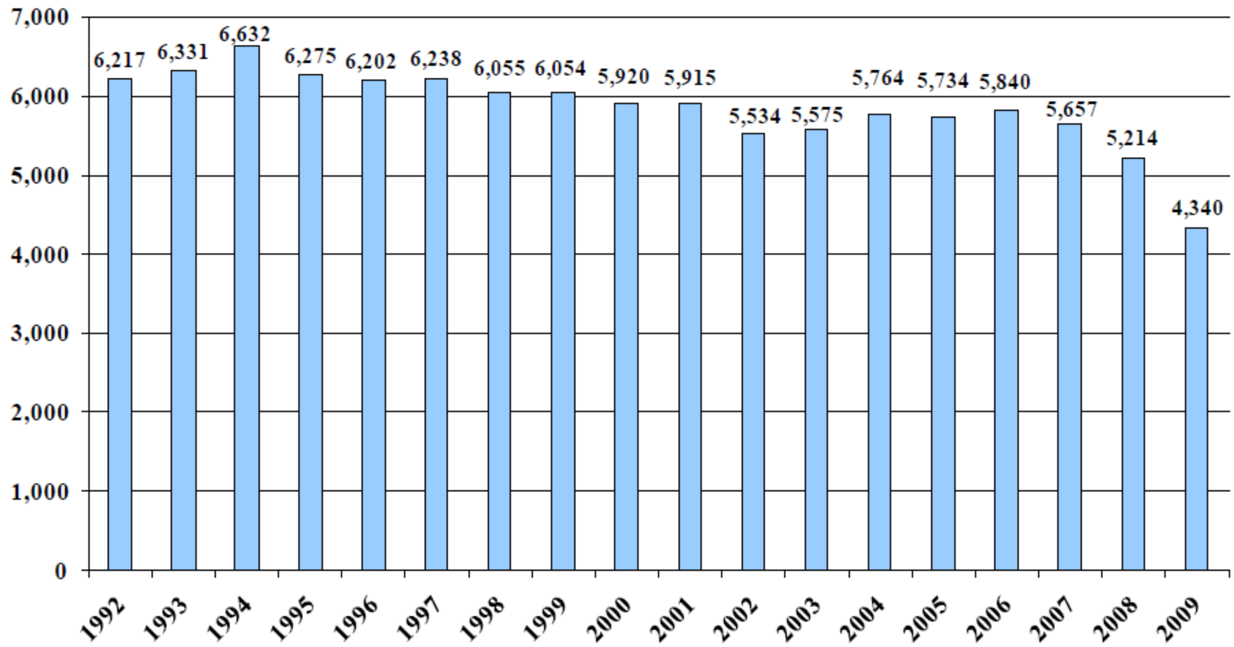
Due to the extensive preventive and mitigative measures established in these plans, the probability of accidents occurring and the potential impact associated with an accident will be reduced.

5.4.1 Conventional Accidents and Personnel Injury

The risks of events such as trips and falls, strains, electrocution, crushing, and pinching associated with project activities such as working at heights, working with heavy equipment both during construction and during routine operation of the plant will not be different from those on any other industrial project of similar scope and duration.

Occupational health and safety aspects of mining and milling operations are heavily regulated. In the past two decades the number of occupational fatalities and injuries in this sector shows a decreasing trend. In 2009, there were a total of 4,340 occupational fatal injuries in the United States. Among these fatalities, 651 were related to natural resources and mining operations. A total of 242 fatalities were due to falls and contact with objects and equipment. This is 6% of the total occupational fatalities (DOL 2010). In 2003, 297 fatalities were due to falls and contact with objects and equipment. The 2009 number shows a 20% decrease compared with the 2003 number in spite of growth in the sector. Figure 5.3 shows the number of occupational fatalities from 1992 to 2009.

Figure 5.3 Occupational Fatalities*



*Source: DOL 2010

Energy Fuels has prepared a comprehensive health and safety plan and emergency response plan and committed to full implementation of these plans and an extensive training program on their implementation. In addition, availability of personal protection equipment, and compliance with Federal (e.g., MSHA, EPA) and Colorado (CDPHE, CDOPS) regulations will ensure that occupational accidents are kept to a minimum.

5.4.2 Spill of Radioactive Materials

Uranium bearing solutions are stored in storage tanks, handled in process vessels, and transported through piping systems. A spill of these solutions could occur as a result of the following events:

- Overflow of storage or process vessels;
- Leaks or rupture in storage tanks and process vessels;
- Failure of valves or other piping system components;
- Failure of the pumps;
- Failure of other process components such as screens and filters.

The occupational and environmental impact of a radioactive material spill is bounded by the spill of yellowcake slurry. In a study by Mackin, *et al.* (2001), the failure of a yellowcake thickener and potential release of radionuclides to the atmosphere through a thickener failure was assessed.

For the purposes of the analysis, it was assumed that a tank failure or pipe break causes the yellowcake slurry to spill, with 20 percent of the thickener content being spilled inside and outside the building. Analysis was done for a variety of wind speeds, stability classes, release durations and receptor distances. For receptor distances of 100 and 500 m (330 and 1,600 ft) doses from such spills were calculated to be 0.25 and less than 0.01 mSv (25 and 1 mrem), respectively. Both of these are less than 25 percent of the CDPHE annual dose limit for the public of 100 mrem.

For the proposed mill, the distance of the mill process buildings from the property boundary and from the administration building is larger than 100 m, therefore no significant radiological risks and/or health related impacts to the office worker in the administration building and a member of the public are expected from a spill in the mill process buildings.

In the case of such a spill, doses to the unprotected worker could exceed the 0.05 Sv (5 rem) annual dose limit specified in the Colorado Radiation Control Regulations (6 CCR 1007-1, Part 4) if workers did not evacuate the area relatively quickly after the accident. It should be noted that in the above analysis, no expedited response or cleanup and no credit for personal protection equipment (e.g., respirators) was assumed. The analysis also used ICRP Class Y solubility ("insoluble") instead of more realistic class W or D solubility for uranyl peroxide that is produced today. This adds another layer of conservatism that resulted in potential overestimation of the occupational doses.

