Attachment 7.2-1

Estimated Radiation Doses from the Lost Creek ISR, LLC Lost Creek In Situ Recovery Facility

March 2008

INTRODUCTION

Lost Creek ISR, LLC (a wholly owned subsidiary of Ur–Energy) is planning to construct and operate an in situ facility for recovery of uranium at a location in central Wyoming (Lost Creek Project). The permit area is 38 miles northwest of Rawlins, Wyoming in the Great Divide Basin. In order to estimate the potential impact to members of the public residing near the facility, radiation doses were modeled using the MILDOS-AREA code. MILDOS-AREA has been approved for this use by the U. S. Nuclear Regulatory Commission.

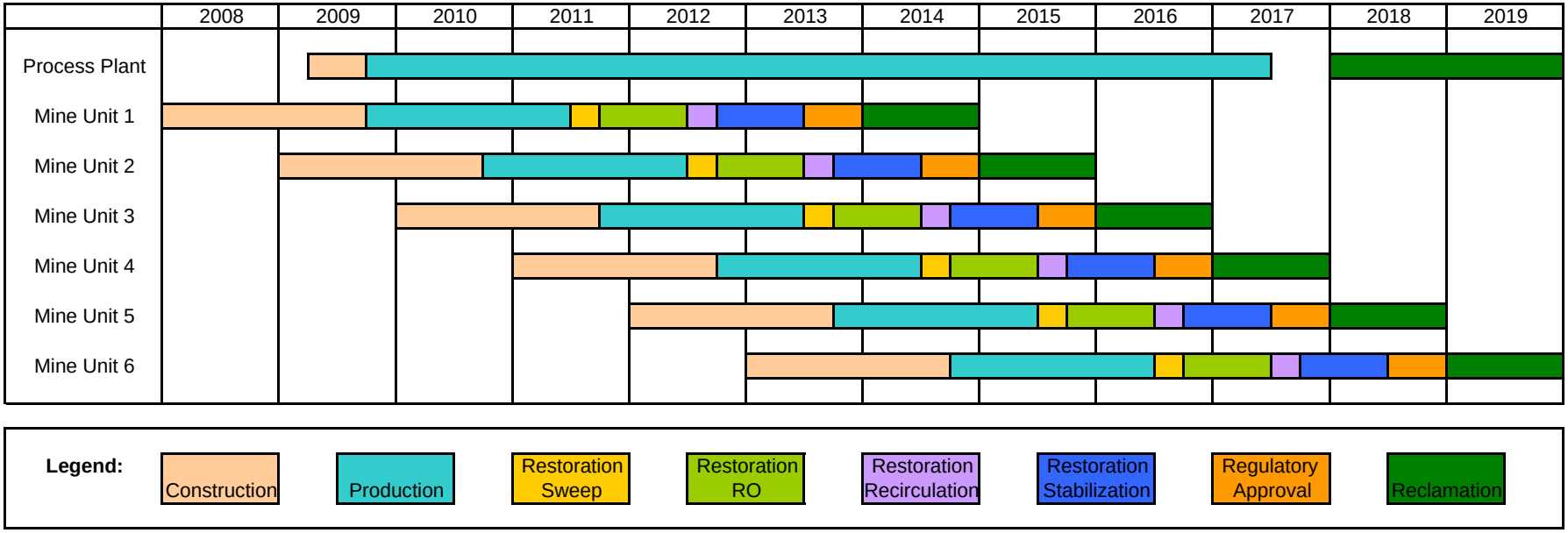
PROJECT DESCRIPTION

The Lost Creek Project will consist of six mine units that will be developed for injection and recovery of uranium leaching solutions over an eight year period. The leaching solution or lixiviant, which consists of groundwater augmented with oxygen and carbon dioxide, is pumped into the underground ore body to mobilize the uranium. Extraction wells remove the lixiviant containing uranium (pregnant solution) from the ore body. The uranium is then extracted from the pregnant solution by passing through ion exchange columns.

Mine units and processes are staged as shown in Figure 1. The plan calls for installation of new wells in Mine Unit 1 (MU-1) to begin in 2009 and be completed in 2010. The underground ore will be lixiviated (termed "Uranium Production" on the figure) beginning approximately eight months following the initiation of new well installation. Production in MU-1 will continue into the first quarter (Q1) of 2011. Restoration of MU-1 will begin in the fourth quarter (Q4) of 2011 and continue for approximately the first half of 2012 (Q1-2). Mine Units 2-6 will follow the same pattern with initiation of each subsequent unit in the year following the previous mine unit installation. Restoration of the planned mine units should be completed by the end of 2017.

The Ion Exchange facility, located at the main plant, will be operational beginning in the fourth quarter (Q4) of 2009 and will continue more or less constantly through the first half of 2016. Lixiviant will be pumped from each active mine unit to the Ion Exchange facility for elution.

Lost Creek Project Development, Production and Restoration Schedule



POTENTIAL RADIOACTIVE EFFLUENTS

Uranium-238 in the ore body ultimately decays to ^{226}Ra and then ^{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. Because the facility will not have a dryer, there is no potential for release of radionuclides in airborne particulates. Thus, radon gas is the only potential radioactive effluent. The MILDOS code was used to estimate potential doses to members of the public and workers from radon released during the following operations:

- *New wells:* When drilling new wells into the ore body, drill cuttings, including ore, are transported to the surface in drilling mud. Cuttings are stored in mud pits where ^{222}Rn may be released to the atmosphere.
- *Producing mine units*: 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.

MILDOS MODELING

The computer code MILDOS-AREA was used to estimate potential radiation doses from planned 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 assumptions and parameters are addressed below.

METEOROLOGY

Meteorological conditions greatly influence dispersion of radionuclides from estimated releases during the year. The proposed Lost Creek plant has a meteorological station that records wind speed, wind direction, and stability class simultaneously. However, an entire year of data is not yet available, so data from the Lost Soldier site were used. Lost Soldier is located about 12 miles northeast of the Lost Creek site. Data for the Lost Soldier site for the period April 2006 through April 2007 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 at the Lost Soldier site come from the west (W), west northwest (WNW) and northwest (NW) nearly 60% of the time.

Table 1. Wind Direction Frequency (April 2006 – April 2007).

Direction from	Frequency
N	0.02022
NNE	0.00981
NE	0.01118
ENE	0.01887
E	0.02035
ESE	0.01815
SE	0.03502
SSE	0.05787
S	0.05513
SSW	0.05364
SW	0.03563
WSW	0.03789
W	0.15696
WNW	0.30398
NW	0.11932
NNW	0.04596
Total	1.00000

EQUATIONS USED TO CREATE RADON RELEASE ESTIMATES

Equations used by MILDOS to estimate releases are those detailed in NUREG-1569, Appendix D. Therefore, releases from a new mine unit are given by the following:

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

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).

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 ^{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),

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).

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).

INPUT PARAMETERS

Important parameters for various source types are shown in Table 2. Size and mine unit- dependent parameters are given in Table 3. The specific mine unit parameters include location relative to the Central Plant or Ion Exchange Facility.

Table 2 Important input parameters.

All sources	Thickness of ore body	3.7 m
	Density of ore body	1.94 g/cm^3
New Well sources	Number of mud pits/yr	935
	Ore material added to mudpit	2.5E5 g/y
	Duration of storage in mudpit	4 days
	% U_3O_8	0.055%
Production Mine Unit sources	Emanation fraction	0.25
	Fraction of radon in solution	0.80
	Rate of radon venting	0.01/day
	Treated water purge rate	3.3E5 L/d
	% U_3O_8	0.055%
	Volume in circulation	Varies with size of unit
Ion Exchange columns	Column volume	1.41E5 L
	Column unloading rate	0.68/day
	Porosity of resin	0.4
	% U_3O_8	0.055%
Restoration Mine Unit sources	Emanation fraction	0.25
	Volume in circulation	Varies with size of unit
	Operating days	365/yr
	Treated water purge rate	7.63E5 L

Table 3 Mine unit-specific parameters.

