Estimates of Radiation Doses to Members of the Public from the Piñon Ridge Mill

Prepared for:

Energy Fuels Resources Corporation

44 Union Boulevard, Suite 600
Lakewood, Colorado 80228

Prepared by:

Two Lines, Inc.

896 Overview Road
Grand Junction, Colorado 81506
(970) 260-2810
(309) 214-2569 (fax)

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1.0 INTRODUCTION

Regulations pertaining to radiation control promulgated by the State of Colorado require that radiation doses to members of the public from licensed activities do not exceed the applicable dose limits. This report was prepared for Energy Fuels Resources Corporation (Energy Fuels) to demonstrate that the operations of the Piñon Ridge Mill will be in compliance with the regulatory requirements.

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 Property covers approximately 880 acres in the southeastern portion of Paradox Valley. The proposed Piñon Ridge Mill is located at 16910 Highway 90, approximately 7 miles east of Bedrock, Colorado and 12 miles west of Naturita, Colorado. Refer to Figure 1 for the site location.

The Piñon Ridge Mill includes an administration building, a 17-acre mill, a 30-acre tailings cell (expansion capacity to 90 acres), a 40-acre evaporation pond (expansion capacity to 80 acres), an approximately 6-acre ore storage pad, and access roads. The mill is designed to process Western Slope ore containing uranium and vanadium produced from mines located within a reasonable truck-haul distance on the Colorado Plateau. The mill will initially process 500 tons of ore per day, but is designed to accommodate future expansion of production capacity to 1,000 tons per day ("tpd"). The capacity of the ore pad is approximately 100,000 tons of ore. The projected operating life of the facility is 40 years, operating 24 hours per day, 350 days per year at 500 tpd.

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. The activity of U-238 was calculated as follows:

$$\text{Activity} = [0.0023 \text{ g } U_3O_8/\text{g ore}][0.85 \text{ g U-238/g } U_3O_8][330{,}000 \text{ pCi U-238/g U-238}]$$

$$\text{Act. Conc.} = 647 \text{ pCi U-238/g ore}$$

The U-238 decay products were assumed to be in equilibrium with the parent in the ore. Therefore, the decay product activity would be equal to the U-238 activity.

Potential doses to the public from operations were modeled using calculated emissions data from point sources and expected radionuclide concentrations in surface materials that constitute the area sources. The emissions data were calculated by Kleinfelder and submitted in the Air Pollution Emissions Notices (APENs) (Kleinfelder 2009a) and APEN Response #1 Submittal (Kleinfelder 2009b). The expected radionuclide concentrations of area sources were based on the radionuclide concentrations of the ore with the expectation that uranium removal was 96% efficient, in the case of tailings beaches. Refer to Figure 2 for locations of the point and area sources.

2.0 RADIATION DOSE ASSESSMENT

The MILDOS-AREA Code, commonly called MILDOS (Argonne National Laboratory, 1998), was used to estimate potential radiation doses to members of the public from proposed milling operations. MILDOS was developed by the Department of Energy's Argonne National Laboratory for the Nuclear Regulatory Commission to calculate radiation doses from uranium mills. Argonne National Laboratory is responsible for maintaining and updating the program. Version 2.2 of MILDOS was used for this analysis. Version 3.07 of MILDOS-AREA became available in December 2008 but was not used, due to concerns about calculations having to do with the dusting algorithm.

MILDOS allows input of user-defined release rates for radionuclides from point sources. It also calculates release rates for area sources, based on user-defined surface radionuclide concentrations, source area, and meteorological conditions. The user defines the boundaries and elevations of the area (quadrilateral) sources as well as the three-dimensional locations of point sources, relative to a designated point on the mill site. Generally, the base of the yellowcake stack location is defined as the 0,0,0 point. Because there is not a yellowcake stack at the Piñon Ridge Mill, the location of the yellowcake dryer was used as the origin point. The user also defines the locations of up to 48 receptors.