To minimize the likelihood and impact of spills, Energy Fuels has prepared the Materials Containment Plan and Emergency Response Plan, which will be implemented throughout the operating life of the Mill Facility. The mill facilities are designed to contain chemical reagents, fuels, and process streams by monitoring of instrumentation. Any spills or leaks will normally be detected by leak detection systems, loss of system pressure, observation, or flow imbalance. The potential for exposure of workers and effluent release to the environment in the event of an accident is further reduced by secondary containment throughout the mill.

Design features including the selection of the appropriate materials of construction in combination with regular inspections and maintenance will minimize the potential for leaks or failures in major process equipment and components important to safety. Secondary containment is provided for reagent storage, reagent offloading areas, processing buildings, and waste disposal areas so that any leaks or spillage from primary containment does not affect the surrounding environment (i.e., soils, surface water, and groundwater) nor become a source term for air borne release. Tanks and major process vessels are located on concrete floors and enclosed within concrete stem walls or curbs. Secondary containment volumes will be equal to or greater than the volume of the largest tank plus 10 percent. Process and reagent lines, which are not within a curbed secondary containment area, are placed inside an outer pipe sleeve, lined pipe rack, or lined trench. Collection basins and bermed areas are equipped with sumps and sump pumps so that any spilled material can be recovered quickly. Floor sumps in the mill are also equipped with secondary containment and leak detection monitoring between the primary and secondary containment walls.

The above measures will reduce the probability of spills occurring, minimize potential consequences to workers when they do occur, and reduce the probability of a spill reaching the environment. In the unlikely event of an uncontrolled spill, doses to the workers could have a moderate impact depending on the type of the spill, but doses to the general public and office workers would have only a small impact, if any at all.

5.4.3 Spill of Non-Radioactive Materials and Fuel

Similar to many other industrial operations, releases of large amounts of hazardous chemicals, which could adversely affect public and occupational health and safety, are possible. However, they are generally considered unlikely, given commonly applied safety practices, extensive comprehensive Federal and State regulations and the history of safe use of these chemicals, particularly at *Atomic Energy Act* licensed facilities. It should be noted however, that the storage and use of non-radioactive chemicals at the mill is not regulated by NRC or CDPHE, but rather by MSHA, CDOPS, and to a lesser extent, the EPA. The frequency of catastrophic failure of large storage tanks are in the order of 10^{-4} per year (i.e., once every 10,000 years), while the frequency for catastrophic failure of pressure vessels, such as an ammonia storage tank, is in the order of 10^{-5} per year or once every 100,000 years for any similar tank or pressure vessel (CCPS 1989).

These potentially high impact but very low probability events are not assessed in detail in this report based on the premise that the application of common safety practices (as articulated in the mill's Health and Safety, Material Containment, Emergency Response, and SPCC plans) for handling and use of chemicals and other preventive measures are expected to lower the likelihood and potential consequences of these release accidents and therefore lower the risk to very low levels. Additionally, and most importantly, risks (probability of occurrence and severity of impact) associated with this class of events are no different than at any similar industrial facility, independent of the radiological characteristics of a uranium mill. In fact, the risks would be expected to be less than at similar industrial facilities due to the rigorous work control and training programs required at US *Atomic Energy Act* licensed facilities.

Among hazardous materials stored and used on site, the consequence of accidents involving anhydrous ammonia could potentially bound the consequences of scenarios involving other hazardous chemicals. Catastrophic failure of an ammonia storage tank is a very unlikely scenario. However, in a more probable accident, it is possible that the line connected to the storage tank could be ruptured, in which case the release rate is assumed to be limited to 100 g/s (0.2 lb/s) of vapor. Based on this release rate and calculated dilution factor, the resulting maximum conservative concentration of ammonia at the distance of 4,000 m (13,200 ft) is estimated at approximately 8.5 mg/m^3 over the entire period of release (see Appendix A4 for details of the dilution factor). This concentration is less than the American Conference of Government Industrial Hygienists Short Term Exposure Limit (STEL) of 27 mg/m^3 (ACGIH, 2009). Thus, the ammonia release at this rate would pose no substantial health risk to the public. It is expected that upon any release of ammonia, workers would evacuate the scene of the accident immediately. However, if they did not evacuate the area quickly, an unprotected worker could be exposed to higher ammonia concentrations for a short period of time. The Emergency Response Plan (Energy Fuels Resources Corporation, 2009b) would be implemented to mitigate the impact.

Strong bases such as ammonia (NH_3) and sodium hydroxide (NaOH) and strong acids such as sulfuric acid (H_2SO_4) will strongly react with each other, and with water, if accidentally mixed. Therefore, their storage tanks are located in separate secondary containment areas. In addition, precautions are taken to ensure that these chemicals do not inadvertently come into contact with each other during operations.

A spill of toxic or corrosive chemicals, such as sulfuric acid, inside the mill processing areas would pose no significant impact to the public; however, workers in close vicinity of the spill may come into contact with such chemicals. The application of common safety practices and associated safety training for handling and use of chemicals is expected to lower the likelihood of large release events and therefore lower the risk to acceptable levels.

In addition to the preventive and mitigative measures described elsewhere, trucks delivering ammonia park within a concrete apron that is curbed and drains to the storage tank containment area and storage tanks are located within a reinforced concrete containment structure which also protects it from vehicular traffic. Diesel and gasoline are also stored on-site in double walled storage tanks situated within a common concrete containment, with a floor sump and protective aprons to collect spillage during fueling activities. Employees and contractors will be trained in the proper handling, transfer, storage and use of fuels.

The operation of the mill in accordance with a formal work control program is expected to maximize compliance with applicable regulations, protect workers and the environment and minimize the potential for accidents. Overall, the offsite impacts of credible accidents involving hazardous chemicals would be small, while impacts to workers could be moderate. However, these are mitigated by formal and rigorous training requirements and operational and emergency response procedures as described above.