Mine Unit	MU-1	MU-2	MU-3	MU-4	MU-5	MU-6
X (km)*	0.29	0.96	-0.51	1.02	-1.27	1.90
Y (km)*	-0,80	-0.83	-1.14	-0.55	-1.32	-0.77
Z (m)*	-13.4	-11.3	-10.7	-5.8	-14.9	-4.6
Area of active drilling (m^2)	1.66E5	1.62E5	1.55E5	1.69E5	1.88E5	1.88E5
Volume in circulation (L)	1.52E8	1.48E8	1.42E8	1.54E8	1.72E8	1.72E8
* Relative to plant (0,0,0)						

RECEPTOR LOCATIONS

There are no nearby permanent residents near the facility, so receptors were placed at the property boundary as listed in Table 4.

Table 4 Receptor locations.

Receptor	X (km)	Y (km)
NB	0.00	0.33
NEB	0.66	0.66
EB1	3.80	0.92
EB2	3.81	0.11
EB3	3.81	-0.69
SEB1	2.26	-0.71
SEB2	2.26	-1.16
SEB3	0.73	-1.18
SB	0	-2.41
ALT 1	0.74	-1.77
ALT 2	0.75	-2.40
SWB1	-0.66	-2.42
SWB2	-0.64	-4.06
SWB3	-2.57	-4.07
SWB4	-2.58	-2.58
WB	-2.61	0
NWB	-0.33	0.33
IX plant	0	0

Locations of the proposed plant and centroids of the various mine units, as well as specific receptor locations are also shown Figure 2.

POPULATION DISTRIBUTION

There are no towns of any size within 30 km of the proposed site. However, towns within 80 km from the proposed Lost Creek Project include Rawlins, Jeffrey City, Wamsutter and Bairoil. Directions, distances and census data are listed in Table 5.

Table 5 Population distribution surrounding the Lost Creek site.

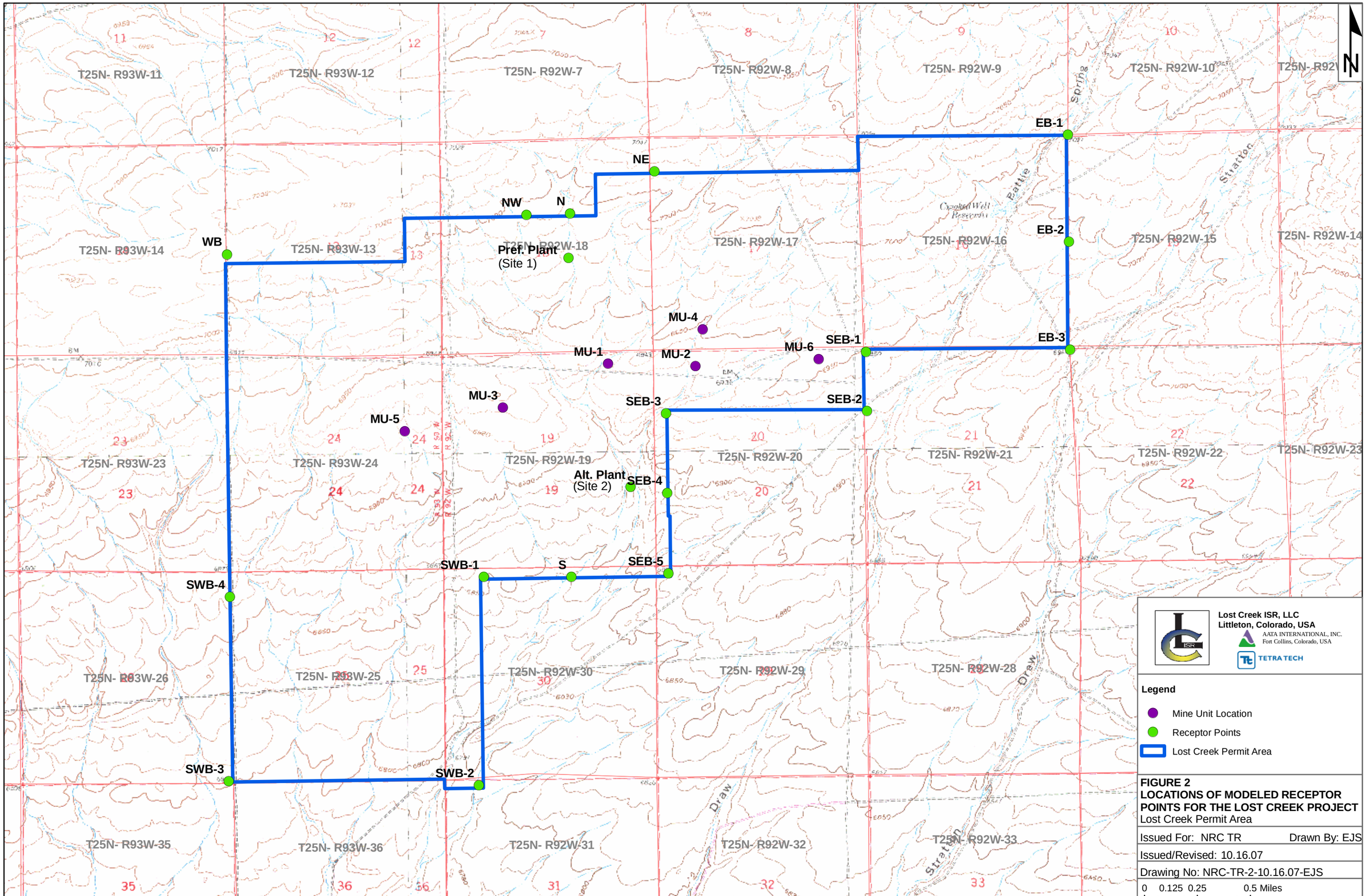
Town	Direction	Distance (km)	Population
Rawlins	SE	75	8500
Jeffrey City	NNE	40	110
Wamsutter	S	50	275
Bairoil	ENE	35	100

SOURCE STRENGTH

The QADJUST factor in MILDOS was used to adjust the timing and fraction of a year that various sources operate in keeping with the pattern shown in Figure 1. The annual rate of release from a specific mine unit was varied depending timing of the release. For example, if a source operated for only ¾ 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.

MODELING ASSUMPTIONS

The proposed plant is situated in the NW ¼ of the SE ¼ of Section 18, Township 25 north, Range 92 west and is the 0,0 point for the MILDOS modeling. An alternate plant location, Plant 2, is situated in the SE ¼ of the NE ¼ of Section 19, Township 25 north, Range 92 west. Hence, Site 2 is located -1.736 km (to the south), 0.478 km (to the east) from the Site 1 location.


