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July 10, 2012

LICENSE SUA-1341
DOCKET NO. 40-8520

Attn: Document Control Desk
U.S. Nuclear Regulatory Commission
Mr. Ron C. Linton, Project Manager
Decommissioning and Uranium Recovery
Licensing Directorate.
Division of Waste Management & Environmental Protection
Office of Federal & State Materials &
Environmental Management Programs
11545 Rockville Pike
Rockville, MD. 20852-2738

RE: Response to RAI's for Supplemental Information to 2008 License Renewal Application (TAC NO. J00564)

Dear Mr. Linton:

Uranium One is providing the following information in response to the Request for Additional Information (RAI's) submitted by NRC on June 7, 2012, in response to the supplemental information to the 2008 License Renewal Application to modify the Christensen Ranch process flow from 4000 to 9000 gallons per minute. As part of this response to RAI's Uranium One has provided the page replacements for the 2008 License Renewal Application that would be affected by the requested increase in flow for the Christensen Ranch. The replacement pages reflect the application of the 1.29 factor to adjust dose information to the requested 9000 gallon per minute (gpm) flow rate for the Christensen Ranch Satellite Facility.

Attached within this submittal please find the following:

- Index of change for page replacement instructions
- Red line strike-through that shows changes made to LRA page replacements
- Revised pages for insertion into the LRA
- Modified page two of the ERG report with the correct half-life for radon

If you have any questions or need additional clarification please contact me at jon.winter@uranium1.com or (307) 234-8235 ext. 331.

Sincerely,

Jon Winter
Manager of Environmental & Regulatory Affairs, Wyoming

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cc: Larry Arbogast

Encl: Page replacements for 2008 License Renewal Application for SUA-1341

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INDEX SHEET FOR SOURCE MATERIALS LICENSE AMENDMENTS

Date 7-10-12
SUA 1341

COMPANY NAME: **Uranium One USA, Inc.** FACILITY NAME: **Irigaray and Christensen Ranch ISR Uranium Project (Willow Creek)** SUA Number: **1341**

Statement: I, Jon Winter an authorized representative of **Uranium One USA, Inc.** declare that only the items listed on this and all consecutively numbered Index Sheets are intended as revisions to the current application document. In the event that other changes inadvertently occurred due to this revision, those unintentional alterations will not be considered approved. Please initial and date.

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PAGE, MAP OR OTHER APPLICATION ENTRY TO BE REMOVED	PAGE, MAP OR OTHER APPLICATION ENTRY TO BE ADDED	DESCRIPTION OF CHANGE
Section 7: Environmental Effects Remove Pages 7-7 through 7-8 Remove Pages 7-10 through7-19	*Section 7: Environmental Effects* Insert revised Pages 7-7 through 7-8 Insert revised Pages 7-10 through 7-19	*Section 7: Environmental Effects* Changes made to dose estimates by applying the 1.29 factor to adjust from 7000 gpm as shown in MILDOS model to the requested 9000 gpm. Changes reflect the new MILDOS dose calculation outputs with a 1.29 factor applied for the requested 9000 gpm production increase.
ERG MILDOS Report (Willow Creek) Remove Page 2	ERG MILDOS Report (Willow Creek) Replace Page 2	ERG MILDOS Report (Willow Creek) Corrected typo for radon half-life. Changed from 3.2 to 3.82 days

RAI #1

Provide updated pages to the 2008 License Renewal Application (LRA) to reflect the dose calculations in Section 7.3, Radiological Effects, and any other pertinent information for the proposed 9000 gallons per minute (gpm) flow rate.

The current submission includes dose calculations for a 7000 gpm flow rate based on a MILDOS analysis performed by Environmental Restoration Group, Inc. (ERG), not the requested 9000 gpm flow rate. For example, Section 7.3.3.4 provides TEDE information to individual receptors and the dose for a 7000 gpm production flow rate. Additionally, population doses, and other information, need to be revised to reflect the adjustment for a 9000 gpm flow rate. The licensee instructs the staff to apply a conversion factor of 1.29; however, the licensee should provide this information.

Uranium One Response

Uranium has applied the 1.29 factor to the dose calculation in Section 7.3 of the License Renewal Application (LRA) and provided replacement pages reflecting the adjusted dose information. Pages that are being replaced in Section 7.3 Radiological Effects are as follows:

Pages 7-7 through 7-8
Pages 7-9 through7-19

Dose calculations have been adjusted to reflect the 9000 gpm flow rate requested and replacement pages for the License Renewal Application denoting this adjustment are being provided within this RAI response package.