5.4.4 Failure of Air Cleaning Systems

In order to control the emission of dust and toxic fumes, baghouses and wet scrubbers will be used throughout the mill facility. Baghouses are located at the feed hopper, dry (i.e., solid) reagent tanks and bins, and at the yellowcake and vanadium oxide packaging areas. Scrubbers are located at all other process emission points including the emissions from the baghouses in the two packaging areas.

In case of failure of air cleaning systems, the off gases from the mill would be released to the atmosphere for a short period of time, before the process could safely be shut down (telemetered systems provide early indication to operators in the control room and other locations within the plant). The off-gases from the mill uranium drying operation typically carry entrained solid particles of yellowcake with a rate of 1,400 g/hr (3.1 lb/hr). If the baghouse and scrubber fail, some of this material could be released to the environment. The leach and preleach circuits, which share a common H_2SO_4 scrubber, are interlocked with the scrubber so that if the scrubber fails, the leach circuits will automatically shut down in a controlled manner.

An analysis of unmitigated release of yellowcake dust (for eight hours) from a uranium dryer conservatively estimated that an individual at the distance of 2,000 m (6,500 ft) would receive a 50-year dose commitment to the lung of approximately 86 mrem (NRC 1980, NUREG 0706). There are no residents living within this distance of the mill. The analysis may have also used class Y solubility ("insoluble") for the U_3O_8 product of older mills instead of more realistic class W or D solubility for the uranyl peroxide (UO_4) that will be produced by modern low temperature vacuum dryers. This may result in an overestimate of the dose using the NUREG 0706 analysis.

Although quantitative data are unavailable, catastrophic baghouse and scrubber failure, which would go un-noticed for eight hours, is highly unlikely due to control room alarms and the severe pressure drop that would be identified by operators. Progressive failure, in which case the plugging of vents causes backpressure, would be readily detectable during operational checks and would probably produce inefficiencies, rather than complete failure.

In addition, the uranium drying circuit including operation of the dryer and its off-gas treatment system is frequently checked (twice per shift) as a part of the formal plant procedures. A drop in pressure would indicate failure of either the baghouse or the scrubber, in which case drying and packaging operations would be terminated until the baghouse and scrubber were repaired and returned to service.

In the very unlikely event of an unmitigated release of uranium dust, doses to the general public would have only a small impact because of the relatively large distance to the nearest downwind resident (3 miles or about 15,800 feet).

5.4.5 Spill of Tailings Slurry

Accidental release of the tailings slurry to the environment might result from the following events:

- rupture in the tailings piping;
- overflow of the tailings slurry from the cells;
- failure of the tailings embankment caused by an earthquake, flood-water breaching, or structural failure.

The tailings discharge pipes are installed within a lined trench that has vehicle crossings where the trench intersects secondary roads.

The storm water ponds, drainage diversions, ditches and culverts are designed for the 100-year, 24-hour storm volume and peak discharge. The ponds are designed to retain (with no discharge) the 100-year, 24-hour storm volume and include emergency overflow outlets, consisting of a pipe network, sized to convey the peak discharge from a 1,000-year storm event to the evaporation ponds for containment. The evaporation ponds and tailings cells are designed and operated with adequate capacity to contain runoff from the 1,000-year storm event.

Failure of a tailings embankment because of an earthquake would be unlikely since the site is in a zone of low to moderate seismicity (Kirkham and Rogers, 1981) based on the number of sizable earthquakes that have occurred in the historical and more recent record. The largest known natural earthquake in the vicinity of the site was magnitude 5.5 in 1960 earthquake near Ridgway, about 60 km southwest of the site (Sheehan *et al,* 2003: Blume and Sheehan, 2003). Several earthquakes of magnitude 4 or higher have occurred in this region with the most recent one being a magnitude 4.1 on November 7, 2004, located west of Montrose.

The proposed tailings cells are mostly incised with an average depth of about 80 feet and an average embankment height above ground level of about 20 feet. Internal slopes are 3 horizontal to 1 vertical (3H:1V) while external slopes range from 5H:1V to 10H:1V. The three tailings cells were designed in accordance with the International Building Code (IBC) based on a Magnitude 4.8 earthquake occurring at a distance of approximately 10 miles from the site. Minimum static and pseudo-static factors of safety ranged from 2.0 to 4.9 and 1.7 to 2.7, respectively, during the life of the cells, with the highest factors of safety occurring during the post-closure period (Golder, 2008).

From the above discussion, it appears that the probability of catastrophic failure of the tailings embankment is very small. However, sufficient data are not available to estimate the small probability of the occurrence of a natural disaster that could result in a release of tailings slurry to the environment. Tailings slurry releases have occurred in the past and the consequences associated with these events have been documented. The design of the Piñon Ridge Mill embankment retention system will conform to NRC Regulatory Guide 3.11 for new mills (NRC 2008). Table 5.2 contains a summary of recorded incidents in the period 1954 through 1994[1]. It is interesting to note that almost all of the failures were due to poor construction, poor operating practices, and/or flooding. Only one embankment failure was related to an earthquake event.