T25N- R93W-11
T25N- R93W-12
T25N- R92W-7
T25N- R92W-8
T25N- R92W-9
T25N- R92W-10
T25N- R93W-14
T25N- R93W-13
T25N- R92W-18
T25N- R92W-17
T25N- R92W-16
T25N- R92W-15
T25N- R92W-14
T25N- R93W-23
T25N- R93W-24
T25N- R92W-19
T25N- R92W-20
T25N- R92W-21
T25N- R92W-22
T25N- R92W-23
T25N- R93W-26
T25N- R93W-25
T25N- R92W-30
T25N- R92W-29
T25N- R92W-28
T25N- R93W-35
T25N- R93W-36
T25N- R92W-31
T25N- R92W-32
T25N- R92W-33
WB
NW
N
NE
EB-1
EB-2
EB-3
Pref. Plant
(Site 1)
MU-1
MU-2
MU-3
MU-4
MU-5
MU-6
SEB-1
SEB-2
SEB-3
SEB-4
SEB-5
Alt. Plant
(Site 2)
SWB-1
SWB-2
SWB-3
SWB-4
S
Lost Creek ISR, LLC
Littleton, Colorado, USA
AATA INTERNATIONAL, INC.
Fort Collins, Colorado, USA
TETRA TECH
Legend
Mine Unit Location
Receptor Points
Lost Creek Permit Area
FIGURE 2
LOCATIONS OF MODELED RECEPTOR POINTS FOR THE LOST CREEK PROJECT
Lost Creek Permit Area
Issued For: NRC TR
Drawn By: EJS
Issued/Revised: 10.16.07
Drawing No: NRC-TR-2-10.16.07-EJS
0 0.125 0.25 0.5 Miles

MILDOS - 10

For both plant locations, sources were modeled according to the staging shown in Figure 1. New mine units, producing mine units, and restoration were modeled using the MILDOS-prescribed format and inputs for that type of source. Releases from the Ion Exchange columns were modeled in conjunction with purge water releases from the producing mine units at the location of the plant (0,0). Radon releases from restoration purge were also assumed to occur at the centroid of the plant. Venting from producing mine units and restoration wells was calculated assuming that the venting occurred at the centroid of the mine unit under consideration. Because the facility does not have a dryer, no particulates are released. So, all calculated doses come solely from radon releases.

Results are summarized below, and the output printouts are included as Appendix A.

MODEL RUNS

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

- New Wells were modeled for each of the six proposed mine units over a total period of seven annual time steps beginning in 2009.
- Production Wells were modeled for each mine unit over a total period of eight annual time steps from 2009 through 2016. Venting and purge were modeled separately, but with the same staging, because they are assumed to occur at different release locations.
- Ion Exchange Facility operation and releases were modeled over a series of eight annual time steps from 2009 – 2016, corresponding with production purges.
- Restoration purges and venting were modeled separately for each mine unit with the same time staging over a total period of seven annual time steps from 2011 – 2017.

As described above, the period of each year in which dose was calculated was varied using the QADJUST factor. So, for some time steps, certain mine units would be turned on or off depending on the staging shown in Figure 1 above.

MODELING RESULTS

CALCULATED RADON RELEASE RATES

Total estimated radon releases summed over the different source types are shown by year in Table 6. Operational year 2015 is the year of maximum radon release. The results are also shown in Figure 3.

Table 6. Calculated annual radon releases by source type.

	Total Estimated Radon Releases (Ci)								
	2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
New Wellfields	5.11E-03	5.72E-03	5.72E-03	5.72E-03	5.72E-03	5.72E-03	6.10E-04	0.00E+00	0.00E+00
Production Venting	4.17E+00	1.20E+02	1.48E+02	1.42E+02	1.51E+02	1.54E+02	1.62E+02	3.38E+01	0.00E+00
IX+Prod Purge	9.49E-01	2.74E+01	3.42E+01	3.41E+01	3.42E+01	3.42E+01	3.32E+01	6.78E+00	0.00E+00
Restoration Venting	0.00E+00	0.00E+00	3.73E+01	1.11E+02	1.08E+02	1.08E+02	1.18E+02	1.27E+02	8.45E+01
Restoration Purge	0.00E+00	0.00E+00	1.92E+01	5.77E+01	5.77E+01	5.77E+01	5.80E+01	5.79E+01	3.86E+01
Total	5.13E+00	1.48E+02	2.38E+02	3.45E+02	3.50E+02	3.53E+02	3.72E+02	2.25E+02	1.23E+02

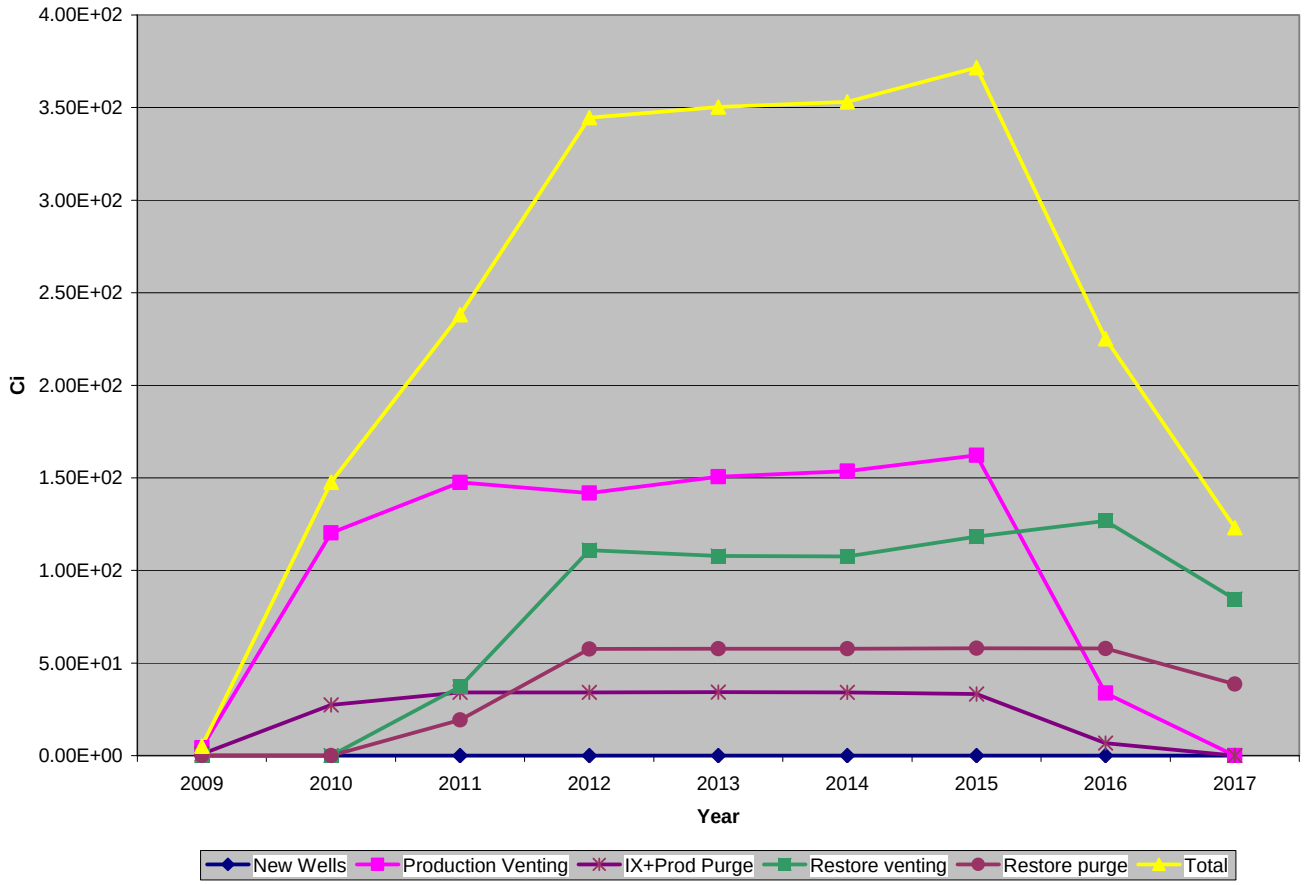


Figure 3. Calculated radon releases by source by year.