RAI #2

Clarify the 10 percent radon release rate in the well fields.

It is unclear to the NRC staff if the 10 percent of the total radon release rate is from production fluid released or from radon releases in each wellfield. Provide a basis for the 10 percent radon release rate used in the analysis.

Uranium One Response

The production fluid system from the wellfield to the Satellite Facility is a closed system until maintenance is performed on either the IX columns or wellfield production lines. The 10% radon release rate is based on historical operational information and is a conservative estimate on radon release from the wellfield and Satellite facility during maintenance events to the systems. This same 10% assumption was used for MILDOS calculations for other Uranium One satellite facilities that underwent NRC licensing review and approval.

RAI #3

Confirm the mine unit production areas used in the MILDOS calculations.

The LRA Section 7.3.3.1, Table 7.3-1, concerns parameters used to estimate and characterize source terms and shows that the mined area will be 1.65E+5 square meters per year (m^2/yr), or equivalent to 39.5 acres /year. The LRA indicates in Table 3.1 that the current production area (mine units (MU) are 202 acres (84 +71+57 =202 acres or 8.2E5 m^2). These MUs include 2-9. The assumptions for the MUs that will be operating in each year need to be clarified as to what value should be used in the MILDOS calculation.

Uranium One Response

The acreages listed in Table 3-1 are Estimated Mining Disturbance for multiple Mine Units (MUs) and also includes disturbance from exploration and delineation drilling as indicated in Table 3.1. The 39.5 acres used in the MILDOS is an estimate based on average size for a particular wellfield. Regardless, the size of the production area or MU will have no effect on the MILDOS output as this is based on production flow rate not the size of the wellfield.

RAI #4

Confirm the radon-222 half-life uses in the supplemental information.

Page 2 of the ERG Report listed the radon-222 half-life as 3.2 days. This appears to be a typographical error since the half-life is reported as 3.82 days in the technical information.

Uranium One Response

The reference to the half-life of radon-222 as 3.2 days on page 2 of the ERG Report is a typographical error. The correct half-life of 3.82 days was utilized in the calculation for MILDOS. Uranium One will provide a corrected page 2 to NRC for insertion into the ERG Report.

RAI #5

Explain the apparent contradiction between the 2875 Ci/yr radon-222 releases reported in Section 3.2.1.1 of the ERG Report and the 1480 Ci/yr radon releases reported in the LRA supplemental pages in LRA Section 7.3.3.1.1.

There appears to be a problem with information transfer from the ERG Report to the LRA, Section 7.3, supplemental pages. ERG Section 3.2.1.1 for the Willow Creek Christensen Ranch satellite facility dated August 2011 indicates that the radon-222 release to production fluid is 2875 Ci/yr. The supplemental information , Page 7-12, Section 7.3.3.1.1 indicates that the radon release to production fluid is 1480 Ci/yr. Both documents indicate that the NRC Regulatory Guide 3.59 equations and the same operations parameters were used to determine the radon-222 release rate to production fluid.

Uranium One Response

The information on page 7-12 indicating the radon-222 release rate to production fluid of 1480 Ci/yr is incorrect, and was an information transfer issue from the ERG report to the LRA. The correct value is 2875 Ci/yr which reflects the 7000 gpm utilized in the MILDOS calculation. Section 7.3.3.1.1, page 7-12 has been corrected to show the radon-222 release to production fluids is 2875 Ci/yr times the 1.29 correction factor (3709 Ci/yr) to adjust for the increase from 7000 gpm as shown in the MILDOS calculation to 9000 gpm requested as part of the supplemental information request.

RAI #6

Correct or confirm the production column values in the LRA Table 7.3-2

The LRA Table 7.3-2, Estimated Radon-222 Release (Ci/y), has an apparent "addition" error in the production column. However, the total column is correct for the total for all production units and the Christensen Ranch satellite facility.

Uranium One Response

The addition error in the production column has been corrected.

RAI #7

Clarify in the LRA the type of dryer used at the Willow Creek Irigaray facility.

