Response to RAI-13 Regarding MILDOS

Estimated Radiation Doses To Members of the Public from the Lost Creek Project including the Eastern Expansion, Sweetwater County, Wyoming

Prepared for:

Lost Creek ISR, LLC
5880 Enterprise Drive, Suite 200
Casper, WY 82609

Prepared by:

Two Lines, Inc.
896 Overview Rd.
Grand Junction, Colorado 81506
(970) 260-2810
Fax (309) 214-2569

Revised December, 2017

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

Lost Creek ISR, LLC (a wholly owned subsidiary of Ur-Energy USA Inc.) operates an *in situ* facility for recovery of uranium at a location in south-central Wyoming (Lost Creek Project). The permit area is 38 miles northwest of Rawlins, Wyoming in the Great Divide Basin (Fig. 1). The central processing plant is situated in the NW 1/4 of the SE 1/4 of Section 18, Township 25 north, Range 92 west and is the 0,0 point for the MILDOS modeling. The region is sparsely populated with no permanent residents closer than 15 km away.

To estimate the potential radiation doses to potential and actual members of the public near the facility, radiation doses were modeled using the MILDOS-AREA code, version 3.10 as revised February 2012. The most recent version of MILDOS-AREA, version 4.01, was released in 2016. This report revision was developed using the older version 3.10.

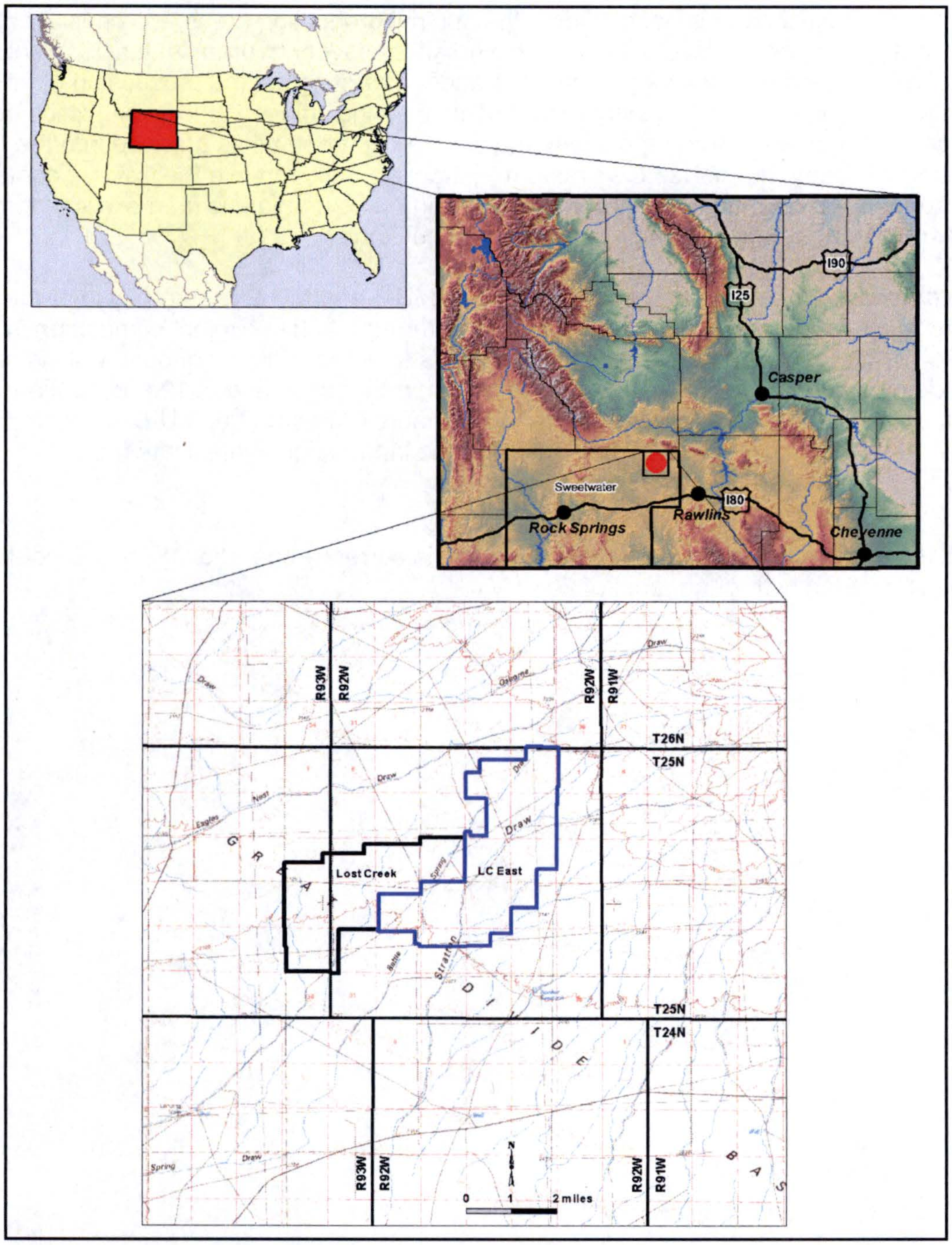


Figure 1. Map of project location.

2.0 PROJECT DESCRIPTION

The Lost Creek Project expansion, including the original production areas, will consist of eleven mine units (MU) that will be developed for injection and recovery of uranium leaching solutions over a twelve year period. Locations of the RAs and the existing central processing plant (CPP), within the permit boundary are shown in Fig. 2. The leaching solution or lixiviant, which consists of groundwater augmented with an oxidant and source of carbonate, is pumped into the underground ore body to mobilize the uranium. Extraction wells remove the lixiviant containing uranium (termed "pregnant solution") from the ore body. The uranium is then extracted from the pregnant solution by passing through ion exchange columns.