MAXIMUM DOSES TO INDIVIDUAL RECEPTOR LOCATIONS

Preferred Location (Plant 1)

For releases from the preferred location, estimated maximum annual total effective dose equivalents (TEDE) at individual receptor locations are shown below in Table 7 and Figure 4. The maximum dose for any receptor point occurs in 2015 at the SEB1 receptor location. This dose results exclusively from exposure to radon decay products, since there are no particulate releases from the facility. For this reason, the 40 CFR 190 annual dose commitments are zero in all cases. The shape of estimated doses through time reflects both the staging in different processes and their locations. For example, the centroid of mine unit 6 is located nearby to and upwind from receptor location SEB1.

Table 7. Total Effective Dose Equivalent to Maximum Individual by Location from Preferred Plant Location (mrem/yr).

	Total Effective Dose Equivalent to Maximum Individual (mrem/yr)								
Receptor location	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
NB	2.19E-02	6.22E-01	8.51E-01	1.40E+00	1.23E+00	1.25E+00	1.12E+00	7.61E-01	4.11E-01
NEB	1.41E-02	4.07E-01	6.43E-01	8.78E-01	9.58E-01	7.80E-01	7.68E-01	4.19E-01	2.40E-01
EB1	1.62E-03	4.73E-02	9.39E-02	1.13E-01	1.36E-01	1.04E-01	1.92E-01	1.02E-01	8.62E-02
SB	1.48E-03	4.24E-02	5.78E-02	1.30E-01	1.01E-01	2.82E-01	1.70E-01	1.67E-01	1.67E-02
SWB4	5.81E-04	1.66E-02	2.31E-02	4.10E-02	3.50E-02	5.68E-02	4.06E-02	3.22E-02	7.97E-03
WB	1.57E-03	4.48E-02	6.32E-02	1.17E-01	1.00E-01	1.55E-01	1.11E-01	8.71E-02	2.38E-02
NWB	1.33E-02	3.78E-01	5.09E-01	9.46E-01	8.01E-01	8.92E-01	7.12E-01	4.98E-01	2.39E-01
EB2	2.37E-03	6.85E-02	1.17E-01	1.52E-01	1.86E-01	1.49E-01	2.15E-01	1.12E-01	8.34E-02
EB3	3.36E-03	9.75E-02	1.81E-01	2.19E-01	2.75E-01	2.09E-01	3.82E-01	1.98E-01	1.66E-01
SEB1	8.02E-03	2.36E-01	5.23E-01	5.49E-01	9.01E-01	6.30E-01	3.01E+00	1.58E+00	1.66E+00
SEB2	9.96E-03	2.96E-01	6.96E-01	6.70E-01	9.61E-01	5.67E-01	1.56E+00	7.67E-01	7.54E-01
SEB3	6.28E-02	1.77E+00	1.60E+00	1.92E+00	8.35E-01	6.24E-01	4.08E-01	2.48E-01	1.01E-01
SWB3	3.94E-04	1.13E-02	1.65E-02	2.68E-02	2.38E-02	3.14E-02	2.56E-02	1.82E-02	6.41E-03
SWB2	5.70E-04	1.64E-02	2.33E-02	3.89E-02	3.35E-02	5.62E-02	4.25E-02	3.37E-02	8.90E-03
SWB1	1.11E-03	3.19E-02	4.44E-02	8.23E-02	6.94E-02	2.02E-01	1.31E-01	1.26E-01	1.38E-02
SEB4	5.02E-03	1.42E-01	1.56E-01	4.54E-01	2.81E-01	4.53E-01	2.08E-01	1.84E-01	3.22E-02
SEB5	2.57E-03	7.30E-02	9.03E-02	2.22E-01	1.54E-01	3.11E-01	1.73E-01	1.60E-01	2.23E-02

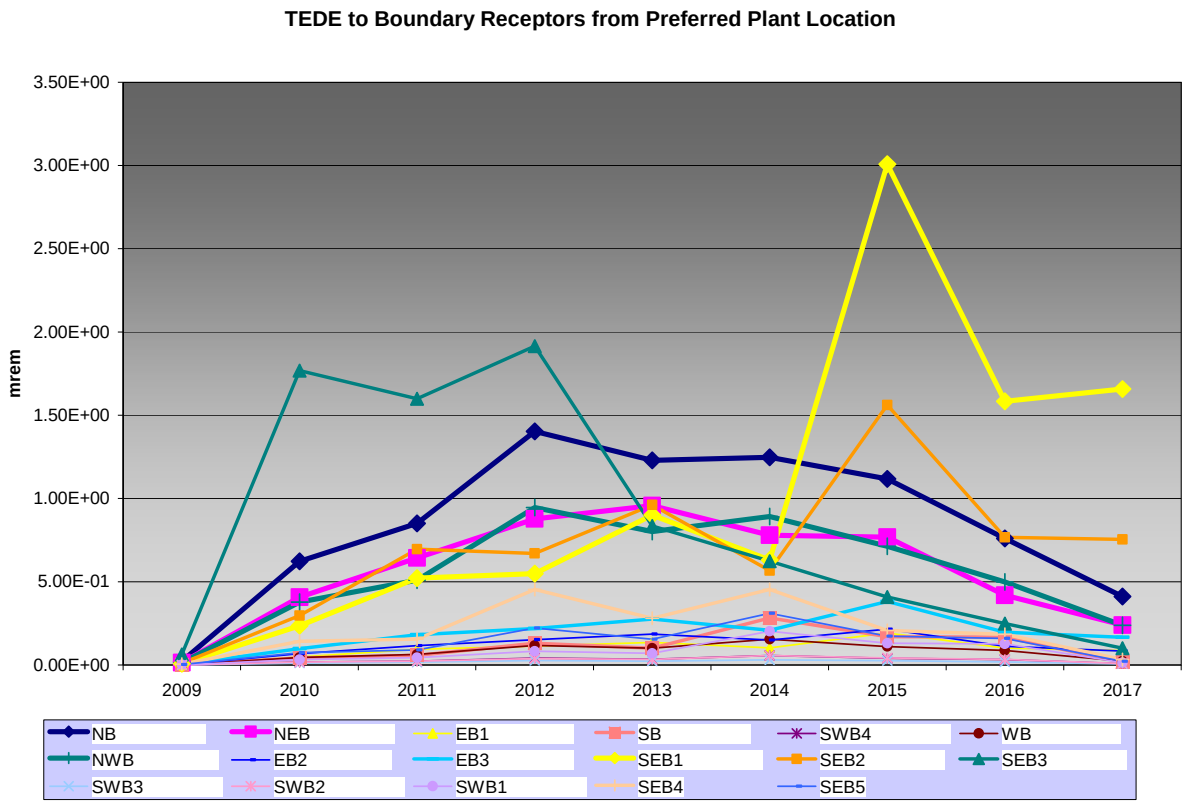


Figure 4. Total effective dose equivalent to maximum receptor from preferred plant location.

As shown in Figure 5, the vast majority of the dose to the SEB1 receptor location results from venting releases during production and restoration phases. These releases are modeled as occurring at the centroid of the mine unit. Most mine units are to the west of SEB1 and predominant winds have a westerly component nearly 60% of the time.