The description of the yellowcake dryer appears to be inaccurate. LRA, Section 7.3.3.1.6, describes the yellowcake dryer as a vacuum rotary type. LRA Section 7.3 states, "The uranium contained in the regenerant from the production ion exchange columns will be precipitated and subsequently vacuum dried." Subsequently, LRA Section 7.3 describes the yellowcake dryer as a propane-fired multi-hearth dryer.

Uranium One Response

In review of the LRA it was noticed that Section 7.3, page 7-7 of the May 2008 LRA that the first sentence of the fourth paragraph incorrectly referenced a vacuum dryer. Irigaray currently utilizes a propane-fired multi-hearth for drying and packaging operations. The supplemental data package modified this from "The drying and packaging operations at Irigaray will be conducted under vacuum; and as such, the only significant routine emission at the Facility will be radon daughters" to "The drying and packaging operations at Irigaray will be conducted using a propane-fired multi-hearth dryer with emissions controlled by a high efficiency water scrubber." Apparently the reference to a vacuum drier was overlooked in Section 7.3.3.1.6 and not corrected as part of the supplemental data package update.

Uranium One will correct the reference to a vacuum dryer in Section 7.3.3.1.6 to indicate the "The yellowcake dryer is a propane-fired multi-hearth dryer with emissions controlled by a high efficiency water scrubber."

RAI # 8

Clarify the deep disposal well(s) ability to handle and dispose of up to 315 gpm brine generated at a 9000 gpm flow rate capacity during the Joint Production / Restoration Phase of operations.

Uranium One Response

In accordance with Wyoming Department of Environmental Quality Water Quality Division (WDEQ-WQD) approved Class I UIC Permit 00-340 (dated November 3, 2000) four deep waste disposal wells (Christensen Ranch Disposal Wellfield) are permitted for the injection of ISR wastewater from production operations and ground water restoration activities. Accordingly, two of the four wells (CR 18-3 and CR DW No. 1) have been operating since 2000 and are currently in use. Wells CR No. 2 and CR No. 3 are approved in UIC Permit 00-340 but have not yet been constructed as they are not required until ground water restoration commences, and the volume of wastewater increases such that additional disposal capacity is required.

The current Permit Renewal Application for UIC Permit 00-340 was submitted to the WDEQ-WQD in May 2010 and contains detailed information related to the four permitted injection wells including; injection zones thickness, seismicity information, "Area of Review" calculations, injection pressure calculations, etc. For each well, an estimated *average* injection rate of 75 gpm per well was assumed for the life of the project for the "Area of Review" and injection pressure calculations. The permitted maximum injection rate for each well is conditioned at 250 gpm. Historic disposal rates for the existing wells exhibited maximum injection rates of 104 gpm for CR DW No. 1 and 95 gpm for 18-3. It is assumed that the two wells to be installed (CR No.2 and CR No. 3) will be completed in the same formation and will operate in a similar fashion as the two existing wells. Therefore the wastewater disposal capacity of the four wells operating together will range from a maximum of approximately 400 gpm to a minimum of at least 315 gpm.

It is anticipated that the maximum production flow rate will be approximately 8200 gpm, restoration flow will be managed to maintain flows within the operating capacities of the site disposal system (315 gpm – 400 gpm). Therefore, at the point when the maximum production flow is reached (8200 gpm – or 82 gpm bleed) the disposal capacity for restoration flows would still be approximately 233 gpm. The current projected maximum restoration flow is 225 gpm.

RAI # 9

Demonstrate that the Willow Creek ISR Project has the waste disposal capacity or a contingency plan to insure that wellfield bleed can be maintained and restoration can be completed if one of the disposal wells fails

Uranium One Response

The response to RAI # 8 demonstrates that there will be adequate capacity to dispose of the estimated wastewater volumes pending the approval of additional disposal capacity form CR DW No.2 and CR DW No3. Based on the current production/restoration schedule a third disposal well would not be needed to increase the capacity above that of the existing two wells until early 2016. If one of the waste disposal wells is unavailable the surge capacity at the four lined evaporation ponds will be utilized until the well is repaired and the other wells will be utilized at their maximum capacity. It is also an option to temporarily reduce the wastewater generated by restoration activities for a given mine unit until the well is repaired and put back into service.

RAI #10

Confirm LRA pages 5-4a through 5-5 are to be removed and replaced by pages 5-4a through 5-5, dated February, 2012.