MUs and processes are staged as shown in Fig. 3. MU-1 and MU-2 is currently in production. Other RAs will be added as shown and will produce through 2021. Project completion is planned for 2030. Production will begin 12-18 months after the initiation of new well installation, noted as development on Fig. 3. Restoration of MU-1 will begin in late 2019 and continue into 202. Following MUs will be staged as shown in the figure. Mine Unit 6, MU-6 shown in Fig. 2, is mineralization in the FG horizon and is not included in the original application or this application.

The Ion Exchange facility, located at the main plant, is currently operational and will continue more or less constantly through most of 2030.

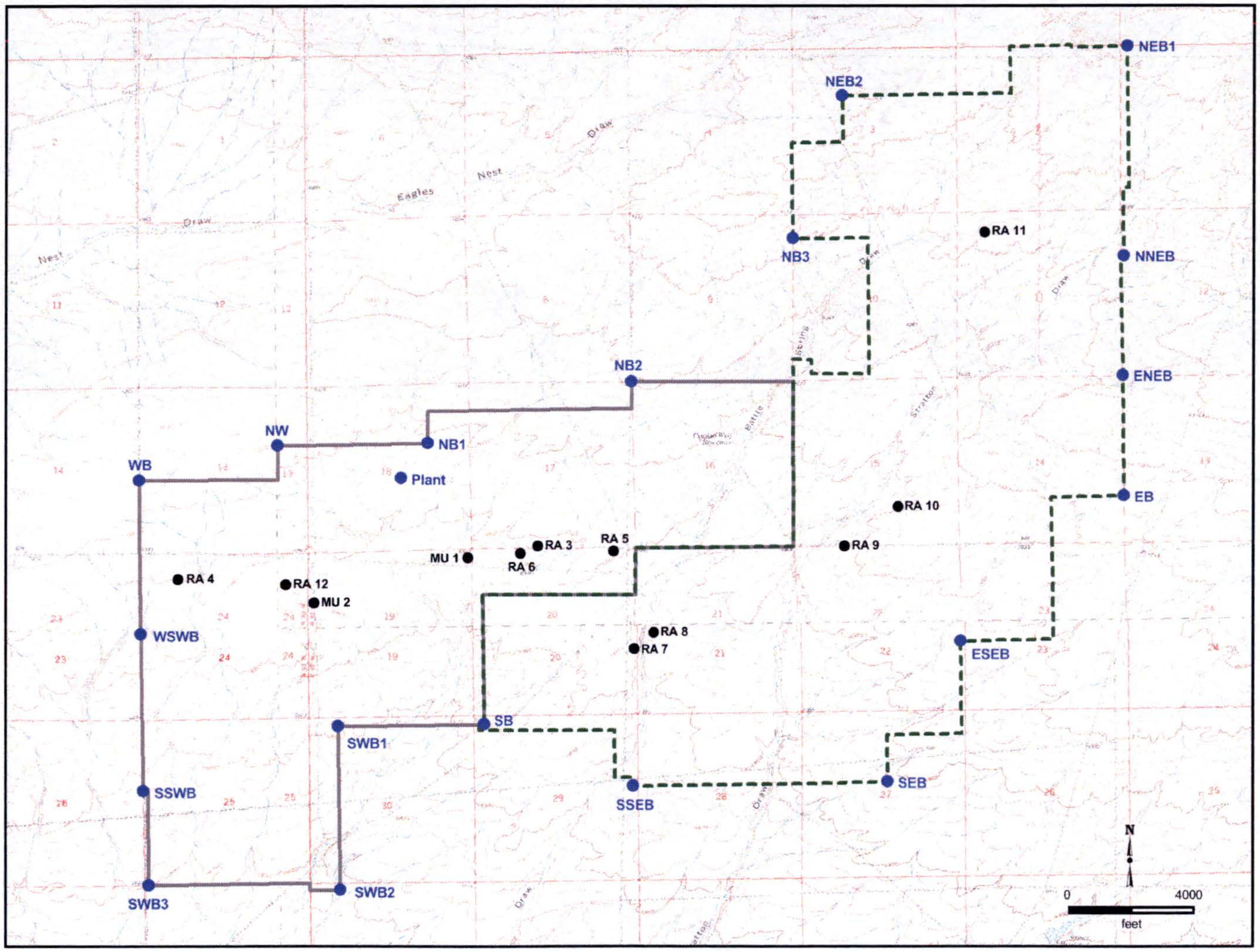
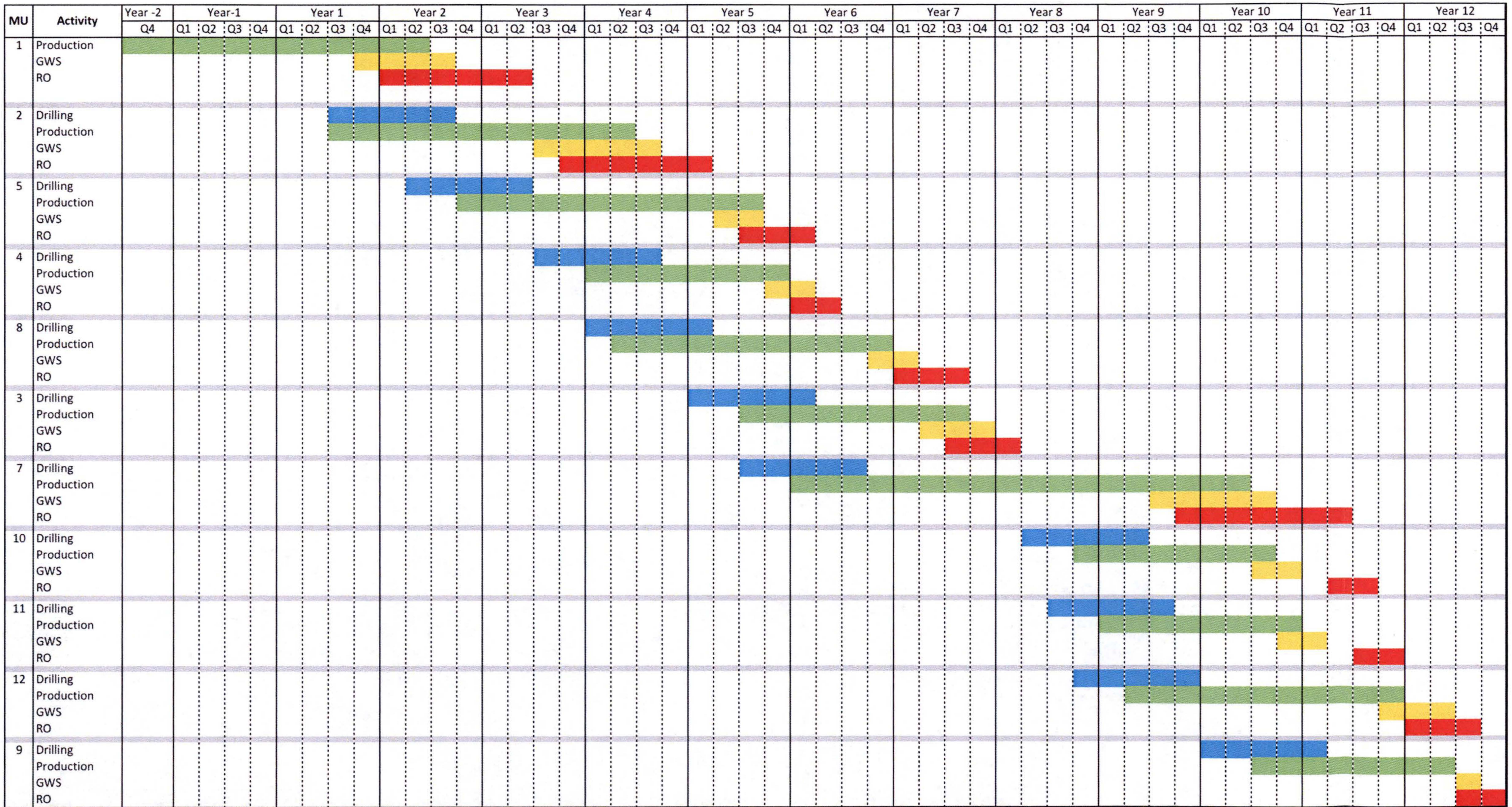