Doses to the north boundary (NB) receptor location, which is the closest point to the ion exchange columns have a maximum value of approximately 1.4 mrem in 2012 (Figure 6). Doses at NB are dominated by restoration purge, releases from the IX columns and production purge, which seems reasonable, given the close proximity (330m) to the plant centroid.

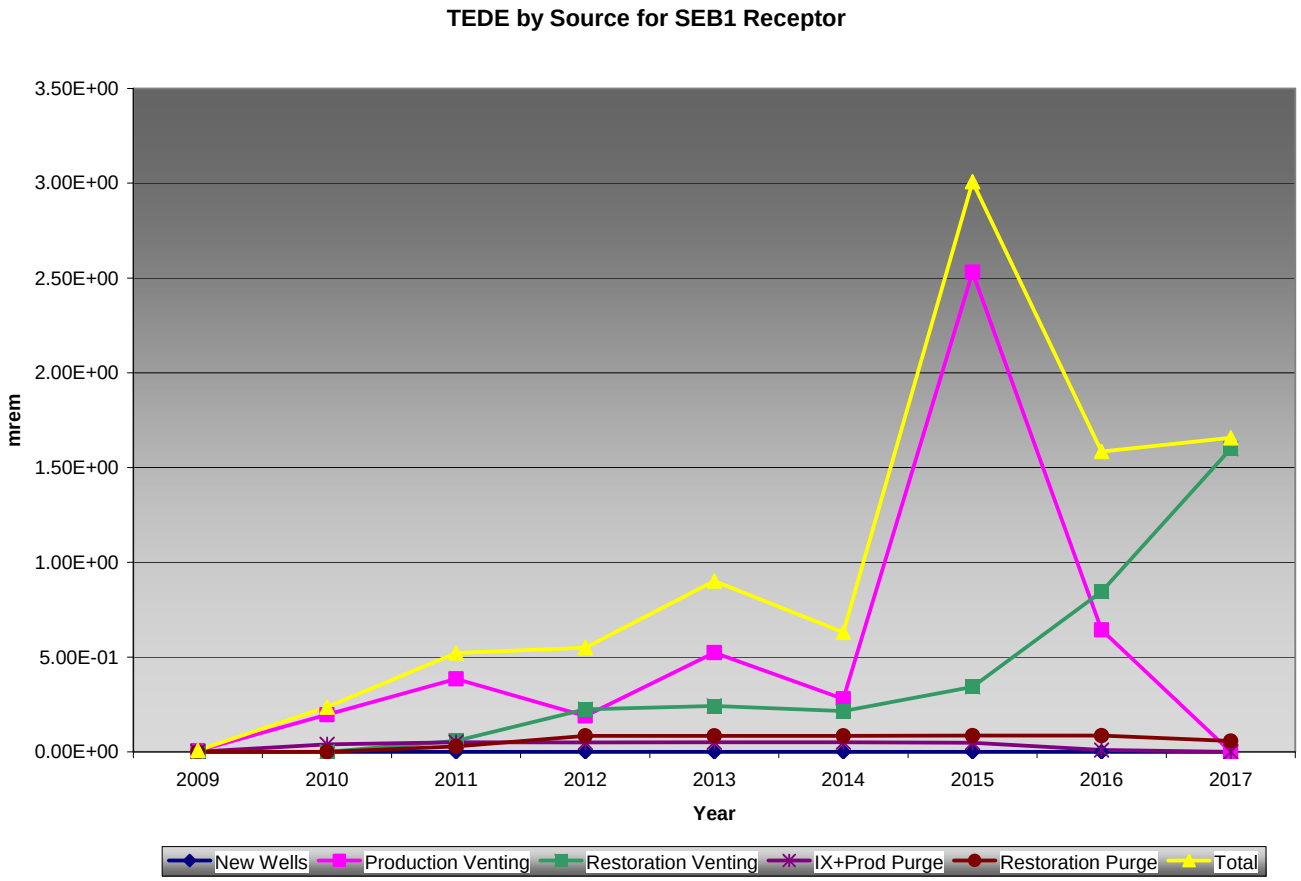


Figure 5. Total effective dose equivalent by source for SEB1 receptor location.

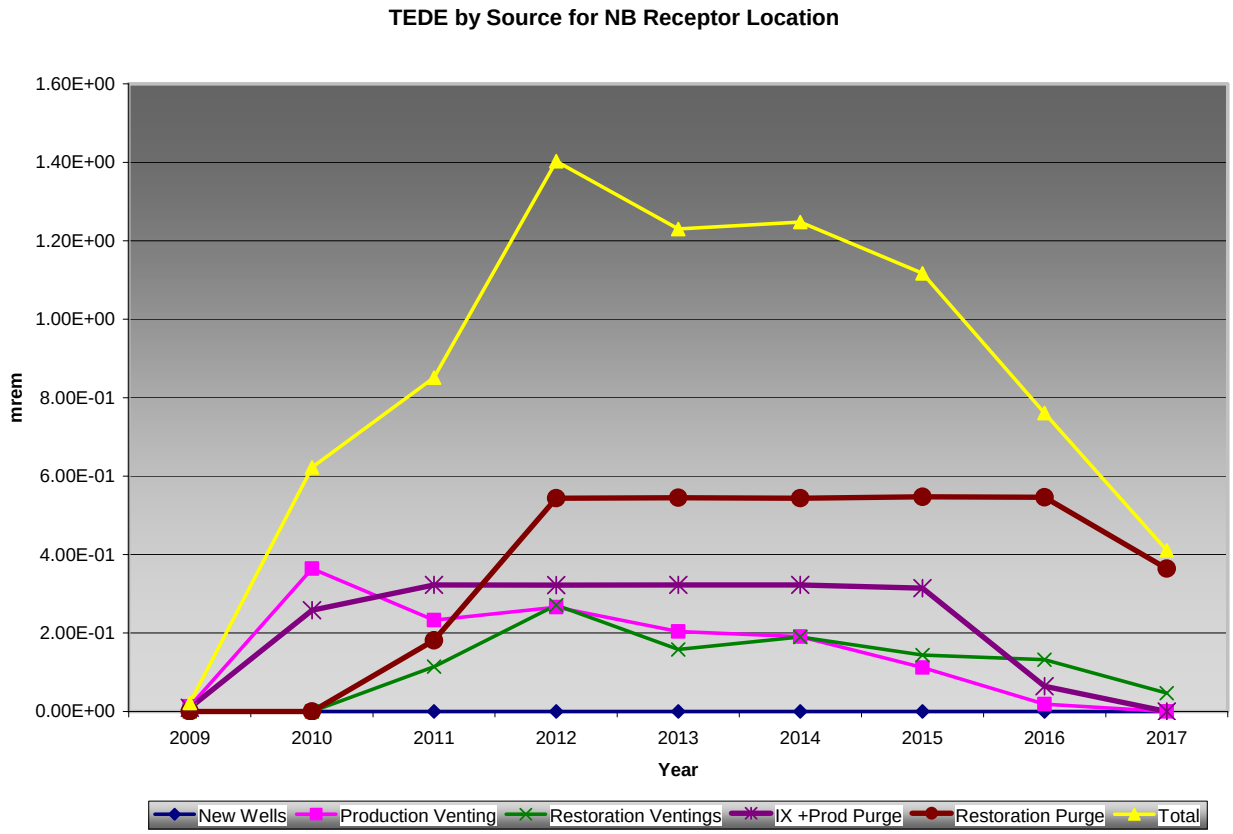


Figure 6. Total effective dose equivalent by source at the north boundary (NB) receptor location.