The NRC staff cannot find page 5-4a in the LRA to be replaced by page 5-4a dated February, 2012. LRA page 5-5, dated May, 2008 has more information than is being replaced by page 5-5 dated March 7, 2012.

Uranium One Response

There is no page 5-4a in the 2008 LRA to be removed. Page 5-4a dated February 2012 is a new page to be inserted between pages 5-4 and 5-5. Some information that was previously contained on page 5-5 dated May 2008 has been incorporated onto the new page 5-4a dated February 2012.

7.3 RADIOLOGICAL EFFECTS

Uranium One USA, Inc. (Uranium One) is proposing to increase the wellfield production for Willow Creek Christensen Ranches operating uranium in-situ recovery facility to a production and restoration flow of approximately 9000 and 1000 gallons per minute (gpm), respectively. An assessment of the radiological effects of the Christensen Ranch-Irigaray facility (the Facility) must consider the types and potential consequences of radiological emissions and potential pathways present.

The Facility will use fixed-bed pressurized down flow ion exchange columns to separate uranium from the pregnant production fluid and treat restoration solutions. The uranium contained in the regenerant from the production ion exchange columns will be precipitated and subsequently vacuum dried.

In addition to ion exchange treatment, the groundwater restoration process will use reverse osmosis to remove the dissolved solids. Liquid and solid waste disposal will occur via direct deep well injection, placement into new or existing surface impoundments, or offsite disposal at an appropriate licensed disposal facility.

The Facility will consist of a main processing plant (Irigaray) and a satellite facility (Christensen Ranch), where an ion exchange system similar to the one described above will operate. The resin from the satellite facility will be transferred to the main processing plant for elution. An average of 1 resin transfer per day from the satellite facility is anticipated. Uranium precipitation, drying, and packaging operations will be conducted at the main processing plant.

The drying and packaging operation at Irigaray will be conducted using a propane-fired multi-hearth dryer with emissions controlled by a high efficiency water scrubber. Atmospheric radon-222 is expected to be the predominant pathway for impacts on human and environmental media with smaller potential impacts form long lived radionuclides emitted from the yellowcake dryer stack. Plans are being considered to add an additional vacuum drying system to the current operations which under vacuum; as such, the only significant routine emission at the Facility will be radon-222 gas. Radon-222, a decay product of radium-226, is dissolved in the lixiviant as it travels through the ore to a production well where it is brought to the surface. The concentration of radon-222 in the production solution and estimated releases were calculated using the methods found in US NRC Regulatory Guide 3.59, "Methods for Estimating Radioactive and Toxic Airborne Source Terms for Uranium Milling Operations" (NRC 1987) and NUREG 1569 "Standard Review Plan for In Situ Leach Uranium Extraction License Applications" (NRC 2003). The details of and assumptions used in these calculations are found in Section 7.3.3

MILDOS-AREA (ANL 1997) (see Appendix D for the MILDOS printout) was used to model radiological impacts on human and environmental receptors (e.g., air and soil) using site-specific release estimates, meteorological and population data, and other parameters. All of the pathways related to air emissions of radon-222 and airborne particulates are evaluated by MILDOS-AREA. The estimated radiological impacts resulting from routine site activities are compared to applicable public dose limits as well as naturally occurring background levels.

7.3.1 Exposure Pathways

Figure 7.3-1 presents exposure pathways from all potential sources at the Facility. The

predominant pathways for planned and unplanned releases are identified. Atmospheric radon-222 is expected to be the predominant pathway for impacts on human and environmental media with smaller potential impacts from long lived radionuclides emitted from the yellowcake dryer stack. Potential impacts of releases can be expected in all quadrants surrounding the Facility, the magnitude of which is driven predominantly by wind direction and atmospheric stability. As a noble gas, radon-222 itself has very little radiological impact on human health or the environment. Rather, it is the radon-222 decay products that are of concern. Radon-222 has a relatively short half-life (3.82 days) and its decay products are short-lived, alpha-emitting, nongaseous radionuclides. Figure 7.3-1 shows that all exposure pathways, with the possible exception of skin absorption, can be important depending on the environmental media impacted.

7.3.2 Exposures from Water Pathways

The mining solutions in the ore zone will be controlled and adequately monitored to ensure that migration does not occur. The overlying and underlying aquifers, if present, will also be monitored.