MILDOS uses the Gaussian Plume Model to calculate dispersion of airborne radionuclides. The meteorological data set used in this analysis was derived from the best available site-specific hourly meteorological data collected on a 10-m meteorological tower at the Mill including wind speed, direction, and stability-related information. MILDOS does not consider water-borne releases, but the Mill is designed to be a zero-discharge facility and will not have any routine water release points.

Fifteen perimeter receptor locations, identified as Fence 1 through Fence 15 were modeled for the Piñon Ridge Mill analysis, as shown in Figure 2. Other locations included the nearest residences and locations of population centers. Figures 3 and 4 show receptor locations of nearby residences and population centers, respectively. In addition, potential dose to a number of on-site locations, such as the planned administration building, unloading area, etc. were modeled.

MILDOS calculates the concentrations of the U-238 decay series radionuclides in air at each receptor location. Ground concentrations are calculated using deposition models.

MILDOS has the capability to calculate radiation doses with and without contributions from radon to receptors in four age groups (infant, child, teen, and adult) for the following pathways:

- direct inhalation of radionuclides in airborne particulate matter
- inhalation of radon and its decay products
- ingestion of meat, milk, and vegetables produced at the receptor location
- direct gamma radiation from radionuclides in air and deposited on the ground surface.

3.0 SOURCE TERMS

Radionuclides may be released from the processing site during ore storage, ore handling, processing, and waste material disposal. The process was described in detail in the Facility Operating Plan (Energy Fuels and Visus, 2009).

Ore will be dumped from the dumping platform to the ore pad in most cases. In some instances, ore will be dumped directly onto the ore pad. The ore is then moved to stockpiles on the ore pad where it is stored until it is processed. When a batch of ore will be processed, the ore is transferred to the feed hopper, which is enclosed in a three sided building equipped with water sprays and a dust collector. The ore is then processed through the leaching, extraction, precipitation and packaging systems. Solid by-product material (tailings) is mixed with waste liquids (raffinate) and transferred to the tailings cells for permanent waste storage.

MILDOS was run for several sets of sources and the estimated doses summed to provide a total dose. The various runs included the following sources:

- **Mill Point Sources:** Operational mill point sources include the feed hopper dust collector, SAG mill stack, leach building stack, vanadium dryer stack, and ore handling. As with some conventional mills, the Piñon Ridge Mill will not have fine ore storage.
- **Ore:** Approximately 100,000 tons of ore received can be stored on the ore pad. Emissions from the ore were modeled as described in NRC (1987). Material releases from wind erosion were accounted for in the model. Mean concentrations of uranium in the ore were assumed to be in equilibrium with decay products.
- **Tailings Cells:** Wind erosion from the initial tailings cells were included in the source terms. It was assumed that uranium removal was 96% efficient. Uranium decay products were assumed to be in equilibrium with the original concentrations.

3.1 Mill Source Emission Rates

The mill point source emission rates were estimated based on calculations in the APEN and APEN response #1 submittals for the Piñon Ridge Mill (Kleinfelder, 2009a and 2009b, respectively). Table 1 lists emission rates calculated by MILDOS for both point sources and area sources.

Table 1 Mill Operational Emission Rates

Source	Particulate Radionuclide Release Rate (Ci/yr)			
	U-nat	Th-230	Ra-226	Pb-210
Truck Dumping	2.00E-03	2.00E-03	2.00E-03	2.00E-03
Haulage to Ore Pad	5.35E-04	5.35E-04	5.35E-04	5.35E-04
Ore Pad Wind Erosion	3.99E-03	3.99E-03	3.99E-03	3.99E-03
Ore Feed Hopper Dust Collector	1.18E-05	1.18E-05	1.18E-05	1.18E-05
SAG Mill Stack	5.90E-06	5.90E-06	5.90E-06	5.90E-06
Leach Building Stack	0	1.30E-05	1.30E-05	1.30E-05
Vanadium Dryer Stack	5.60E-04	0	0	0
Tailings Cell (15 ac)	2.91E-04	7.27e-03	7.27E-03	7.27E-03
Tailing Cell (1.5 ac)	2.86EE-05	7.14E-04	7.14E-04	7.14E-04
Annual Total	7.39E-03	1.45E-02	1.45E-02	1.45E-02

3.2 Mill Radon Source Terms

When applicable, emission rates for Rn-222 for ore were calculated assuming an emanation fraction of 20 percent for the ore. That is, 20 percent of the radon present in the ore would be free to migrate to the pore spaces and 80 percent would remain in the matrix (NRC, 1981). The Rn-222 concentration in the ore was assumed to be equal to the U-238 concentration.