Table 5.2 Chronology of Uranium Tailings Dam Failures (Source: Wise-Uranium Website)

Date	Location	Parent company	Type of Incident	Release	Impacts
1994	Zirovski vrh, Slovenia	Rudnik Zirovski vrh, Gorenja vas	ongoing slippage of the slope (7 million t) with the "Borst" tailings deposit (600,000 t) on the top, at velocity of 0.3 m per year	-	-
1994, Feb. 14	Olympic Dam, Roxby Downs, South Australia	WMC Ltd.	leakage of tailings dam during 2 years or more	release of up to 5 million m^3 of contaminated water into subsoil	-
1985	Lengenfeld, Vogtland, Germany	Wismut	localized dam failure	-	minor
1984, Jan. 5	Key Lake, Saskatchewan, Canada	Cameco (67%), Uranerz (33%)	overtopping of process water reservoir, due to poor management	87,330 m^3 of contaminated water	-
1979, Jul. 16	Church Rock, New Mexico, USA	United Nuclear	dam wall breach, due to differential foundation settlement	370,000 m^3 of radioactive water, 1,000 tonnes of contaminated sediment	Contamination of Rio Puerco sediments up to 110 km downstream
1979, Mar. 1	Union Carbide, Uravan, Colorado, USA	Union Carbide	two slope slides, due to snow smelt and internal seepage	-	-

1 http://www.wise-uranium.org/mdafu.html

Date	Location	Parent company	Type of Incident	Release	Impacts
1977, Apr.	Western Nuclear, Jeffrey City, Wyoming, USA	Western Nuclear	Tailings slurry overtopped the embankment because of insufficient freeboard space, considerably less slope than the requisite 3 horizontal to 1 vertical, and a loss in structural integrity caused by the melting of snow interpersed with the fill used to construct the embankment.	40 m^3 of tailings and 8,700 m^3 of liquid	"no offsite contamination"
1977, Feb. 1	Homestake, Milan, New Mexico, USA	Homestake Mining Company	dam failure, due to rupture of plugged (frozen) slurry pipeline	30,000 m^3 of tailings and 7,600 - 30,000 m^3 of liquid	no impacts outside the mine site
1976, Apr. 1	Kerr-McGee, Churchrock, New Mexico, USA	Kerr-McGee	dam failure, due to differential settlement of foundation soils	"minor quantity"	-
1971, Mar. 23	Western Nuclear, Jeffrey City, Wyoming, USA	Western Nuclear	dam failure, due to break in tailings discharge line	-	"no offsite contamination occured"
1971, Feb. 16,	Petrotomics, Shirley Basin, Wyoming, USA	Petrotomics	secondary tailing dike failure	7.6 m^3 of liquid	liquid lost to unrestricted area
1967, Jul. 2	Climax, Grand Junction, Colorado, USA	?	tailing dike failure of unapproved retention system	1,200 - 12,000 m^3 of waste liquid	effluent release into Colorado river
1967, Feb. 6	Atlas Corp., Moab, Utah, USA		auxiliary decant failure, overflow from main tailings pond overflowed aux. decant system	1700 m3	
1963, Jun. 16	Utah Construction, Riverton, Wyoming, USA	-	The dam was intentionally breached and a 2-ft depth of effluent was released to prevent uncontrolled release of the impoundment contents during heavy rain		-
1962, Jun. 11	Mines Development, Edgemont, South Dakota, USA	-	dam failure, due to unreported causes	100 m^3	tailings released reached a creek and some were carried 25 miles to a reservoir downstream
1961, Dec. 6	Union Carbide, Maybell, Colorado, USA	Union Carbide	dam failure from unreported causes	280 m^3	effluent released did not reach any stream

Date	Location	Parent company	Type of Incident	Release	Impacts
1960	Gunnar mine, Beaverlodge area, Saskatchewan, Canada	Gunnar Mines Ltd.	dam failure	-	tailings release into Lake Athabasca, creating Langley Bay tailings delta
1959, Aug. 19	Union Carbide, Green River, Utah, USA	Union Carbide	dam failure during flash flood	8,400 m^3	tailings and effluent reach a creek and river
1958, Apr.	Mayluu-Suu tailing #7, Kyrgyzstan		dam failure after earthquake and heavy rain	600,000 m^3	a lot of houses in the town destroyed, people were killed, and the tailings were spread over 40 km down by the river, contaminating flood plains (UNEP/GRID-Arendal)
1954	Lengenfeld, Vogtland, Germany	Wismut	dam failure during flooding event	50,000 m^3	tailings spread 4 km down by the river, create wetland by damming up

From these historical data, the average releases from tailings embankment failure or flooding were approximately 5.5 x 10^7 L (1.4 x 10^7 gallons) of liquids and 1.4 x 10^7 kg (3.2 x 10^7 lb) of solids (NRC 1980). The extent of the area covered would depend upon the specifics of the failure and the terrain and is difficult to calculate here. Scaling from previous estimates on the basis of the total mass of tailings released, the material may be assumed to follow the tributary stream channel for a distance of approximately 2,100 m (6,800 ft), covering a width of approximately 130 m (425 ft), and forming a wedge 3 cm (1-1/4 inches) in average thickness (NRC 1980). However, the maximum release from one of the Piñon Ridge Tailings Cells, would be approximately two orders of magnitude smaller in volume due to the limited areal extent of the cells (i.e., 30 acres) and the relatively small height of the embankments above surface grade (i.e., 20 feet). The extent of area covered would, accordingly be only one percent of that calculated for the historic releases. It is also reasonable to assume that none of these historical events described above involved tailings embankments and impoundments designed per US NRC Regulatory Guide 3.11.

The main radiological concern associated with the deposition of the tailings material is the increase in background radiation levels in the affected and adjacent areas and the eventual transport of these low levels of contamination by wind and rain. These long-term effects would be prevented by removing the contaminated material from the environment via expedient response and clean up actions.

5.4.6 Fire Involving Flammable Liquids

Apart from conventional impacts (e.g. burns and related injuries) to workers, the most significant impact from a fire in the solvent extraction circuit could potentially result in the release of airborne radionuclides.

NRC reported that the frequency of a major solvent extraction fire occurring at a uranium mill was in the range of 4×10^{-4} to 1×10^{-2} per year (NRC 1980). It is expected that the frequency of a large fire would be much smaller in a new mill due to provisions for fire safety and accident prevention. The NRC assessment projected that the maximum individual 50-year dose commitments to the public at 500 m (1,600 ft) and 2,000 m (6,500 ft) resulting from a fire would be approximately 1.36 rem and 0.15 rem to the lung and bone, respectively. This is an extremely conservative estimate, as it was based on dispersion of 1% of the total uranium inventory. In the case of such an unmitigated fire, doses to the unprotected worker could be higher if workers did not evacuate the area quickly after the accident. With consideration of the low likelihood of a large fire resulting in release of radioactive materials, the risk to a member of the public would be small while the risk to a mill worker would be moderate.