Figure 2 Map of modeled location boundaries and mine unit centroids (RA = MU in current terminology).



Note: MU = Mine Unit; GWS = Groundwater Sweep; RO = Reverse Osmosis

Figure 3. Staging of development, production and restoration by mine unit.

3.0 POTENTIAL RADIOACTIVE EFFLUENTS

Uranium-238 (^{238}U) in the ore body ultimately decays to radium-226 (^{226}Ra) and then radon-222 (^{222}Rn). Uranium (including ^{238}U, ^{234}U, and ^{235}U and radon are soluble in the leach solution and may be released during operations. MILDOS-AREA version 3.10 was used to estimate potential doses to members of the public. The users manual for MILDOS was published in 1989 by Argonne National Laboratory (ANL 1989) and has not been updated since that time. MILDOS Version 4.01 was issued in 2016, but was not used for this revised report, due to important changes in methodology for calculating ^{222}Rn doses.

Doses to members of the public may arise from radioactive material released during the following operations:

- ***New wells:*** When drilling new wells into the ore body, drill cuttings, including ore, are brought to the surface in drilling mud. Cuttings are stored in mud pits where ^{222}Rn may be released to the atmosphere.
- ***Production:*** Radon dissolved in the lixiviant may be released in two ways, either from purge water or from gas venting at the wellhead.
- ***Ion Exchange columns:*** Radon gas may be released from the columns as a function of the volume of the columns, the porosity of the resin and the unloading rate of the column.
- ***Restoration activities:*** During the restoration of the mine units, water is circulated within and discharged from the wells in release rates similar to those from producing mine units.

The Lost Creek project utilizes a vacuum dryer and, therefore, no particulate materials are released from the process.

Equations used by MILDOS to estimate releases are those detailed in NUREG-1569, Appendix D as shown below.

New Well Installation

Releases from installation of new wells in a resource area are given by the following equation:

$$Rn_{new} = 10^{-12} * E * L * [Ra] * T * M * N,$$

where Rn_{new} = ^{222}Rn release rate from new mine unit (Ci/yr),

10^{-12} = Ci/pCi,

E = Rn emanation fraction (0.25),

L = ^{222}Rn decay constant (0.181/day),

[Ra] = concentration of ^{226}Ra in ore (pCi/g),

T = storage time in mudpit (d),

M = average mass of ore material in pit (g), and

N = number of mudpits generated per year.

Radon Source Term

The radon source term, S in pCi/d, can be expressed as:

$$S = 10^6 * E * L * [Ra] * A * D * \rho,$$

where $10^6 = cm^3/m^3$,

E = Rn emanation fraction (0.25),

L = ^{222}Rn decay constant (0.181/day),

[Ra] = concentration of ^{226}Ra in ore (pCi/g),

A = active area of ore zone (m^3),

D = average thickness of ore zone (m), and

ρ = bulk density of ore material (g/cm^3).