The primary method of waste disposal at the Facility will be by deep well injection or placement in surface impoundments. Two licensed deep injection well exists at the Facility. Uranium One anticipates the need to add a third deep injection well by January 2016.

The uranium ion exchange, precipitation, drying and packaging facilities will be located on curbed concrete pads to prevent any liquids from entering the environment. Solutions used to wash down equipment will drain to a sump and either be pumped back into the processing circuit or disposal well. The pads will be of sufficient size to contain the contents of the largest tank in the event of a rupture.

No routine liquid environmental discharges, other than waste disposal via deep well injection or lined surface impoundment, are planned and as such, no definable water-related pathways for routine operations exist. There is a surface discharge permit for Christensen Ranch, but any such discharge would be limited in volume and consist of very clean permeate water from reverse osmosis treatment.

7.3.3 Exposures from Air Pathways

The only significant sources of radionuclide emission are radon-222 released into the atmosphere through a vent system in the satellite plant, releases from the wellfields and long lived radionuclides released into the atmosphere through the yellowcake stack at the Irigaray Plant. As shown in Figure 7.3-1, atmospheric releases of radon-222 can result in radiation exposure via three pathways: inhalation, ingestion, and external exposure. The Total Effective Dose Equivalent (TEDE) to a hypothetical person living at receptor locations surrounding the facility as well as actual residences was estimated using MILDOS-Area.

7.3.3.1 Source Term Estimates

The source terms used to estimate radon-222 releases from the Facility include two well fields in production, two restoration well fields, one new well field, and the satellite processing facility. The radon-222 releases from these source terms are calculated using methods described in Sections 7.3.3.1.1 through 7.3.3.1.4 below. For the Christensen Ranch area, mine units 10-12 and 7 were chosen based on their proximity to site boundaries and predominant wind directions. The parameters used to characterize and estimate releases are provided in Table 7.3-1.

Table 7.3-1
Parameters used to estimate and characterize source terms at the Christensen Ranch - Irigaray uranium in-situ recovery facility.

Parameter	Value	Unit	Source
Average ore grade	0.094	%	Application
Ore radium-226 concentration	265	pCi g^{-1}	Reg. Guide 3.59
Mined area	1.6E+05	$m^2\ y^{-1}$	Application
Average lixiviant flow	2.65E+04	L m^{-1}	Application
Average restoration flow	1.89E+03	L m^{-1}	Application
Operating days per year	365	days	Full-time operation assumed
Ore formation thickness	3.7	meters	Application
Ore formation porosity	0.28		Application
Ore formation rock density	1.91	g cm^{-3}	Estimated
Average residence time for lixiviant	8.7	days	Application
Average residence time for restoration solutions	30	days	Application
Average mass of ore material in mud pit	5.2E+05	g	Estimate based on planned activities
Number of mud pits generated per year	300		Estimate based on planned activities

Storage time in mud pits	14	days	Estimate based on planned activities
Radon-222 emanating power	0.2		Reg. Guide 3.59
Radon-222 release rates	0.1	y^{-1}	Estimate based on process
Resin porosity	0.4		NUREG 1569
Ion exchange column volume	1.42E+04	L	Estimate based on planned activities
Number of resin transfers per day (Christensen Ranch only)	2		Estimate based on planned activities
Stack height	16	m	Application
Stack diameter	0.3	m	Application
Stack velocity	11	$m\ s^{-1}$	Application
Radon-222 decay constant	0.181	d^{-1}	NUREG 1569

7.3.3.1.1 Production Releases

Currently, plans are to have up to two wellfield areas that potentially could be mined concurrently. The potential radon-222 releases from the production well fields were estimated using methods described in NRC Regulatory Guide 3.59 as follows:

Radon-222 released (equilibrium condition) to production fluid from leaching is calculated using Equation 1:

$$G = R\rho E \frac{(1-p)}{p} x10^{-6} \qquad \text{(Equation 1)}$$

Where:

G = radon-222 released (Ci m^{-3})
R = radium content of ore (pCi/g)
E = emanating power
ρ = rock density (g cm^{-3})
p = formation porosity

The yearly radon-222 released to the production fluid is calculated using Equation 2:

$$Y = 1.44GMD(1-e^{-\lambda t}) \qquad \text{(Equation 2)}$$

Where:

Y = yearly radon-222 released to production fluid (Ci yr^{-1})