In order to reduce the risk, the SX Building is equipped with smoke and heat detectors that activate sprinkler systems and all buildings have fire extinguishers in accordance with building codes and county requirements. Any work task that could potentially generate a spark (e.g., welding, cutting with a torch) requires a Radiation Work Permit with strict controls and monitoring. Additionally, explosion-proof equipment and instrumentation is utilized in accordance with electrical code requirements.

A firewater loop, with hydrants at key locations serves as one component of the overall fire protection system. A large portion of the raw water storage tank is dedicated to fire protection. The tank feeds the firewater loop and the electric water pumps are equipped with a backup diesel generator in the event of power loss. Hose reels are also situated in the various buildings in close proximity to the fire hydrants so that fire hoses can be quickly attached to the hydrants and pulled to the location of a fire, if one were to occur.

During the mill fire assessment and design of fire suppression systems, a water mist system with linear heat detection was recommended based on the preliminary design of the solvent extraction building and associated equipment. The components of the fire suppression and detection systems will be re-evaluated during final design. Fire suppression may include one or more of the following systems: water mist system, deluge foam system, and open-head water sprays.

5.4.7 Propane Explosion

The off-gas from the uranium dryer is vented to the yellowcake packaging room through a baghouse and a wet scrubber. An explosion in the dryer or the fuel piping could blow off the ductwork associated with the ventilation system and disperse yellowcake into the room and then into the atmosphere.

The consequences of explosion accidents are limited by the concentration of yellowcake dust that can be maintained in the air. NRC provided an estimate of the public dose due to an explosion in a uranium dryer based on an estimate of 100 mg/m^3 of yellowcake dust in the room's air (NRC 1980). For a room with a volume on approximately 1,000 m^3 (35,000 ft^3), the quantity of yellowcake released to the room air was estimated to be approximately 10,000 g (22 lb). This estimate was based on the conservative assumption that all of the material would be swept out into the environment when the room is ventilated. It was estimated that if 100% of the insoluble particles were in the respirable size range, individuals at the distance of 2,000 m (6500 ft) would receive 50-year dose commitments to the lung approximately 69 mrem. Therefore, the potential impact to a member of the public for this accident would be small, especially since the nearest downwind resident is about 3 miles (15,800 feet) away.

In the case of such an explosion, doses to the unprotected worker could exceed the 0.05 Sv (5 rem) annual dose limit specified in CDPHE regulations if workers did not evacuate the area quickly after the accident. In order to reduce the risk, only required operations personnel are allowed within the packaging area and they are required to wear appropriate PPE including air-purifying respirators, gloves, and coveralls. A viewing area is provided above the packaging area for guests and non-operations personnel. The packaging area is routinely washed down to prevent the accumulation of dust on the surface of equipment and walls. Given the provisions of PPE, the occupational radiological impact during an explosion is expected to be low.

5.4.8 Airplane Crash

Based on a study conducted by Lawrence Livermore National Laboratory (Kimura et. al. 1996), the likelihood of an aircraft crash at sites at locations similar to the proposed mill site is less than 1×10^{-7} per year (i.e., once every 10,000,000 years). This likelihood is dominated by general aviation crashes typically involving small non-commercial, non-military aircraft. The likelihood of a crash by commercial or military aircraft at the PHCF is much less than 1×10^{-7} per year. Because of the low likelihood (essentially "incredible") of this occurring, airplane crash events are not expected to cause significant risk to workers and members of the public.

5.4.9 Tornado and High Wind

An assessment of impact of release of radioactive materials due to tornado was reported by NRC (NRC 1980). Based on a conservative assumption that the tornado lifts about 11,400 kg (25,100 lb) of yellowcake, the maximum exposure occurs at a distance of approximately 4 km (2.5 miles) from the mill, the 50-year dose commitment to the lungs of an individual was estimated to be 8.3 x 10^{-7} rem. For individuals at the fence line 500 m (1600 ft) the 50-year dose commitments were estimated to be 2.2 x 10^{-7} rem.

Between 1950 and 1995, there have been 1,160 tornados in Colorado with various strengths (26 tornados per year)[2]. Given that the area of Colorado is 104,100 square miles, the frequency of tornados will be 2.5×10^{-4} tornados per year per square mile. Assuming that the mill building footprint is approximately 0.25 square miles, the frequency of a tornado striking the mill process buildings is approximately 6×10^{-5} per year. This is a highly conservative estimate since the vast majority of tornadoes occur in eastern Colorado.

With low frequency of occurrence and low impact, the risk of a tornado striking the mill and impacting a member of the general public is judged to be low.

High winds were considered in the meteorological data used in the MILDOS analysis (Little 2010). An event of a magnitude greater than the Design Basis Wind (DBW) would be considered a very low probability event and effects would be mitigated by implementation of the Emergency Response Plan.

5.4.10 Flood

The mill is located on an elevated pad and the stormwater ponds, drainage diversions, ditches and culverts are designed for the 100-year, 24-hour storm volume and peak discharge. The ponds are designed to retain (with no discharge) the 100-year, 24-hour storm volume and include emergency overflow outlets, consisting of a pipe network, sized to convey the peak discharge from a 1,000-year storm event to the evaporation ponds for containment. The evaporation ponds and tailings cells are designed and operated with adequate capacity to contain runoff from the 1,000-year storm event. No significant impact on the members of the public is expected from flood events and therefore the risk is considered low.

5.4.11 Building Fire or Wildfire

Given the fire prevention and control systems and measures previously described, a building fire with the intensity capable of starting a major fire in the solvent extraction circuit is unlikely. The

[2] http://www.disastercenter.com/colorado/tornado.htmlColorado Tornados

impact of such a fire would be similar to the accident scenario discussed in Section 4.4.7. Although smaller fires might be expected on a more frequent basis, they would likely be controlled with no major impact off site.