Radon in Production Water

The ^{222}Rn concentration in process water at equilibrium, C_{Rn} (pCi/L) , is described by:

$$C_{Rn} = (10^6 * [Ra] * A * D * \rho * E * L * f) / [(L + v) * V + F_p + F_i],$$

where $10^6 = cm^3/m^3$,

[Ra] = concentration of ^{226}Ra in ore (pCi/g),

A = active area of ore zone (m^3),

D = average thickness of ore zone (m),

ρ = bulk density of ore material (g/cm^3),

E = Rn emanation fraction (0.25),

L = ^{222}Rn decay constant (0.181/day),

f = fraction of radon source carried by circulating water (unitless),

v = rate of radon venting during circulation (per day),

V= volume of water in circulation (L),

F_p = purge rate of water (L/d), and

F_i = water discharge rate from ion exchange column resin unloading (L/d).

The rate of ^{222}Rn release from purge water, Rn_w (Ci/y), is given by:

$$Rn_w = 3.65E\text{-}10 * C_{Rn} * F_{p,} ,$$

where 3.65E-10 = day-Ci/pCi-yr,

C_{Rn} = concentration of radon in process water (pCi/L), and

F_p = purge rate of water (L/d),

Likewise, the rate of ^{222}Rn release from venting, Rn_v (Ci/y), is given by:

$$Rn_v = 3.65E\text{-}10 * v * C_{Rn} * V, ,$$

where 3.65E-10 = day-Ci/pCi-yr,

v = rate of radon venting during circulation (per day),

C_{Rn} = concentration of radon in process water (pCi/L, and

V= volume of water in circulation (L).

Ion Exchange Columns

The water discharge rate from ion exchange column resin unloading, F_i (L/day) , is calculated by:

$$F_i = N_i * V_i * P_i ,$$

where

N_i = number of ion exchange column unloadings per day

V_i = Volume of ion exchange column (L) and

P_i = porosity of resin material (unitless).

The annual ^{222}Rn discharge from unloading of ion exchange columns, Rn_x , Ci/y, is given by:

$$Rn_x = 3.65E\text{-}10 * F_i * C_{Rn} ,$$

where

3.65E-10 = day-Ci/pCi-yr,

F_i = water discharge rate from ion exchange column resin unloading (L/d) and

C_{Rn} = concentration of radon in process water (pCi/L).

4.0 MODELING

As mentioned above, MILDOS-AREA was used to estimate potential radiation doses from the planned expansion of Lost Creek ISR operations. MILDOS (ANL, 1989) was originally developed to estimate doses from conventional uranium milling operations, including large area releases such as ore storage pads and tailings beaches. Inputs to the dose are limited to uranium decay chain radionuclides. MILDOS was subsequently updated in 1998 to address potential impacts of uranium *in situ* leaching operations. In situ leach specific types of source terms, such as production wells and restoration wells are included in the updated version. Modeling parameters and assumptions are addressed below.

Meteorology

Meteorological conditions greatly influence dispersion of radionuclides from estimated releases during the year. The Lost Creek facility has a meteorological station that records wind speed, wind direction, and stability class simultaneously. A six-yr meteorology data set encompassing 2007-2012 was used for this modeling exercise. These data 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. As shown in Table 1, winds from the south-southwest, southwest, west-southwest and west directions account for approximately 46% of the total. No other direction accounts for as much as 8% of the total.

Table 1. Percentage of wind from each direction, 2007-2012.

Direction from	Percentage of total hours	Direction from	Percentage of total hours
N	6.21	S	5.05
NNE	5.26	SSW	9.15
NE	4.90	SW	11.68
ENE	4.08	WSW	14.26
E	3.97	W	10.86
ESE	4.18	WNW	4.96
SE	3.71	NW	3.37
SSE	3.93	NNW	3.68
Total..........100.00			

Receptor Locations

There are few permanent receptors in the vicinity of the Lost Creek project. The village of Baroil is approximately 28 km to the northeast of the CPP. The Sweetwater uranium project mill, located 9.9 km to the southwest, has a security guard who is considered a member of the public for the purposes of this modeling exercise. Other receptor locations modeled are on the boundary of the project permit area.

Table 2. Location of modeled receptors.

Receptor Designation	X (km)+	Y (km)+	Z(m) *
CPP	0	0	0
WB	(2.55)	(0.02)	16
NWB	(1.20)	0.32	15
NB1	0.26	0.34	6
NB2	2.25	0.94	25
NB3	3.84	2.33	43
NEB2	4.31	3.72	54
NEB1	7.11	4.20	74
NNEB	7.08	2.16	49
ENEB	7.07	1.00	44
EB	7.08	(0.17)	47
ESEB	5.48	(1.58)	4
SEB	4.77	(2.95)	(8)
SSEB	2.28	(2.99)	(28)
SB	0.81	(2.41)	(35)
SWB1	(0.61)	(2.41)	(35)
SWB2	(0.59)	(4.00)	(53)
SWB3	(2.45)	(3.95)	(51)
SSWB	(2.51)	(3.04)	(40)
WSWB	(2.53)	(1.52)	(13)
Baroil	26.20	10.90	(24)
Sweetwater	(3.25)	(9.39)	(93)
+ negative numbers indicate west or south *rounded to the nearest meter			

Population Distribution

There are only small towns within 30 km of the proposed site. However, towns within 80 km from the proposed Lost Creek Project include Rawlins, Sinclair, Jeffrey City, Wamsutter and Bairoil. Directions, distances and estimated 2010 populations are listed in Table 3.

Table 3. Population distribution surrounding the Lost Creek site.

Town	Direction	Distance (km)	Population
Rawlins	SE	68	9259
Sinclair	SE	75	453
Jeffrey City	NNE	40	110
Wamsutter	S	50	451
Bairoil	ENE	28	106

Input Parameters for MILDOS Model

Parameters that apply to the entire project are shown in Table 4. Parameters specific to a resource area are listed in Table 5.