G	=	radon-222 released at equilibrium (Ci m^{-3})
M	=	lixiviant flow rate (L min^{-1})
D	=	production days per year (d)
λ	=	radon-222 decay constant (d^{-1})
t	=	lixiviant residence time
1.44	=	unit conversion factor

Using Equations 1 and 2 and the parameters in Table 7.3-1, the radon-222 release rate to production fluid is ~~1480~~3709 Ci yr^{-1}. NRC Regulatory Guide 3.59 assumes all radon-222 that is released to the production fluid is ultimately released to the atmosphere, which in the case of ion exchange columns operating at atmospheric pressure in an open system is an appropriate, conservative assumption. In cases where pressurized ion exchange columns are used and wellfields are operated under pressure, the majority of radon released to the production fluid stays in solution and is not released. Fugitive radon-222 is released from occasional well field venting for sampling events, small unavoidable leaks in well field and ion exchange equipment, and maintenance of well field and ion exchange equipment. For this reason, an annual release of 10% of the radon-222 from the production fluid is assumed to occur in the well fields. An additional 10% release in the ion exchange circuit is assumed. This release includes any releases from the worst case bleed stream (125 gallons per minute). Given these assumptions, the annual radon-222 released from production in the wellfields and the satellite facility is 372 and 334 Ci yr^{-1}, respectively. In the MILDOS-AREA model simulations, the wellfield release of 374 Ci yr^{-1} was distributed equally among Mine Areas 7 and 10-12.

7.3.3.1.2 Restoration Releases

Radon-222 releases resulting from wellfield restoration activities were estimated in the same manner as the production activities above (i.e. using Equation 2) but modified for the lower restoration flow rate and longer restoration fluid residence time, both of which are listed in Table 7.3-1. A 10% release in the wellfield, as in the production release, was assumed. A 100% release was assumed at the treatment facility since it is not known whether the restoration water treatment will be under pressure. These assumptions yield a radon-222 release rate of 26 Ci yr^{-1} in the wellfield and 231 Ci yr^{-1} at the satellite facility. In the MILDOS-AREA model simulations, the wellfield release of 26 Ci yr^{-1} was distributed equally among Mine Area 7 and 10-12.

7.3.3.1.3 New Well Field Releases

Radon-222 releases resulting from new wellfield development activities were estimated using methods described in NUREG-1569 as follows:

$$Rn_{nw} = E\lambda[Ra]TmNx10^{-12} \qquad \text{(Equation 3)}$$

Where:

Rn_{nw}	=	Radon-222 release rate from new well field (Ci yr^{-1})
E	=	emanating power
[Ra]	=	concentration of radium-226 in ore (pCi g^{-1})
λ	=	decay constant of radon-222
T	=	storage time in mud pit (d)
m	=	average mass of ore material in the pit (g)
N	=	number of mud pits generated per year
10^{-12}	=	unit conversion factor (Ci pCi^{-1})

Using Equation 3 and the parameters in Table 7.3-1, the yearly radon released from new well field development is 0.02 Ci yr^{-1}. In the MILDOS-AREA model simulations, the new wellfield release was assumed to occur at Mine Areas 7 and 10-12.

7.3.3.1.4 Resin Transfer Releases

The radon-222 release resulting from resin transfers from the Christensen Ranch satellite facility was estimated using methods described in NUREG-1569 as follows:

$$Rn_x = 3.65x10^{-10} F_i C_{Rn} \qquad \text{(Equation 4)}$$

Where:

Rn_x	=	Radon-222 release rate from resin transfers (Ci yr^{-1})
F_i	=	water discharge rate from resin unloading (L d^{-1})
C_{Rn}	=	Steady state radon-222 concentration in process water (pCi L^{-1})
$3.65x10^{-10}$	=	unit conversion factor (Ci pCi^{-1})(d yr^{-1})

The steady state radon-222 concentration in process water (C_{Rn}) was estimated from the following expression:

$$C_{Rn} = \frac{Y * 1.9x10^6}{M} \qquad \text{(Equation 5)}$$

Where:

C_{Rn}	=	Steady state radon-222 concentration in process water (pCi L^{-1})
Y	=	yearly radon-222 released to production fluid (Ci yr-[1])
M	=	lixiviant flow rate (L min^{-1})
$1.9x10^6$	=	unit conversion factor (pCi Ci^{-1})(yr min^1)