Radon releases from mill tailings beaches were calculated using the method of Nielson and Rogers (1986) that is codified in the WISE uranium radon flux calculator (http://www.wise-uranium.org/ctb.html). Whenever possible, site-specific parameters were used as outlined in Golder (2010), except that the tailings beaches were considered to be 50% saturated and 50% unsaturated. Given that Energy Fuels intends to maintain saturated beaches during operations at all times, the assumption that one-half of the beach is unsaturated is a conservative approach to the modeling.

3.3 Ore Storage

MILDOS calculates particulate emissions based on resuspension factors and site-specific meteorological data. The code uses a default "enrichment" factor of 2.5 to account for an enhanced concentration of radionuclides in the airborne particulate matter compared to the concentration in the bulk material. The code also calculates radon emissions from ore storage assuming a unit rate of 1.0 pCi Rn-222/m^2 –s per pCi Ra-226/g.

The assumption was made that the average ore stockpile coverage of the ore stockpile pad was 3 ac (0.012 km2) in area. The maximum size of a typical stockpile is approximately one-third of an acre, which is equivalent to roughly 10,000 tons of ore or 20 days of mill feed. Allowing for travel ways and space between piles, approximately 10 stockpiles of 10,000 tons each (total of 100,000 tons) can be stored within the ore pad area (Energy Fuels and Visus, 2009). The total coverage of the ore pad is approximately 3 ac at maximum capacity. For this reason, the value of 3 ac, which was used as an average, is a conservative value.

MILDOS calculates the emission rate based on resuspension factors and meteorological data but allows adjustment of that rate based on dust suppression measures taken. The distribution of particle sizes for airborne particulates from the ore pad wase set at 30% 7.7 μm activity median aerodynamic diameter (AMAD) and 70% 54 μm AMAD, which is the default usage in

MILDOS. Larger particles tend to be transported shorter distances. An adjustment factor of 0.5, as described in Appendix C of NRC Regulatory Guide 3.59 (NRC, 1987), was applied to account for the reduction in dusting due to frequent watering of the ore to contain dust.

3.4 Tailings Impoundment

Radionuclide concentrations in tailings were estimated by assuming that uranium removal was 96% efficient and the remaining decay products remained in equilibrium. Mean radionuclide concentrations in the ore and tailings beaches are given in Table 2. Tailings beaches were assumed to be comprised of sandy materials, while the tailings slimes, having a concentrations of 1211 pCi/g are to be covered with water and are not modeled by MILDOS.

Table 2 Radionuclide Concentrations Used to Model Area Source Surface Material

Area	U-238 (ρCi/g)	Th-230 (ρCi/g)	Ra-226 (ρCi/g)	Pb-210 (ρCi/g)
Ore Pad	647	647	647	647
Tailings Beaches	12.1	302.5	302.5	302.5

Locations of the modeled point sources and area sources are shown in Figure 2.

MILDOS calculates the particulate emission rates based on resuspension factors and site-specific meteorological data. As with the ore storage piles, particle sizes for airborne particulates from the tailings beaches were set at 30% 7.7 μm AMAD and 70% 54 μm AMAD. The emission rates can be adjusted to take into account a reduction in dust emissions due to dust suppression measures taken during the year. For the tailings beaches, an adjustment factor of 0.5 (a 50 percent reduction) was applied to simulate watering of the beaches to control particulate emissions. This factor follows guidance given in NRC Regulatory Guide 3.59 Appendix C (NRC, 1987). The code calculates the radon emissions based on an emanation rate of 1 pCi/m^2-s per pCi/g Ra-226. No adjustment was made for radon emissions reduction.