Table 4. Important Input Parameters.

Source	Parameter	Value
All	Thickness of ore body	3.7 m
	Porosity of ore body	0.26
	Density of ore body	1.94 g/cm^3
New Wells	Number of mud pits/yr	935
	Ore material added to mud pit	2.5E+05 g/y
	Duration of storage in mud pit	4 days
	% U_3O_8	0.055%
Mine Unit Production	Emanation fraction	0.25
	Fraction of radon in solution	0.80
	Rate of radon venting	0.01/day
	% U_3O_8	0.055%
	Volume in circulation	Varies with size of unit
	Purge rate	3.27E+05 L/d
Ion Exchange columns	Column volume	1.41E+05 L
	Column unloading rate	0.68/day
	Porosity of resin	0.4
	% U_3O_8	0.055%
Mine Unit Restoration	Emanation fraction	0.25
	Volume in circulation	Varies with size of unit
	Purge rate	3.27E+05 L/d
	Operating days	365/yr

Table 5. Mine unit-specific parameters.

Mine Unit	Location of centroid (relative to CPP)			Area of active drilling (m^2)	Maximum volume in circulation (L)
	X (km)	Y (km)	Z (m)		
MU1	0.29	(0.80)	(13)	1.76E+05	1.69E+08
MU2	0.96	(0.83)	(11)	2.91E+05	2.81E+08
MU3	(0.51)	(0.83)	(11)	1.18E+05	1.14E+08
MU4	1.02	(0.55)	(6)	1.10E+05	1.07E+08
MU8	(1.27)	(1.32)	(15)	1.11E+05	1.07E+08
MU7	2.29	(1.66)	(5)	2.64E+05	2.55E+08
MU3	1.34	(0.66)	(8)	1.13E+05	1.09E+08
MU12	(1.12)	(1.04)	(11)	1.33E+05	1.28E+08
MU10	4.87	(0.28)	9	7.29E+04	7.20E+07
MU9	4.35	(0.66)	5	8.80E+04	8.65E+07
MU11	5.71	2.39	44	7.11E+04	7.05E+07

Modeling Assumptions

Sources were modeled according to the staging shown in Figure 3. New resource area development, releases from radon in purge water and from venting during both production and restoration, and Rn releases during ion exchange were modeled using the MILDOS-prescribed format and inputs for that type of source. Radon releases from production and restoration purge water was assumed to occur at the location of the central processing plant. Radon releases from venting was assumed to be at the centroid of the resource area in question.

Because the facility has a vacuum dryer, no particulates are released. So, all calculated doses come solely from radon releases.

Inhalation, direct exposure from material deposited on the surface (ground) and submersion in contaminated air (cloud) were calculated for all receptors. Food pathways were included for vegetables and cattle grown in the area. It was assumed that all cattle feed was from pasture grass, not hay or other feed. The milk pathway was turned off for all receptors because there is no commercial dairy in the vicinity. Doses were calculated for an 8760-hr year, a conservative assumption meaning that, unless otherwise noted, the receptor is present at that location 100% of the time.

Source Strength Adjustment

The QADJUST factor in MILDOS was used to adjust the timing and fraction of a year that various sources operate in keeping with the staging shown in Figure 3. The annual rate of release from a specific resource was varied depending timing of the release. For example, if a source operated for only 3/4 year, QADJUST was set at 0.75 to account for that diminished output on a yearly basis. By varying QADJUST in this way, it was possible to plot the variation in dose as the project progresses.

Model Runs

Dose modeling was conducted in several MILDOS Code runs as follows:

- New resource development was modeled in run New1-10 that encompassed all resource areas except MU-1 for which development is complete.
- Production purge releases were represented by runs named PP1-6 and PP6-12. Two runs were necessary because of the number of time steps and the number of sources (mine units), both of which are limited to 10 by the MILDOS code. Releases of radon from purge water was assumed to occur at the CPP.
- Production venting was modeled using runs PV1-6RA and PV6-12 for the same reason. Releases of radon from venting were assumed to occur at the centroid of the RA.
- The IX1-12 run was used to model releases of Rn from the ion exchange columns. The Rn release rate was set at a constant throughout the project.
- Restoration purge was modeled using runs RP1-8 and RP9-12. Again, two runs were necessary because of the number of sources and time steps.
- Restoration venting was represented by runs RV1-8 and RV9-12.

In all cases, the modeling time step was set at one year. Hence, run PP6-12 contains 7 one year time steps.

5.0 MODEL RESULTS

This section presents the results of the MILDOS modeling.

Radon Release Rates

Potential annual radon release rates calculated by MILDOS from input parameters during the project from the various sources are listed in Table 6. The radon release rate varies with the sources that are active during all or part of a given year. Releases from the IX columns are assumed to be constant over the life of the project. Other project years vary depending on the mine unit be processed at any given point in time.

Table 6. Calculated annual quantities released by source (Ci).

	Project Year											
Source	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
New well development	4	11	7	12	12	7	0	9	16	0	0	0
Ion exchange columns	274	274	274	274	274	274	274	274	274	274	274	274
Production venting	222	255	212	329	408	392	240	257	395	306	112	40
Production purge	48	56	48	72	87	32	0	8	86	102	63	16
Restoration venting	40	160	212	264	170	84	271	62	59	270	199	130
Restoration purge	8	32	32	32	40	47	65	8	1	18	33	39
Total	596	788	785	983	992	837	850	617	831	971	681	498

Dose to Individual Receptor Locations

Estimated maximum annual total effective dose equivalents (TEDE) at individual boundary receptor locations are shown below in Table 7 and Figure 4. The maximum dose of 8.61 mrem for any boundary location is estimated to occur at boundary location NB1 in year 6. Receptor NB1 is the location of the maximum dose in each year of the project, due to it's location near the CPP.