Alternate Location (Plant 2)

For releases from the alternate location (Plant 2), estimated maximum annual total effective dose equivalents (TEDE) at individual receptor locations are shown below in Table 8 and Figure 7. The maximum dose, 2.96 mrem, for any receptor point occurs in 2015 at the SEB1 receptor location. The shape of estimated doses through time reflects both the staging in different processes and their locations. By moving the plant to the alternative location, doses to the SEB3 location increase slightly from 1.92 mrem/yr to 2.47 mrem/y in the maximum year relative to doses if the plant is at the preferred location. It is important to note that moving the plant affects only releases from the ion exchange columns and the purge water, because we assume that all other releases occur at the centroid of the mine unit.

Table 8. Total Effective Dose Equivalent to Maximum Individual by Location from Alternate Plant Location (mrem/yr).

TEDE To Maximum Individual By Year and Location (mrem)									
Receptor	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
NB	1.40E-02	3.97E-01	4.11E-01	6.46E-01	4.72E-01	4.91E-01	3.65E-01	2.28E-01	9.26E-02
NEB	1.09E-02	3.13E-01	4.59E-01	5.63E-01	6.43E-01	4.65E-01	4.55E-01	1.97E-01	1.07E-01
EB1	1.62E-03	4.75E-02	9.43E-02	1.14E-01	1.37E-01	1.04E-01	1.93E-01	1.03E-01	8.65E-02
SB	1.78E-03	5.11E-02	7.47E-02	1.60E-01	1.30E-01	3.12E-01	1.99E-01	1.87E-01	2.90E-02
SWB4	6.51E-04	1.87E-02	2.71E-02	4.78E-02	4.18E-02	6.36E-02	4.73E-02	3.70E-02	1.08E-02
WB	1.54E-03	4.40E-02	6.18E-02	1.15E-01	9.75E-02	1.52E-01	1.08E-01	8.55E-02	2.28E-02
NWB	9.21E-03	2.61E-01	2.79E-01	5.52E-01	4.06E-01	4.97E-01	3.20E-01	2.20E-01	7.23E-02
EB2	2.17E-03	6.28E-02	1.05E-01	1.33E-01	1.67E-01	1.30E-01	1.96E-01	9.87E-02	7.54E-02
EB3	3.10E-03	9.01E-02	1.67E-01	1.94E-01	2.50E-01	1.84E-01	3.57E-01	1.80E-01	1.56E-01
SEB1	7.47E-03	2.21E-01	4.92E-01	4.97E-01	8.48E-01	5.78E-01	2.96E+00	1.55E+00	1.63E+00
SEB2	9.71E-03	2.89E-01	6.82E-01	6.45E-01	9.36E-01	5.42E-01	1.54E+00	7.50E-01	7.43E-01
SEB3	6.85E-02	1.94E+00	1.92E+00	2.47E+00	1.39E+00	1.18E+00	9.63E-01	6.42E-01	3.36E-01
SWB3	4.38E-04	1.26E-02	1.90E-02	3.10E-02	2.80E-02	3.57E-02	2.98E-02	2.11E-02	8.19E-03
SWB2	6.34E-04	1.82E-02	2.69E-02	4.51E-02	3.97E-02	6.24E-02	4.86E-02	3.81E-02	1.15E-02
SWB1	1.38E-03	3.98E-02	5.98E-02	1.09E-01	9.59E-02	2.28E-01	1.57E-01	1.44E-01	2.50E-02
SEB4	5.99E-03	1.70E-01	2.10E-01	5.47E-01	3.74E-01	5.46E-01	3.00E-01	2.50E-01	7.13E-02
SEB5	3.33E-03	9.49E-02	1.33E-01	2.96E-01	2.28E-01	3.84E-01	2.46E-01	2.12E-01	5.32E-02

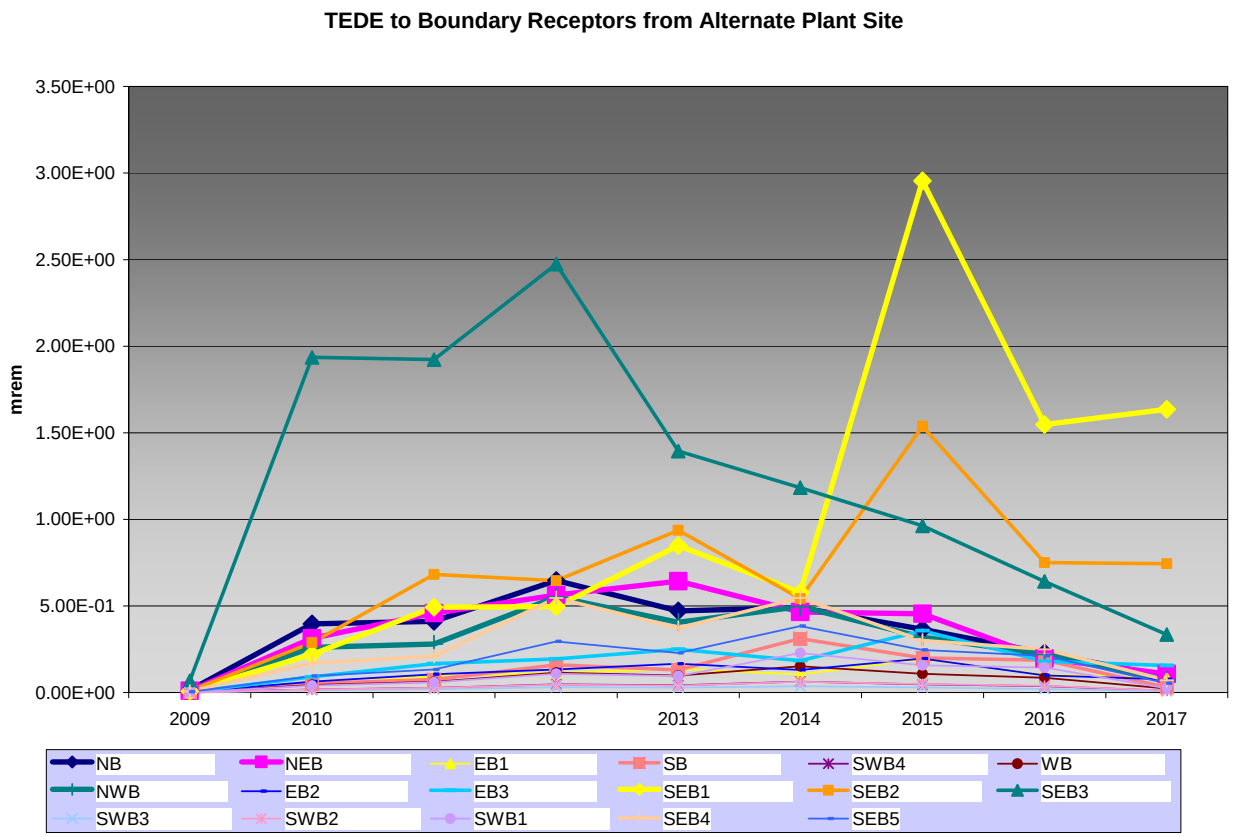


Figure 7. Total effective dose equivalent to maximum receptor from alternate plant location.

As shown in Figure 8, the major source of dose for the SEB1 receptor location is venting during production and restoration. This is to be expected because of the proximity of the mine units to the SEB1 receptor as shown in Figure 2.