Four tailings cell scenarios were modeled to assess the effect of impoundments in different locations on the various receptor locations. These scenarios represented maximum tailings cell deposition during different periods of the mill's operational lifetime and are explained in greater detail in Section 5.

3.5 Meteorological Data

Meteorological conditions greatly influence resuspension and dispersion of radionuclides from point and area sources during the year. The Mill has two meteorological stations that record wind speed, wind direction, and stability class simultaneously among other parameters. Data for the period of April 2008 through March 2009 were converted to the site-specific joint frequency distribution (STAR file) required as input by MILDOS. These calculations were performed using the STARMD program which is based on the Sigma-Theta method in EPA 454/R-99-005 (EPA, 1987). STAR data represent percentages of time for each wind direction (16 compass points) in particular wind speed and stability classes. The data were entered into the MILDOS data set to calculate the annual public dose estimates. Refer to Figure 5 for wind roses for both meteorological sites representing data from April 2008 through March 2009. As suggested in the Yuan et al. (1989, pg 28), wind data from the 10 m tower were used for the MILDOS modeling.

4.0 RECEPTORS

For the most part, locations for the receptors were determined using an aerial photograph and GIS mapping to calculate the distance from the mill in kilometers east and north and meters elevation with the yellowcake dryer location as the reference point. Residential receptors and their coordinates are given in Table 3. A positive value of X or Y indicates that the receptor point is east or north of the facility, respectively. Likewise, negative values of X and Y are west and south of the facility. A negative value of Z indicates that the receptor is at lower elevation than the base of the yellowcake dryer. Z was limited to -45 m and +100 m.

Table 3 Location of nearby residences.

Residential location	X (km)	Y (km)	Z (m)
Herron	-5.05	-4.68	-45
Boren	-7.57	6.11	-45
Kinder	-7.62	6.09	-45
Davis/Fehlman	5.30	-2.65	32
Hurdle	6.37	3.18	56
Hogan	-3.70	-0.96	100

In addition, potential doses were estimated to residents of the towns of Naturita, Bedrock, Telluride, Norwood, and Montrose, Colorado and Moab, Utah. As shown in Fig. 2, a series of 15 receptor locations were situated at the property boundary. The fence line receptors do not represent actual residents, but are important to understanding the potential for exposure to inadvertent receptors, however limited.

5.0 RADIATION DOSE ESTIMATES

5.1 Assessment

MILDOS calculates doses for several different organs with and without radon. The 40 CFR 190 doses exclude radon exposure since the 40 CFR 190 criterion is 25 mrem per year to any organ (except the thyroid for which the criterion is 75 mrem) or the whole body, excluding dose due to radon. The critical organs are the bone surface and the lung. The infant is the critical age group for lung dose and the teen, for bone dose. Doses to these organs as well as the effective doses were summarized for each age group. In addition, the total effective dose equivalent (TEDE), including radon decay products, was calculated for each age group.

The average effective area of the ore storage pad was set to 3 ac (0.012 km^2) for the operating life of the facility. Figure 6 shows four scenarios for location of tailings beaches during the life of the mill. These four scenarios indicate the points in time in which two tailings cells would be active simultaneously and the maximum area of tailings beaches would be exposed. Initially, each tailings impoundment will be below grade, which likely inhibits particulate transport. For simplicity, each tailings scenario was modeled separately as a single time step rather than attempting to use multiple time steps. This is a legitimate approach because mill operation will be essentially constant over the lifespan of each scenario. The dusting algorithm in MILDOS v. 2.20 was used.

Food pathway parameters were set a at default value of 0.5 or 50%. This means for either individual or population receptors ½ of the total livestock feed requirement is satistied by pasture, which is subject to contamination by potential mill releases. Potential dose from food pathways represents a very small number relative to inhalation doses, regardless of the food chain parameter. Because there is no dairy farm in the area, the milk pathway was not modeled.

The known population of actual residences and towns were added to the annulus in which they are located. Within the 5 km annulus, a single resident was listed in each direction and distance regardless of whether actual residents were present. This is a very conservative assumption, as the actual number of residents within 5 km of the Mill is approximately 10 whereas the dose estimate assumed 64 residents within 5 km of the Mill. Locations of residences within 5 km of the mill are shown in Figure 3.