This calculated dose results exclusively from exposure to radon decay products, since there are no particulate releases from the facility. For each receptor point, dose from inhalation contributes over 99% of the total modeled dose. Doses from submersion in a plume, direct exposure to contaminated ground surface, and ingestion of vegetables and meat represent less than 1% of the dose. Further, because doses result only from releases of radon with consequent decay products, the 40 CFR 190 annual dose commitments, which are exclusive of radon exposure, are zero in all cases.

The shape of estimated doses through time reflects both the staging of different processes and their locations. It is important to note that there are no actual receptors at the boundary locations, but it is presumed that an actual receptor could reside at or near that location. In all years, the maximum calculated dose was to boundary receptor NB1 which is located nearest to the processing plant.

The actual receptors modeled for this project reside at the village of Baroil, which is approximately 28 km to the east-northeast of the plant and the security guard who resides in a mobile home at the Sweetwater facility that is about 10 km to the southwest of the CPP. The maximum, modeled dose at Baroil is 0.352 mrem in year 6. Making the assumption that the Sweetwater security guard is on-site 100% of the time, that person would receive approximately 0.051 mrem also in year 6.

Table 7. Maximum total effective dose equivalent (TEDE) at various receptor locations.

Lost Creek - Summary of TEDE Doses To Maximum Individual By Year												
Receptor	Yr 1	Yr2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11	Yr 12
WB	4.40E-01	5.86E-01	6.16E-01	7.71E-01	8.64E-01	8.56E-01	5.02E-01	4.61E-01	4.49E-01	4.35E-01	4.27E-01	4.18E-01
NWB	1.31E+00	1.64E+00	1.68E+00	1.90E+00	2.04E+00	2.03E+00	1.47E+00	1.25E+00	1.39E+00	1.46E+00	1.33E+00	1.18E+00
NB1	6.97E+00	8.00E+00	7.76E+00	8.15E+00	8.46E+00	8.61E+00	7.81E+00	6.24E+00	7.82E+00	8.30E+00	7.68E+00	6.35E+00
NB2	7.08E-01	9.27E-01	9.13E-01	1.18E+00	1.13E+00	1.20E+00	1.09E+00	7.53E-01	8.22E-01	7.52E-01	7.11E-01	5.24E-01
NB3	2.74E-01	3.59E-01	3.55E-01	4.46E-01	4.36E-01	4.87E-01	4.22E-01	3.84E-01	4.51E-01	4.28E-01	3.33E-01	2.35E-01
NEB2	1.83E-01	2.40E-01	2.37E-01	2.96E-01	2.91E-01	3.23E-01	2.73E-01	2.76E-01	3.26E-01	3.15E-01	2.16E-01	1.54E-01
NEB1	1.13E-01	1.49E-01	1.48E-01	1.85E-01	1.83E-01	2.11E-01	1.77E-01	2.10E-01	2.52E-01	2.49E-01	1.46E-01	1.00E-01
NNEB	1.30E-01	1.73E-01	1.71E-01	2.18E-01	2.12E-01	2.58E-01	2.22E-01	2.93E-01	3.62E-01	3.91E-01	2.04E-01	1.28E-01
ENEB	1.30E-01	1.75E-01	1.73E-01	2.21E-01	2.13E-01	2.72E-01	2.37E-01	2.35E-01	3.13E-01	3.09E-01	2.51E-01	1.47E-01
EB	1.15E-01	1.55E-01	1.54E-01	1.97E-01	1.89E-01	2.57E-01	2.25E-01	2.12E-01	2.86E-01	2.76E-01	2.45E-01	1.42E-01
ESEB	1.28E-01	1.75E-01	1.73E-01	2.24E-01	2.12E-01	3.24E-01	2.89E-01	2.64E-01	3.47E-01	3.37E-01	2.92E-01	1.65E-01
SEB	9.56E-02	1.30E-01	1.29E-01	1.69E-01	1.63E-01	2.44E-01	2.13E-01	1.92E-01	2.52E-01	2.19E-01	2.19E-01	1.26E-01
SSEB	1.49E-01	2.10E-01	2.09E-01	2.75E-01	2.54E-01	6.61E-01	6.06E-01	5.44E-01	6.50E-01	3.53E-01	3.34E-01	1.02E-01
SB	3.55E-01	5.21E-01	5.16E-01	7.05E-01	5.68E-01	6.18E-01	4.66E-01	3.26E-01	3.39E-01	2.62E-01	2.29E-01	1.43E-01
SWB1	3.40E-01	4.90E-01	5.33E-01	6.55E-01	7.22E-01	7.00E-01	3.46E-01	2.71E-01	2.87E-01	2.54E-01	2.44E-01	2.11E-01
SEB2	1.43E-01	1.98E-01	2.00E-01	2.48E-01	2.64E-01	2.74E-01	1.66E-01	1.32E-01	1.42E-01	1.19E-01	1.19E-01	9.83E-02
SWB3	9.65E-02	1.33E-01	1.34E-01	1.77E-01	1.93E-01	2.01E-01	1.17E-01	9.53E-02	9.98E-02	8.36E-02	8.49E-02	7.29E-02
SSWB	1.37E-01	1.89E-01	1.92E-01	2.66E-01	3.02E-01	3.10E-01	1.62E-01	1.35E-01	1.37E-01	1.16E-01	1.20E-01	1.11E-01
WSWB	2.74E-01	3.80E-01	3.99E-01	6.17E-01	7.63E-01	7.59E-01	3.13E-01	2.84E-01	2.68E-01	2.45E-01	2.59E-01	2.78E-01
Baroil	1.84E-02	2.43E-02	2.42E-02	3.03E-02	3.03E-02	3.50E-02	2.80E-02	2.38E-02	2.79E-02	2.44E-02	2.19E-02	1.55E-02
Sweetwater	2.50E-02	3.39E-02	3.39E-02	4.41E-02	4.62E-02	5.08E-02	3.45E-02	2.83E-02	3.09E-02	2.46E-02	2.51E-02	1.96E-02