The water discharge rate from resin unloading (Fi) was estimated from the following expression:

$$F_i = N_i * V_i * P_i \qquad \text{(Equation 6)}$$

Where:

F_i	=	water discharge rate from resin unloading (L d^{-1})
N_i	=	Number of resin transfers per day
V_i	=	volume of resin in transfer (L)
P_i	=	porosity of resin

Using Equations 4 through 6 and the parameters in Table 7.3-1, the radon-222 released from resin transfers from the Christensen Ranch satellite facility is 0.86 Ci yr^{-1}. In the MILDOS-AREA model simulations, the resin transfer release was assumed to occur only at the Christensen Ranch satellite plant site.

7.3.3.1.5 Radon-222 Release Summary

A summary of estimated radon-222 releases from the Facility is presented in Table 7.3-2. The source coordinates in Table 7.3-2 and 7.3-3 are relative to the Christensen Ranch satellite facility.

Table 7.3-2
Estimated Radon-222 releases (Ci yr^{-1}) from Christensen Ranch-Irigaray Facility.

			Radon-222 Releases (Ci yr^{-1})				
Location	**X (km)**	**Y (km)**	**Production**	**Restoration**	**Drilling**	**Resin Transfer**	**Total**
CR Mine Area 7	0.66	1.71	186	13	0.02	0	199.02
CR Mine Area 10-12	-1.16	-0.74	186	13	0.02	0	199.02
CR Satellite Plant	0	0	334	231	0	0.8642	565.86
Irigaray Thermal Dryer	-7.09	9.22	0	0	0	0	0
Total			706281	257	0.04	0.8642	963.90

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Notes:
CR = Christensen Ranch

7.3.3.1.6 Other Airborne Radionuclide Releases

The yellow cake dryer stack at the Irigaray location will have minimal releases of long lived radionuclides including natural uranium, radium-226, thorium-230, and lead-210. The yellow cake dryer is a propane-fired multi-hearth with emissions controlled by a high efficiency water scrubbervacuum rotary type; resulting in minimal particulate emissions. The emission quantities of these radionuclides were taken from monthly release rates reported in "*Cogema Resources Company Yellow Cake Dryer Stack Test Report*" (WEST 2005) and scaled to reflect annual emission quantities. These quantities are summarized in Table 7.3-3.

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Table 7.3-3
Estimated long-lived radionuclide releases (Ci yr^{-1}) from Irigaray Facility.

			Long-Lived Radionuclide Releases (Ci yr^{-1})			
Location	**X (km)**	**Y (km)**	**Natural Uranium**	**Radium-226**	**Thorium-230**	**Lead-210**
Irigaray Thermal Dryer	-7.09	9.22	0.009	2.6E-06	4.4E-06	1.1E-04

7.3.3.2 Receptors

Two types of receptors were used in the MILDOS-AREA simulation. First, arbitrary receptors were identified based on an approximate 0.5 km grid system across the site. The grid system was established using a random staring point. A total of 1050 arbitrary receptors were modeled to develop iso-dose curves in and around the permit boundary using a kriging method described in ArcMap GIS software. Second, potential receptor locations were identified and modeled. The receptors used in the MILDOS-AREA simulations are presented in Appendix D and represent directional and residential receptors. The estimated annual exposure hours for receptors in Table

7.3.5 are based on 24 hours per day for one year. Some of the receptors in Table 7.3.5 are within the permit area so the residence scenario may be unrealistic but is a conservative estimate.

Table 7.3-4
Christensen Ranch-Irigaray receptor names and locations

Receptor	X (km)	Y (km)	Distance (km)
1. AS-1	-3.66	-0.46	3.69
2. AS-5A	0.01	-0.05	0.05
3. AS-5B	-0.01	0.01	0.012
4. AS-6	3.51	-3.73	5.12
23. IR-1	-7.18	9.28	11.73
24. IR-3	-7.05	9.22	11.61
25. IR-4	-7.09	10.06	12.31
26. IR-5	-9.22	15.09	17.68
27 IR-6	-6.02	8.50	11.24

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Notes:
AS = Air monitoring station IR = Irigaray