The population distribution within 80-km of the mill site was calculated by taking the average population density of the county in question and multiplying the area (km^2) of the annulus in question (for example, north 1 -2 km, southeast 60-70 km, etc.) by that county's population density (people/km^2). Population centers and their location relative to the 80-km distance is shown in Figure 4. This approach may somewhat skew the population density in the les-densely populated regions of a given county, but it likely has little influence on the total population dose which is spread over 20,000 km^2 (7760 mi^2). For example, the population density of Montrose County is highly skewed towards the eastern portion of the county, due to the location of the City of Montrose. Therefore, using the county-wide population density would tend to skew the population dose to the western portion of the county. Table 4 lists the distribution of population entered into MILDOS for population dose calculations.

Table 4 Population Distribution Surrounding the Mill Site.

Distance from Mill Site (km)	Direction																Total
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	
1.0- 2.0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16
2.0- 3.0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16
3.0- 4.0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16
4.0- 5.0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16
5.0-10.0	88	88	11	89	88	88	88	29	118	29	29	88	88	15	88	88	1112
10.0-20.0	353	353	88	353	1087	988	353	118	196	118	118	353	353	304	353	353	5841
20.0-30.0	589	589	353	589	589	970	196	196	275	196	325	589	589	98	589	589	7321
30.0-40.0	1099	1099	589	824	824	275	275	137	353	275	275	137	137	137	824	1099	8359
40.0-50.0	1413	1413	1413	1060	1060	791	353	177	177	353	177	177	177	177	177	1413	10508
50.0-60.0	1727	1713	1060	1295	1295	432	216	216	216	905	216	216	555	216	216	1727	12221
60.0-70.0	2041	2041	2296	1531	765	603	255	255	573	255	255	2113	255	255	255	2041	15789
70.0-80.0	2355	2355	9049	1573	883	614	294	294	5404	1472	294	294	294	5073	294	2355	32897
1.0-80.0	9669	9655	14863	7318	6595	4765	2034	1426	7316	3607	1693	3971	2452	6279	2800	9669	94112

MILDOS runs were performed for stack releases, ore handling, and each of the four tailings scenarios shown in Figure 6. The tailings scenarios all include ore storage as well as potential particulate releases from tailings beaches. Copies of the input and output files are provided as appendices to this report. The code was run separately for each set of sources: mill point sources, ore pad, and tailings cells. The calculated doses were summed using Excel™ spreadsheets to obtain a total dose from U-238 and its decay products.

5.2 Property Boundary Doses

The MILDOS-AREA code calculates dose estimates for infant, child, teen, and adult age groups. Effective whole body and organ dose estimates excluding Rn-222 doses (40 CFR 190 doses) and the total estimated dose equivalent (TEDE) including Rn-222 are also calculated for each receptor location.

As shown in Fig. 6, four separate scenarios were modeled. Scenario 1, which represents year 1-16, has a tailings beach of 15 ac (0.0063 km^2), represented by 4 smaller beaches, surrounding tailings that are covered by water. In addition a 1.5 ac beach (0.00063 km^2) is also modeled. Scenario 2 is similar except that the beaches are further north. Scenario 3 contains only the 15 ac beach surrounding submerged tailings and Scenario 4 has no uncovered beaches at all.

For the four scenarios shown in Fig. 6, the calculated estimates of the TEDE and the 40 CFR190 effective, bone and lung doses are given in Table 5 for the maximum receptor, regardless of age group or scenario, at each boundary receptor location (Fig. 2). Data in Table 5 include contributions from tailings, ore storage, ore handling and operational point sources.

Table 5 Maximum Doses at Property Boundary.