In order to reduce the probability of a large building fire, a firewater loop, with hydrants at key locations are designed as one component of the overall fire protection system. Hose reels in close proximity to each hydrant provide mill workers with the means for suppressing fires should one occur. The raw water storage tank, which provides dedicated storage for fire protection, feeds the firewater loop. Non-process buildings and the SX Building are equipped with sprinkler systems and all buildings have fire extinguishers in accordance with building codes and county requirements. See the additional discussion on fire suppression systems in section 5.4.6.

A wildfire could also occur in the vicinity of the mill and potentially jeopardize storage areas and buildings. However, the mill is located in an open area with constructed fire breaks (i.e., graveled roads, parking areas, and storage areas) that can be readily accessed in the event of a wildfire by the local fire departments. The mill Emergency Response Plan would also be implemented with fire suppression and earthmoving equipment mobilized by mill personnel to assist in the firefighting effort.

5.4.12 Transportation Accident and Materials Release

Transportation of materials to and from the mill can be classified into four categories:

- Shipments of yellowcake from the mill to a uranium hexafluoride conversion facility in Metropolis, Illinois;
- Shipments of V_2O_5 from the mill;
- Shipments of ore from the mines located in the Colorado Plateau region to the mill;
- Transportation of reagents to the mill by suppliers.

Three credible accident scenarios were assessed in this study. They are:

- Scenario 1: Collision of two vehicles (Crash);
- Scenario 2: Roll over into a ditch or down an embankment;
- Scenario 3: Roll over directly into a river (considered the worst-case environmental accident).

To assess the probabilities and potential consequences associated with these scenarios, a spill into a river was considered the worst-case environmental event. However, any spill could result in a partial release to the atmosphere. It was also assumed that the impact of a yellowcake spill would bound the impact of other spills, although due to the higher frequency of ore shipments, this could also be a source of concern.

Under most circumstances, a spill onto land would be easily contained, which would allow essentially complete recovery of spilled material by the emergency response team. The consequences of a transportation incident, however, if it were to occur in a populated area, could have significant impacts. Given the precautions taken with such materials, the likelihood of an incident in a populated area is considered low and therefore the overall risk of a high consequence accident is considered small.

Based on the DOT hazardous material transportation accident statistics, the transportation route length between the mill and Port Hope conversion facility in Ontario, Canada, and the number of annual shipments, the frequencies of transportation accidents (i.e. rollover and crash) involving yellowcake and ore were calculated at $1.1x10^{-3}$ and $1.7x10^{-2}$ per year, respectively (see Appendix A5 for details).

A prior transportation analysis (NRC, 1980) estimated risks of transporting yellowcake 2,414 km (1,500 mi) to a conversion plant in Illinois. Yellowcake release during a potential traffic accident was calculated considering the degree of loss of package containment for a range of accident severities and information on the likelihood that an accident of a particular severity class would occur when an accident happens. Two models for package response to accident conditions were considered. Model 1 assumed complete loss of package contents for any accident severe enough to breach packages, whereas Model 2 used results from package tests indicating only partial release of contents for accidents sufficient to breach packages. The resulting population dose estimates for these estimated releases from a single accident in an area containing 61 people per km^2 (158 people per mi^2) (i.e., rural residential population living on a given area of land) were 200 person-rem (2 person-Sv) for Model 1 and 14 person-rem (0.14 person-Sv) for Model 2 (NRC, 1980).

An analysis of the dose to the public by NRC, as a result of accidental release of ore during shipping, indicated that the maximum individual 50-year lung dose commitment of 0.014 rem at 2000 m (6500 ft) from the release location (NRC 1980). This would be approximately equivalent to an effective ("whole body") dose of approximately 1.75 mrem compared to a natural background dose over 50 years of 400 mrem / year X 50 years = 20,000 mrem.

An analysis was also performed by the US Department of Energy (DOE 2007) of a severe transportation accident involving uranium ore. For this conservative analysis, the maximally exposed individual was assumed to be located about 33 ft from the site of the accident which was assumed to be the closest and individual (resident) could be to the haul route. It was estimated this individual would receive a radiation dose of 4.9 mrem.

Previously reported accidents involving yellowcake release indicate up to 30 percent of the shipment contents were released (Mackin, *et al*., 2001; Grella, 1983), which is less than the fraction used in the previously mentioned calculations. In all cases reviewed, spills from accidents have been contained and cleaned up quickly (by the shipper with state involvement) without significant health or safety impacts to workers or the public.

As a result of the low probability and the small consequences, the risk of this scenario of yellowcake and ore transportation accidents to members of the public would be small.

A spill of yellowcake or ore into water would potentially pose a severe localized impact on the aquatic environment, as part of the released load could be washed away by the stream from the accident site. The frequencies of rollover and crash at water crossings is calculated at 5.8×10^{-6} per year (once every 180,000 years) and 8.3×10^{-5} per year (once every 12,000 years) for yellowcake and ore shipments, respectively (see Appendix A5 for details).