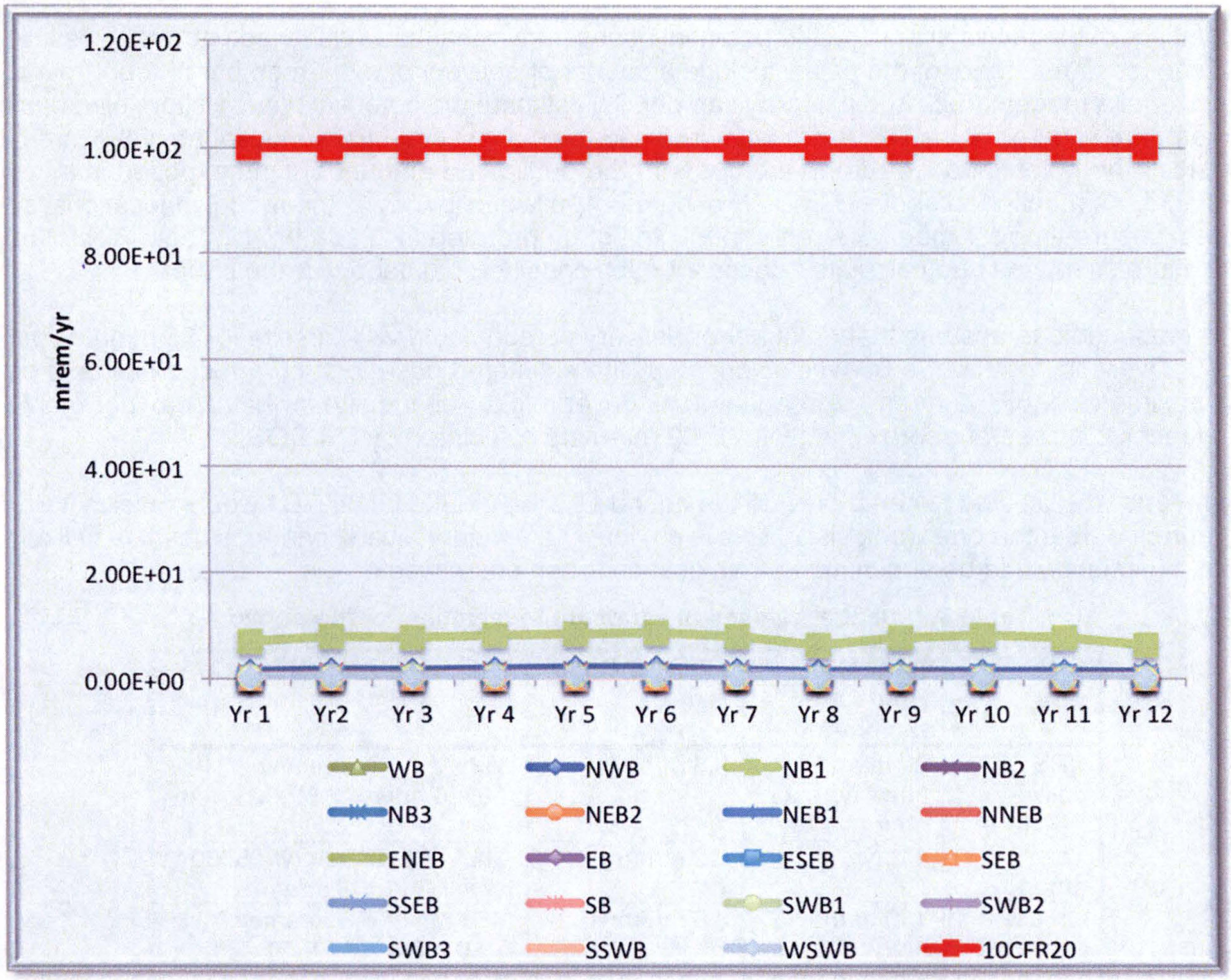


Figure 4. Maximum TEDE (mrem/yr) at each receptor, compared to dose limit.

Estimated Dose to A Transient Member of the Public

Members of the public are subject to potential doses from releases as described above. Possible categories of members of the public include a courier or delivery person, member of tour groups, a driver of a reagent truck and a nearby camper. To estimate the potential dose, visitors of various types were situated at the NB1 location, which had the highest potential annual dose of 8.6 mrem. Besides the potential dose rate to members of the public, the amount of time exposed is a key variable. As mentioned above, MILDOS assumes 100% occupancy at the modeled locations, so the exposure time for members of the public must by prorated for 8760 hr/yr. Table 8 lists the exposure scenarios and calculated doses for each considered category of the public.

It is reasonable to assume that a courier or delivery person could visit the site for 30 minutes per day. Over the course of a 50-week work year, the estimated dose to such a receptor would be approximately 2.5E-02 mrem. A reagent truck driver might visit the site for half a day per month and receive a dose of approximately 4.7E-02 mrem as calculated by MILDOS.

Someone who elected to camp outside the boundary area near location NB1 would receive 1.6E-01 mrem during the one week visit. This is obviously a conservative scenario, since it is unlikely that a camper would be stationary in that location for an entire week.

Table 8. Potential classes of exposure to members of the public.