		40 CFR 190 Dose (mrem/yr)		
Name	**TEDE (mrem/yr)**	**Eff**	**Bone**	**Lung**
Fence 1	3.07E+00	9.91E-01	1.42E+00	7.71E+00
Fence 2	1.47E+00	8.33E-01	1.14E+00	6.40E+00
Fence 3	7.70E-01	1.58E-01	2.34E-01	1.23E+00
Fence 4	1.48E+00	4.00E-01	2.53E-01	3.16E+00
Fence 5	9.39E-01	1.61E-01	8.40E-02	1.25E+00
Fence 6	2.36E+00	1.09E+00	3.04E-01	8.57E+00
Fence 7	5.44E+00	3.75E-01	8.05E-01	2.86E+00
Fence 8	3.10E+00	1.44E-01	4.26E-01	1.09E+00
Fence 9	2.48E+00	3.77E-01	2.86E+00	1.83E+00
Fence 10	2.26E+00	8.05E-01	5.88E+00	4.04E+00
Fence 11	2.69E+00	1.30E+00	9.62E+00	6.55E+00
Fence 12	2.80E+00	1.43E+00	9.46E+00	7.61E+00
Fence 13	6.75E+00	3.35E+00	1.74E+01	1.98E+01
Fence 14	8.21E+00	2.37E+00	8.03E+00	1.64E+01
Fence 15	5.10E+00	2.13E+00	5.51E+00	1.57E+01
Maximum	**8.21E+00**	**3.35E+00**	**1.74E+01**	**1.98E+01**

Doses at the fence line receptors are all below the 100 mrem/yr public dose limit of 10 CFR 20, the 25 mrem/yr effective and organ dose limit from Part 4.14.4 and Criteria 8 in Appendix A to Part 18 of CDPHE regulations, or the 10 mrem/yr constraint from Part 4.5.4. It is also important to note that none of the fence line receptors constitute individual members of the public as defined in 40 CFR 190, but are only points, not actual receptors.

5.3 Doses to Actual Off-site Receptor Locations

Maximum dose estimates for occupied receptor locations in all four age groups are given in Tables 6 through 9. As expected, estimated doses to actual receptor locations are far lower than doses calculated for the fence line receptors. The greatly increased distance to actual receptors serves to reduce the potential dose by several orders of magnitude. For example, the Herron residence is nearly 7 km distance from the mill site. The Hogan is the closest of the actual residences and is 3.8 km away from the mill site.

No age group receives more than 1 mrem/yr TEDE at any actual residential location or town. As expected from the fence line results, no dose limits are exceeded for any of the actual residences or towns. Doses without the influence of radon gas, as specified by 40 CFR 190, are also far lower than those estimated to occur at the fence line.

Table 6 Estimated Annual Doses to Infant Members of the Public (mrem/yr)

Name	TEDE (mrem/yr)	40 CFR 190 Dose (mrem/yr)		
		Eff	Bone	Lung
Herron residence	5.04E-01	1.03E-01	Note 1	7.98E-01
Boren residence	3.28E-01	7.07E-02	Note 1	5.49E-01
Kinder residence	3.27E-01	7.05E-02	Note 1	5.49E-01
Davis/Fehlman residence	3.05E-01	7.79E-02	Note 1	5.83E-01
Hurdle residence	2.21E-01	6.09E-02	Note 1	4.54E-01
Hogan with unknown residents	1.75E-01	2.12E-02	Note 1	1.64E-01
Bedrock	1.30E-01	6.23E-02	Note 1	4.29E-01
Naturita	9.06E-02	2.24E-02	Note 1	1.68E-01
Norwood	3.28E-02	4.15E-03	Note 1	2.89E-02
Montrose	1.18E-02	1.19E-03	Note 1	7.84E-03
Moab, Utah	2.61E-02	1.01E-03	Note 1	7.56E-03
Telluride	1.54E-02	1.29E-03	Note 1	8.47E-03
Maximum	**5.04E-01**	**1.03E-01**	Note 1	**7.98E-01**

Note 1: Infants do not generally consume home grown vegetables; the dose to bone was not calculated.