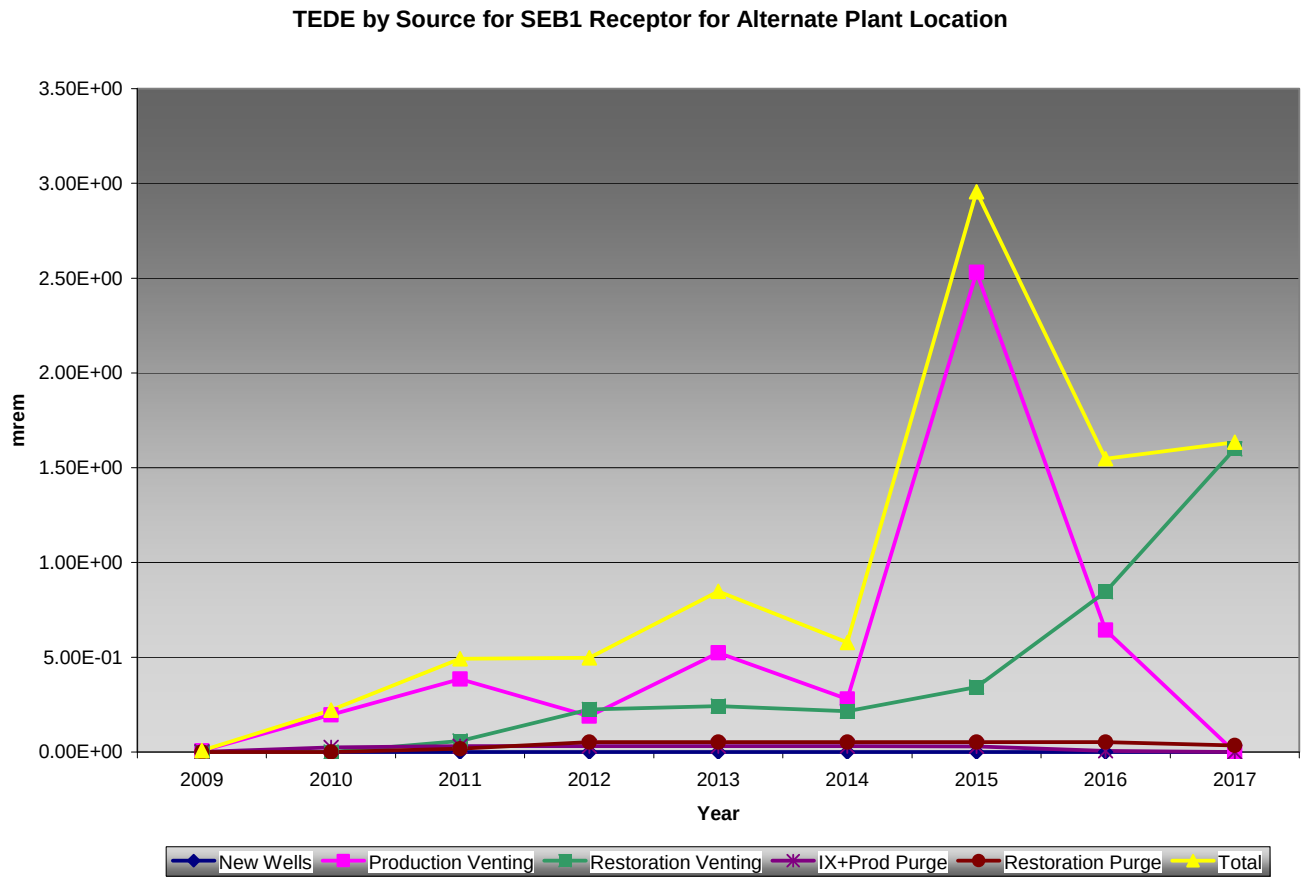


Figure 8. Total effective dose equivalent by type of release for SEB1 receptor location for releases using alternate plant location.

The effect of moving the plant to the alternate plant location can be seen by comparing Figure 9 to Figure 6. Calculated doses to the north boundary (NB) receptor location drop from 1.4 mrem/yr to approximately 0.7 mrem/yr if the ion exchange and purge water releases at the plant occur at the alternate plant location.

In summary, moving the plant to the alternate plant location has very little effect on dose to boundary receptor locations. For either plant location, the doses were far less than the standard of 100 mrem/yr. For actual receptors, doses would be even smaller because of the relatively large distances involved.

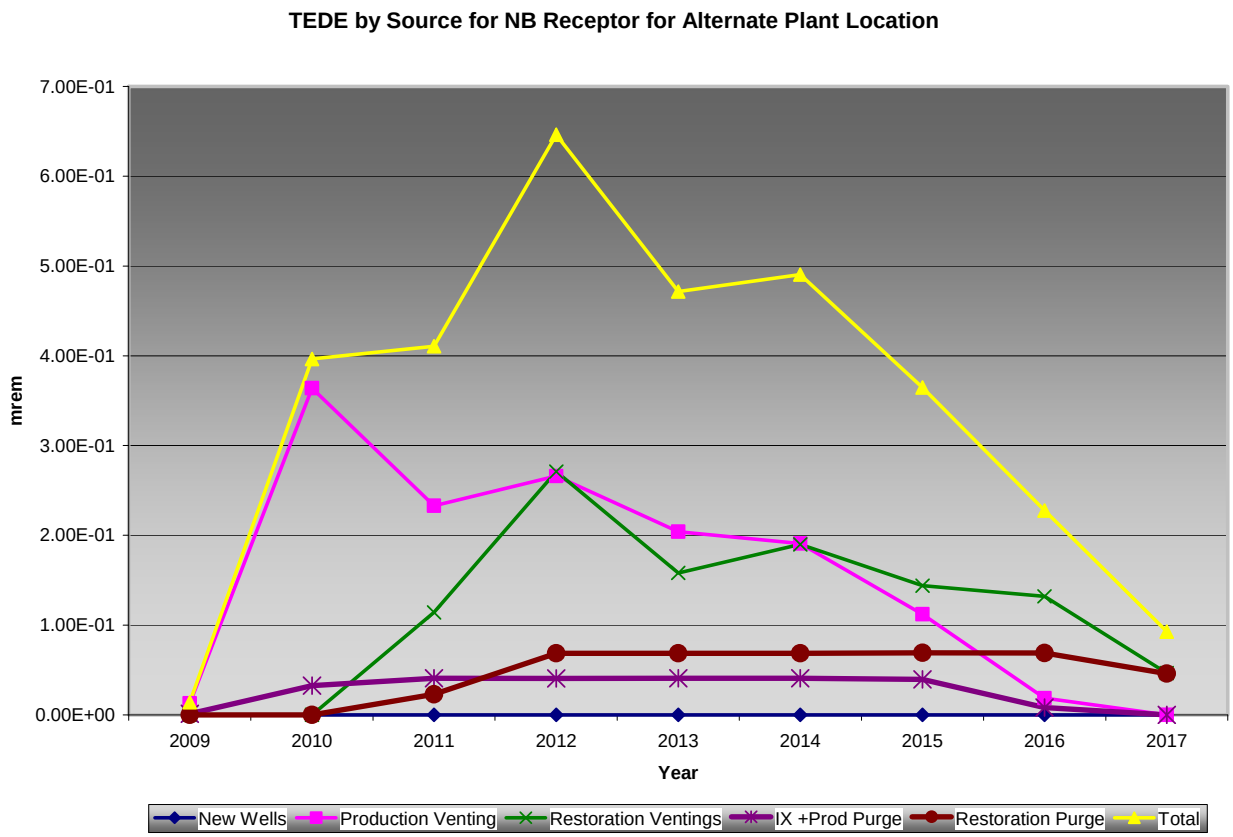


Figure 9. Total effective dose equivalent by source for NB receptor location from alternate plant location.