Class	Annual # Hours Exposed	MILDOS Dose Rate	Estimated Annual Dose (mrem)
UPS delivery	30 min/wk * 50 wk/yr = 25 hr/yr	8.6 mrem/yr	25 hr/yr * 8.6 mrem/yr / 8760 hr/yr = 2.5E-02 mrem
Tour group	4 hr/yr	8.6 mrem/yr	4 hr/yr * 8.6 mrem/yr / 8760 hr/yr = 3.9E-03 mrem.
On-site contrator	160 hr/mo * 3 mo/yr =480hr/yr	8.6 mrem/yr	(480 hr/yr * 8.6 mrem/yr / 8760 hr/yr) = 4.7E-01 mrem/yr
Camper	1 wk/yr * 168 hrs	8.6 mrem/yr	168 hr/yr * 8.6 mrem/yr / 8760 hr/yr = 1.6E-01 mrem

Population Doses

Using the population distribution shown in Table 3, population doses (person-rem/yr) from site releases were calculated for both total effective dose equivalent (TEDE) and the dose to the bronchial epithelium of receptors. Population doses for year 6, the maximum TEDE year, are summarized in Table 9. Maximum population TEDE is calculated to be 7.0E-02 person-rem. The maximum bronchial dose is estimated to be 1.70 person-rem to the population. Such small values are not surprising given the sparse population surrounding the site.

While there is no regulatory limit for population dose, it is interesting to compare results in Table 9 to exposures from natural background. The most recent data indicate that the average American receives approximately 310 mrem from "ubiquitous background" (National Council on Radiation Protection and Measurements [NCRP] 2009). Ubiquitous background is assumed to include external exposure from cosmic radiation, external exposure from terrestrial radiation, internal exposure from inhalation of background radon (^{222}Rn) and thoron (^{220}Rn) and their progeny and internal exposure from radionuclides in the body. For a population of roughly 10,400, the total background dose exceeds 3,200 person-rem TEDE. This is roughly 45,000 times

greater than the estimated dose to the same population from the Lost Creek East expansion.

Table 9. Collective dose to populations with 80 km surrounding the site.

Dose to Population within 80km	
	person-rem
TEDE	7.0E-02
Bronchial	1.70

Uncertainties in Dose Estimates

MILDOS is not designed to calculate uncertainty associated with estimates of doses. Use of the Gaussian Plume Dispersion coefficients and the uncertainty in 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 at the specified receptor location. For any actual resident, this represents a large overestimate of the actual dose that would be received. In a realistic exposure scenario, residents in the vicinity would leave their residence for work or recreation and those absences are not accounted for by the model.

6.0 SUMMARY

Potential releases from the eastward expansion of the Lost Creek Project were modeled using MILDOS-AREA, version 3.10. Releases from drilling of new mine units were assumed to occur at the centroid of the mine unit. Radon releases from the ion exchange columns and purge water during production and restoration were assumed to occur at the CPP. Venting during production and restoration was assumed to occur at the centroid of the mine unit.

Results of MILDOS modeling indicate that no member of the public is likely to receive greater than the 10 CFR 20 limit of 100 mrem/yr TEDE. The maximum modeled dose at any boundary location is approximately 8.6 mrem in the maximum modeled year.

Collective dose to the surrounding population dose, expressed in person-rem/yr, to residents surrounding the project are very small relative to natural background radiation. Because of the long distances to most of the population well less than a person-rem/yr is anticipated from the project. The average background radiation to a person in the United States is 310 mrem, which is over 100,00 times higher than the average dose to members of the public from potential releases from the Lost Creek uranium recovery facility.

REFERENCES

Argonne National Laboratory (ANL), 1989. MILDOS-AREA: An Enhanced Version of MILDOS for Large-Area Sources, June. ANL/ES-161.

Argonne National Laboratory (ANL), 1998. MILDOS-AREA User's Guide (Draft). Environmental Assessment Division, September.

Harley et al. 1985. *Methods for Estimating Radioactive and Toxic Aiirborne Source Terms for Uranium Milling Operations*, NUREG/CR-4088, PNL-5338, prepared by Pacific Northwest Laboratory, Richland, WA for the U.S. Nuclear Regulatory Commission, Washington, D.C. June.

NCRP, 2009. Ionizing Radiation Exposure of the Population of the United States. NCRP Report No. 160. National Council on Radiation Protection and Measurements. March 3 2009.

U.S. Environmental Protection Agency (EPA), 1987. On-Site Meteorological Program Guidance for Regulatory Modeling Applications. EPA-450/4-87-013. U.S. EPA, Office of Air and Radiation, Research Triangle Park, NC 27711.

U.S. Environmental Protection Agency (EPA), 2012. Environmental Radiation Protection Standards for Nuclear Power Operations. Washington, DC: U.S. Government Printing Office; 40 CFR Part 190; Washington, DC: U.S. Government Printing Office; 40 CFR Part 20; 1992; Regulation.

U.S. Nuclear Regulatory Commission (NRC). 1980. Final Generic Environmental Impact Statement on Uranium Milling Facilities. NUREG-0706. NRC Office of Nuclear Material Safety and Safeguards. September.

U.S. Nuclear Regulatory Commission (NRC). 1987. Methods for Estimating Radioactive and Toxic Airborne Source Terms for Uranium Milling Operations, Regulatory Guide 3.59. Office of Nuclear Regulatory Research. March.

U.S. Nuclear Regulatory Commission. Standards for protection against radiation, 1992. Washington, DC: U.S. Government Printing Office; 10 CFR Part 20;. Regulation. http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/full-text.html

https://en.wikipedia.org/wiki/List_of_municipalities_in_Wyoming - list of cities by county and popn