Table 7 Estimated Annual Doses to Child Members of the Public (mrem/yr)

Name	TEDE (mrem/yr)	40 CFR 190 Dose (mrem/yr)		
		Eff	Bone	Lung
Herron residence	4.73E-01	4.95E-02	3.90E-02	3.84E-01
Boren residence	3.07E-01	3.42E-02	2.57E-02	2.65E-01
Kinder residence	3.06E-01	3.40E-02	2.56E-02	2.65E-01
Davis/Fehlman residence	2.71E-01	3.78E-02	1.16E-01	2.78E-01
Hurdle residence	1.94E-01	2.96E-02	1.01E-01	2.17E-01
Hogan with unknown residents	1.68E-01	1.02E-02	8.95E-03	7.90E-02
Bedrock	1.00E-01	3.20E-02	1.28E-01	2.03E-01
Naturita	8.05E-02	1.09E-02	2.89E-02	8.01E-02
Norwood	3.00E-02	2.03E-03	7.08E-03	1.37E-02
Montrose	1.07E-02	5.82E-04	2.09E-03	3.72E-03
Moab, Utah	2.47E-02	4.90E-04	1.07E-03	3.62E-03
Telluride	1.41E-02	6.31E-04	2.29E-03	4.01E-03
Maximum	**4.73E-01**	**4.95E-02**	**1.28E-01**	**3.84E-01**

Table 8 Estimated Annual Doses to Teen Members of the Public (mrem/yr)

Name	TEDE (mrem/yr)	40 CFR 190 Dose (mrem/yr)		
		Eff	Bone	Lung
Herron residence	4.62E-01	2.70E-02	4.89E-02	2.01E-01
Boren residence	2.99E-01	1.85E-02	3.20E-02	1.39E-01
Kinder residence	2.98E-01	1.85E-02	3.18E-02	1.38E-01
Davis/Fehlman residence	2.60E-01	2.28E-02	1.46E-01	1.46E-01
Hurdle residence	1.85E-01	1.92E-02	1.29E-01	1.14E-01
Hogan with unknown residents	1.65E-01	5.58E-03	1.11E-02	4.14E-02
Bedrock	9.02E-02	2.21E-02	1.61E-01	1.11E-01
Naturita	7.74E-02	6.27E-03	3.56E-02	4.20E-02
Norwood	2.96E-02	1.29E-03	8.40E-03	7.23E-03
Montrose	1.08E-02	3.71E-04	2.47E-03	2.00E-03
Moab, Utah	2.52E-02	2.81E-04	1.26E-03	1.90E-03
Telluride	1.43E-02	4.04E-04	2.71E-03	2.16E-03
Maximum	**4.62E-01**	**2.70E-02**	**1.61E-01**	**2.01E-01**

Table 9 Estimated Annual Doses to Adult Members of the Public (mrem/yr)

Name	TEDE (mrem/yr)	40 CFR 190 Dose (mrem/yr)		
		Eff	Bone	Lung
Herron residence	4.61E-01	2.29E-02	5.38E-02	1.68E-01
Boren residence	2.98E-01	1.57E-02	3.47E-02	1.16E-01
Kinder residence	2.97E-01	1.57E-02	3.47E-02	1.15E-01
Davis/Fehlman residence	2.60E-01	2.20E-02	1.62E-01	1.23E-01
Hurdle residence	1.84E-01	1.87E-02	1.44E-01	9.58E-02
Hogan with unknown residents	1.66E-01	4.75E-03	1.20E-02	3.46E-02
Bedrock	8.98E-02	2.16E-02	1.78E-01	9.93E-02
Naturita	7.72E-02	5.66E-03	3.84E-02	3.53E-02
Norwood	2.97E-02	1.19E-03	8.67E-03	6.10E-03
Montrose	1.09E-02	3.40E-04	2.52E-03	1.71E-03
Moab, Utah	2.55E-02	2.45E-04	1.29E-03	1.60E-03
Telluride	1.45E-02	3.70E-04	2.77E-03	1.85E-03
Maximum	**4.61E-01**	**2.29E-02**	**1.78E-01**	**1.68E-01**

5.4 Doses to On-Site Receptor Locations

Energy Fuels staff who work in the administration building are also potential receptors. Those who are classified as radiation workers will be monitored for their occupational exposure. Estimated doses to that receptor location at shown in Table 10. Regardless of tailings scenario, the maximum total effective dose equivalent (TEDE) annual doses to an adult at that location is 4.81 mrem/yr. The maximum organ dose, to bone, is estimated to be 16.1 mrem/yr, which is well below the 25 mrem/yr effective and organ dose limit from Part 4.14.4 and Criteria 8 in Appendix A to Part 18 of CDPHE regulations. It is important to note that the MILDOS-calculated doses are for 8760 hours per year, which is substantially in excess of the exposure time that would be expected for a worker, approximately 2000 hr per year. As such doses expected to be received by workers located in the administration building would be substantially lower than thow shown in .Table 10.