In a study conducted by SENES Consultants Limited (SENES 2009), the impact of a spill of uranium ore slurry and solid mineralized waste into a river in the province of Saskatchewan in Canada was assessed. Although it is recognized that uranium ore from this region of Saskatchewan would be expected to be of higher grade and different chemical composition than ore from the Uravan mineral belt of the Colorado plateau, the physical characteristics of this material related to mobility/transportability in the environment are considered similar and relevant. The assessment showed that even if it was assumed that 100% of the contents of an ore container are washed into the river, the effect on metal and radionuclide concentrations in the surface water would dissipate quickly. The predicted contaminant concentrations in the river were shown to fall below both the Saskatchewan Surface Water Quality Objectives and the Canadian Drinking Water Quality Guidelines within a short distance downstream of the spill location. However, short-term effects within the areas affected by the spill are expected. The assessment considered As, V, Cu, Pb, Cd, Co, Cr, Mo, Se, U, ^{226}Ra, ^{230}Th, ^{210}Pb, ^{210}Po in the ore slurry solids and liquids as well as in the mineralized waste. The relevance of the SENES analysis described above for the Piñon Ridge risk assessment includes:

- The ore slurry assumed in the Saskatchewan case is much more mobile compared with ore and yellow cake. The slurry could be easily dispersed and the soluble components in the liquid phase are dispersed in water rapidly.
- Physical circumstances surrounding the accidental release of mineralized waste is similar to the accidental release of ore.
- It is expected that the concentration of uranium in the mineralized waste is lower than the concentration in the ore.
- Given the high specific gravity of the ore slurry solids, it was predicted that greater than 80% of the solids would settle to the riverbed within 8 to 13 m of the accident site.

However, given the solubility of the uranyl form of yellowcake, a longer stretch of the stream may be affected by elevated water concentrations.

It is expected that the majority of the ore solids in the section of the river next to an accident site would be recovered during the cleanup operation under the direction of local and State authorities. Assessment of the potential effects on sediment contaminant concentrations after clean up in the Saskatchewan study indicated that there could be a measurable increase in some contaminants. The potential long-term effect on benthic invertebrates and other aquatic and terrestrial biota however, was predicted to be within accepted guidelines. In summary, given the very low probability of accidents involving spills to water, expectation of expedient and comprehensive clean up actions and low to moderate impacts, the risks were predicted to be small.

The US Department of Energy in DOE 2007 considered a transportation accident in which uranium ore spilled into a surface water source. DOE also concluded that it is unlikely that any adverse impacts to biota would occur because of the relatively low toxicity and low concentrations of the potentially hazardous constituents of uranium ore. If the ore were spilled into a shallow surface water source, it would be removed before water quality could be adversely affected. Most ore would be in large enough sizes (e.g., cobbles) that it would be recovered easily from the water source. The finer particles would be dispersed by stream flow and would not create a radiological hazard to aquatic life. The DOE concluded that the primary impact to water quality from a spill would be a short-term increase in turbidity and total suspended solids.

In order to further reduce the risk of spills, the trucking companies transporting ore, chemical reagents and fuel to the mill facility and yellowcake and vanadium oxide from the mill facility to other processing facilities are required under DOT regulations to have an emergency response plan in place for responding to accidents and cargo spills. As part of its contracting program, Energy Fuels will verify that these plans are in place and offer the support of its emergency response teams to carriers of ore, yellowcake and other hazardous material shipments in their emergency management planning. The Energy Fuels response teams will have expertise in radiation control and the necessary specialized monitoring equipment that is generally not available to most law enforcement agencies, fire departments, and other first responders. The Energy Fuels response team would also conduct sampling and analysis after the cleanup of any incidents involving radioactive material to verify that the cleanup was thorough and met regulatory requirements.

Licensed haulers deliver ore and reagents to the site, and transport yellowcake and vanadium oxide from the site in semi-trailer and tanker trucks using approved USDOT containers, with the majority of deliveries occurring during daylight hours. All the packages will meet specifications of 49 CFR Part 173. The reagents will be stored on site in pre-packaged totes, barrels, and bulk bags within weatherproof buildings and/or in closed bulk storage tanks. Containers will be properly labeled with both the name of the product and safety placards that meet the requirements outlined in the USDOT Emergency Response Guidebook (ERG 2008). Containers will be chemically and physically compatible with the media stored and meet applicable local, state and federal storage regulations, including secondary containment. The additional safety controls for radioactive materials in transport in 10 CFR Part 71 and compliance with both DOT and NRC transportation regulations add confidence that reagents, ore and yellowcake can be shipped safely with a low risk of affecting the environment.

Railroad crossings were also considered as areas of interest with respect to train-truck collisions. While the number of railroad grade crossing fatalities, injuries, and crashes are small in comparison to others, these incidents have the potential of greater consequences (DOT 2010 http://safety.fhwa.dot.gov/xings/xing_facts.cfm).

- As of December 2009, the United States had 136,041 public at-grade crossings. Of these crossings, approximately 42,301 have gates, 22,039 have flashing lights, and 1,196 have highway traffic signals, wigwags, and bells.
- In 2009, there were 1,896 incidents at public highway-rail crossings in the United States that resulted in 247 deaths, and 705 injuries. Only 11 accidents involved trucks.
- In 2009, 431 people were killed and 343 were injured while trespassing on railroad rights-of-way and property.

This statistics suggest the rate of truck-train accidents is about 8×10^{-5} per year. This frequency is one order of magnitude less than the frequency of crash and rollover on roads (1.1×10^{-3} per year).

5.4.13 Transportation Accident Fire

Data published by the U.S. Department of Transportation indicates that fires occurred in less than 0.5% of large truck crashes (U.S. DOT 2006). Given the frequency of traffic accidents involving yellowcake of 7.9×10^{-4} per year (see Section 5.4.12) and a conservative conditional probability of 0.005 for fire-related accidents, the frequency of a traffic accident involving fire would be 3.9×10^{-6} per year. Additionally, the probability of such fire spreading to the cargo and resulting in the dispersal of a considerable amount of yellow cake is very unlikely. The impact of such a low probability accident would be potentially moderate to high, but these extremely rare potential impact scenarios were not quantified in this document because the probability of occurrence of the event approaches "incredible" proportions (i.e., a probability of 10^{-6} essentially means a return period of once every 1,000,000 years compared to the 40 year operating life of the facility).