POPULATION DOSES

Using populations as shown in Table 5 above, 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 dose results are summarized in Table 9. The maximum estimated annual population dose is 1.87E-2 person-rem to the population within 80 km and 6.39 person-rem to all populations. While there is no regulatory limit for population dose, it is interesting to compare results in Table 6 to exposures from natural background. Again using the population data in Table 5, and assuming 350 mrem/yr from natural background, the natural background population dose would be approximately 3.1E3 person-rem/yr, or approximately 160,000 times higher than the maximum year of the Lost Creek project. The location of the plant at either the preferred location of

the alternate location would not influence population exposures because of the large distances involved and the relatively small distance between the preferred and the alternate plant locations.

Table 9. Dose to populations surrounding the proposed site.

	2009	2010	2011	2012	2013	2014	2015	2016	2017
	Total Effective Dose Equivalent (person-rem)								
Population within 80 km	1.29E-03	1.16E-02	1.45E-02	1.78E-02	1.80E-02	1.80E-02	1.87E-02	1.07E-02	3.87E-03
Population outside 80 km	4.38E-01	3.98E+00	4.94E+00	6.08E+00	6.14E+00	6.18E+00	6.37E+00	3.62E+00	1.32E+00
All populations	4.40E-01	3.99E+00	4.95E+00	6.10E+00	6.16E+00	6.19E+00	6.39E+00	3.63E+00	1.32E+00
	Bronchial Dose (person-rem)								
Population within 80 km	5.51E-03	1.59E-01	2.58E-01	3.68E-01	3.77E-01	3.73E-01	3.99E-01	2.39E-01	1.33E-01
Population outside 80 km	2.29E-01	6.60E+00	1.06E+01	1.54E+01	1.56E+01	1.58E+01	1.66E+01	1.01E+01	5.50E+00
All populations	2.35E-01	6.76E+00	1.09E+01	1.58E+01	1.60E+01	1.62E+01	1.70E+01	1.03E+01	5.64E+00

OCCUPATIONAL DOSES

Although it is outside the scope of the model, potential annual doses to a worker at the facility were modeled using MILDOS by creating hypothetical receptors nearby the plant. Four locations of the worker were defined by varying the (x,y) coordinates in km as (0,0.1), (0.1, 0), (0, -0.1), and (-0.1, 0). That places the hypothetical worker 100 meters N, E, S, and W from the plant. Annual doses were calculated to each worker location, multiplied by 0.22 (2000/8760) and averaged (Table 10, Figure 10). Calculated doses are well below occupational limits at less than 1 mrem annually. While this is an exceedingly low number it reflects the design of the facility which has radon releases occurring through a vent above the roof of the plant. Actual workers will be monitored and experience with other facilities of this type lead to the expectation that occupational doses will be very low.

Table 10 Dose to "Worker" Locations Calculated by MILDOS.

	Dose (mrem/y*)								
Location	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
100 m N	4.70E-03	1.33E-01	1.43E-01	2.37E-01	1.84E-01	1.89E-01	1.52E-01	9.81E-02	4.79E-02
100 m E	6.53E-03	1.85E-01	1.91E-01	3.00E-01	2.26E-01	2.23E-01	1.87E-01	1.18E-01	6.07E-02
100 m S	5.81E-03	1.63E-01	1.56E-01	2.52E-01	1.71E-01	1.74E-01	1.26E-01	7.93E-02	3.53E-02
100 m W	5.94E-03	1.69E-01	2.21E-01	3.81E-01	3.23E-01	3.34E-01	2.86E-01	1.96E-01	1.04E-01
Average	5.75E-03	1.63E-01	1.78E-01	2.93E-01	2.26E-01	2.30E-01	1.87E-01	1.23E-01	6.20E-02

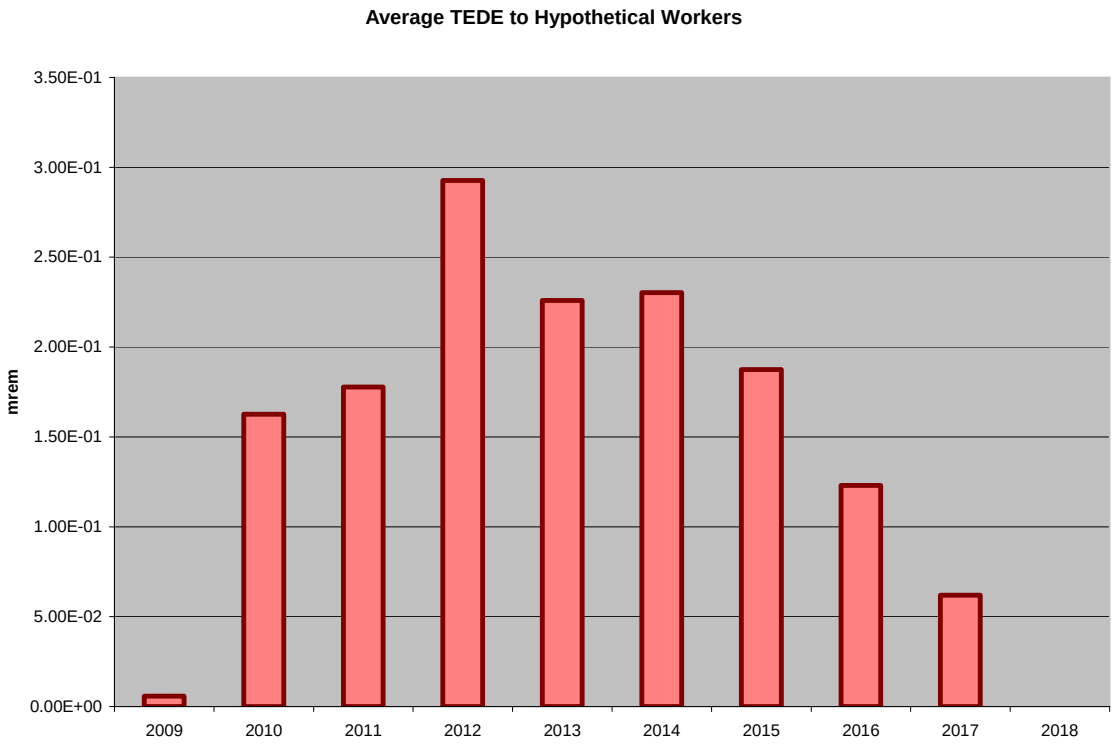


Figure 10 MILDOS-calculated doses to a hypothetical average worker located 100 m N, E, S and W from the plant.

SUMMARY

Results of MILDOS modeling show that boundary receptors receive only about 3% of the 10 CFR 20 limit of 100 mrem per year total effective dose equivalent (TEDE), whether the plant is located at either the preferred location or the alternative location. The major source of dose varies with receptor location and depends on staging of the releases through time at the various source locations. Releases from new mine units venting during production and restoration are assumed to occur at the centroid of the mine unit, so the location of the "plant" has no impact on those releases. Actual receptors are far removed from the permit area and would have even lower doses.

Because of the region's sparse population, very little population dose (person-rem/yr) occurs from the plant. Background exposures to surrounding populations are more than 1.6E5 times higher than contributions from the proposed facility. Doses to workers from releases at the facility are expected to be far below occupational dose limits and will be monitored during operations as required to provide documentation of actual exposures.

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.

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.

Appendix A to
Attachment 7.2-1

MILDOS Output Printouts

Estimated Radiation Doses from the
Lost Creek ISR, LLC Lost Creek In Situ Recovery Facility

March 2008