Table 10 Annual Doses to Workers Located in the Administration Building

TEDE (mrem/yr)	40 CFR 190 Dose (mrem/yr)		
	Eff	Bone	Lung
4.81E+00	1.52E+00	1.61E+01	5.21E+00

Doses at alternative administration building locations were calculated and are discussed in Appendix A. Doses at other on-site locations, such as the dumpling platform, reagent unloading area and kerosene-ammonia unloading area were found to be higher than those in Table 10. However, the potential for exposure at those locations is substantially lower than those to workers in the administration building because the frequency of exposure is considerably lower.

5.5 Population Doses

Using populations as shown in Table 4 above, 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 11.

Table 11 Dose to Populations Surrounding the Piñon Ridge Site

	Dose to population (person-rem)		
	Within 80 km	Outside 80 km	All
Total effective dose equivalent	2.28E-01	5.41E-01	7.68E-01
Bronchial dose	7.41E+00	4.93+00	1.23E+01

The maximum estimated annual population dose is 0.228 person-rem to the population within 80 km and 0.768 person-rem to all populations. While there is no regulatory limit for population dose, it is interesting to compare results in Table 11 to exposures from natural background. Again, using the population distribution in Table 4 and assuming 350 mrem/yr (NCRP 2009), the natural background population dose would be 11,900 person-rem or approximately 15,000 times higher than the incremental population dose potentially created by the Piñon Ridge mill. The vast majority of this dose is from inhalation of radon and particulates and external radiation. Only about 4% of the total results from intake of foodstuffs.

5.5 Uncertainties in Dose Calculations

The MILDOS code is not designed to calculate uncertainty associated with estimates of dose. The Gaussian Plume dispersion coefficients and the dose conversion factors themselves introduce an unknown amount of uncertainty into estimated doses at receptor locations. Doses calculated by the code represent an entire year of occupancy (i.e. 24 hours per day, 365 days per year) at a specified receptor location. For most residents, this represents a large overestimate of the actual dose that would be received.

There is some uncertainty regarding the distribution of particle sizes that will be released from the SAG mill, insofar as MILDOS modeling is concerned. To expore the possible impact to dose, a sensitivity analysis was conducted as described in Appendix B. Predicted doses for particle size 2, composed of 100% AMAD 1.5 µm particles, were 1.64 times higher than if the particle size 1, 3 µm AMAD, was used. Particle size set # 2 is the default choice for grinders, rod mills, etc. and was used in this modeling exercise. In total, releases from the SAG mill represent a very small fraction of the total doses, so this would seem to be only a minor concern.

6.0 CONCLUSIONS

Estimated radiation doses to members of the public due to operations and material storage at the Piñon Ridge Mill are well below the criteria set in 40 CFR 190, 10 CFR 20 and applicable CDPHE regulations. Incremental doses are within the range of background variability. In no case did the estimated effective dose or dose to any single organ exceed 25 mrem per year as specified in 40 CFR 190 and Criteria 8 in Appendix A to Part 18 of CDPHE regulations. The effective doses from airborne particulate matter were below the CDPHE Part 4.5.4 constraint limit of 10 mrem per year. The maximum calculated effective dose to any adult member of the public from all sources including radon was less than 100 mrem/yr, as specified in 4.14.1.1 of CDPHE regulations.

Doses to nearby residents are well below doses that are received from natural background radiation. Doses from natural backround to the population surrounding the site out to a distance of 80 km are approximately 16,000 times higher than the incremental doses potentially created by the Piñon Ridge Mill.

7.0 REFERENCES

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