5.4.14 Transportation Accident and Release of Ammonia

A truck shipment of anhydrous ammonia to the mill, if involved in a severe accident, could result in a significant environmental impact. The number of shipments of anhydrous ammonia to the mill is expected to be approximately 3 times more frequent than the yellowcake shipments from the mill. However, ammonia is expected to be shipped from a supplier closer to the mill than the conversion facility in Illinois. Therefore, it is expected that the frequency of a rollover and crash of an ammonia truck, which could result in catastrophic release of ammonia, would be smaller than that of yellow cake truck (7.9×10^{-4} per year). If a small amount of ammonia is released, the impact to a member of the public is expected to be small, however, the driver, if injured or trapped, could be exposed to elevated ammonia concentrations before being evacuated by an emergency response team. If a large amount of ammonia is released, both members of the public and the driver could be exposed to high ammonia concentrations. Unmitigated impact could be high. However, the emergency response team would evacuate the areas affected by the release to reduce the exposure of the public. Large quantities of ammonia, involving numerous shipments, are transported on US highways every day without incident. Although the impacts of an accident could be moderate to large, the probability of an accident occurring would be very low, especially in a populated area,

5.4.15 Common Cause and Cumulative Scenario

The accident scenarios analyzed in this study are low frequency accidents. Occurrence of independent accidents at the same time is extremely unlikely. For example, accidental fire in the SX circuit and transportation accidents at the same time is on the order of 10^{-6} and lower.

However, there are common cause accidents which share their initiating events. Alternatively some accidents may result in secondary accidents. For example an explosion in propane storage may initiate a secondary fire. In most of these cases, the conditional probability of a secondary accident is decreased through mitigative and preventive measures. For example, the distance between the propane storage tanks and the SX building will ensure that an accidental propane explosion would not initiate a fire at the organic storage tanks or the SX Building.

In extreme cases and under extremely unlikely circumstances, common cause accidents with multiple human and environmental effects may occur. Beyond design basis (BDB) accidents (e.g., BDB earthquake or BDB tornado) are examples of such accidents. The cumulative impact of such accidents could be large. However, these accidents are very unlikely given the low incidence of these types of natural disasters in western Colorado. In addition, the emergency response plan will be in place to reduce the severity of the impact of such accidents.

6.0 SUMMARY AND CONCLUSIONS

This study analyzed the risk of the following mill operations:

- Transport of ore and reagents to the mill and transport of yellowcake and vanadium concentrates from the mill to out-of-state processing plants
- On-site storage and use of ore, reagents, and fuels
- Mineral processing operation including process components in the following areas:
  - Ore Handling and Grinding
  - Leaching and CCD Thickeners
  - Uranium Solvent Extraction (SX)
  - Uranium Precipitation, Drying, and Packaging
  - Vanadium Oxidation and Solvent Extraction (SX)
  - Vanadium Precipitation, Drying, and Packaging
  - Waste Disposal Facilities including Tailings Cells and Evaporation Ponds

The effects of normal operation were assessed for workers, members of the public at the plant boundary and nearest residence, and wildlife. The assessment indicated that radiological doses to members of the public are due to exposure to gamma radiation, inhalation of dust (yellowcake, ore, and tailings), inhalation of radon gas and daughter products, and through the food chain. Potential wildlife impacts were due to exposure to gamma radiation, exposure to tailings as well as through the food sources.

The assessment indicated that the maximum dose to a member of the public would be well below the regulatory limit of 100 mrem/yr. The exposure pathways to wildlife were found to be incomplete due to the mitigative measures at the waste disposal facilities and/or due to the absence of food sources or exposure media. The assessment also indicated that exposure to organic vapors and acid fumes, heavy metals, and dust resulted in negligible risk to members of the public or to wildlife.

Radiological exposure of an office worker in the Administration Building is primarily due to exposure to dust from tailings and ore stockpiles, while the radiological exposure of an operational worker is due to exposure to gamma radiation, radon gas and daughter products, dust (yellowcake, ore, and tailings), organic vapor and acid fumes. The radiological exposure of a truck driver is due to the exposure to gamma radiation and dust (yellowcake and ore). The analysis indicates that safe operations are enhanced through the development and implementation of the health and safety plan, radiation protection procedures, and extensive training. Occupational doses are expected to be well below regulatory limits during normal operations.

A summary of the assessment of probability and impacts of the selected bounding accident scenarios as discussed in section 5 are provided in Table 6.1 below.

Table 6.1 Summary of Probabilities and Impacts for Accident Scenarios

Accident Scenario	Workers			Members of Public and Environment		
	Probability	**Impact**	**Risk**	**Probability**	**Impact**	**Risk**
Conventional Accidents and Personnel Injury	medium	low	Low	-	-	-
Unscheduled Explosion	Low	Moderate	Low	Low	Low	Low
Spill of Radioactive Materials	Low	Moderate	Low	Low	Low	Low
Spill of Non-Radioactive Materials and Fuel	Low	Moderate	Low	Low	Moderate	Low
Failure of Air Cleaning Systems	Low	Moderate	Low	Low	Moderate	Low
Spill of Tailings Slurry	Low	Low	Low	Low	Low to Moderate	Low
Fire Involving Flammable Liquids	Low	Moderate	Low	Low	Low	Low
Propane Explosion	Low	Moderate	Low	Low	Low	Low
Airplane Crash	Extremely Low	High	Low	Low	Moderate	Low
Tornado and High Wind	Low	Moderate	Low	Low	Low	Low
Flood	Low	Low	Low	Low	Low	Low
Building Fire	Low	Moderate	Low	Low	Low	Low
Transportation Accident and Materials Release	Low	Moderate	Low	Low	Moderate	Low
Transportation Accident Fire	Low	Moderate	Low	Low	Moderate	Low
Transportation Accident and Release of Ammonia	Low	Moderate	Low	Low	Moderate	Low

The above summary indicates that estimates of risks, including considerations for mitigation, of the identified bounding accident scenarios to workers, members of the public and the environment are low. The design of new mills (including the proposed project) follows more recent and robust design and performance criteria that will minimize the occurrence of radiological accidents, chemical spills and releases. Implementation of strict health and safety protocols, chemical management procedures, and emergency response procedures are designed to minimize the potential impact of an accident or release to the environment should it occur.

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