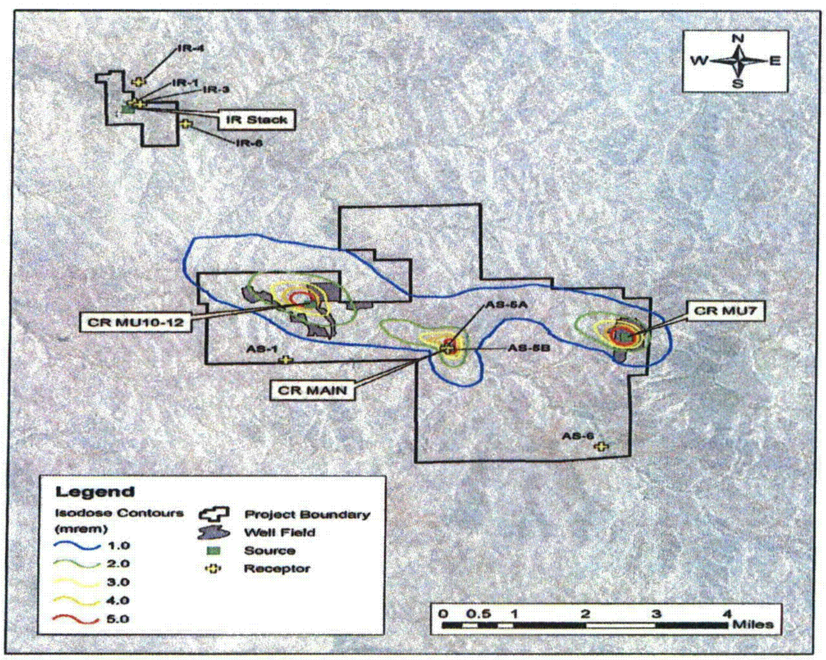

Figure 7.3-2 Iso-Dose Map of Willow Creek ISR Project

7.3.3.3 Miscellaneous Parameters

The meteorological data used in the MILDOS-AREA model is from the Joint Frequency Distribution data presented in Appendix D4 of the Mine Permit No. 478 Christensen Ranch amendment application (1988).

The population distribution used in the MILDOS-AREA model to estimate population doses is from the demographic information presented in Section 2.0 of this amendment application.

7.3.3.4 Total Effective Dose Equivalent (TEDE) to Individual Receptors

In order to show compliance with the annual dose limit found in 10 CFR 20.1301, COGEMA has demonstrated by calculation that the TEDE to the individual most likely to receive the highest dose from the Facility operation is less than 100 mrem per year. The results of the MILDOS-AREA simulation for each potential receptor location in Table 7.3-5 are presented in Table 7.3-6.

An evaluation of the TEDE follows:

1) The maximum TEDE of 3.4 mrem/yr, located 200 meters south of the Christensen Ranch satellite facility, is 3.4 percent of the public dose limit of 100 mrem/yr. Occupationally exposed workers would be expected to be at this location for a fraction of their work time.

2) The TEDE to the site's nearest residents ranged from 0.14 to 3.4 mrem/yr.

3) All dose rates outside the permit boundary are less than 3 mrem per year and in most instances all dose rates outside the permit boundary are less than 1 mrem/yr as demonistrated in Figure 7.3-2. These estimates are based on 100% occupancy for a year.

4) The effect of the Facility operation at any potential resident is less than or equal to 3.4 mrem/yr TEDE.

5) The contributions from long-lived radionuclide emissions from the thermal dryer stack at Irigaray were not significant and ranged from 0.003 to 0.5 mrem/yr to an adult. The highest dose estimate was 200 meters south of the Irigaray thermal dryer, which is within the permit boundary. This is well below public dose requirements in 40 CFR Part 190 and the 10 mrem/yr constraint rule in 10 CFR 20.1101, both of which exclude doses from radon-222.

6) Even if 100% of the radon-222 contained in production fluids were released to the atmosphere (i.e. 100% released instead of 10%), the TEDE at receptor locations surrounding the Facility would be less than the 100 mrem/yr public dose limit and the radon-222 air concentrations would be less than the radon-222 Effluent Concentration at boundary locations.

7) The air concentrations for long-lived radionuclides (uranium-228, thorium-230, radium-226, and lead-210) are well below their respective Effluent Concentrations at all receptor locations.

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Table 7.3-5
MILDOS-Area predicted radon-222 concentrations and estimated TEDE at directional receptors surrounding the Christensen Ranch-Irigaray uranium processing facility.

Receptor	Distance (km)	Rn-222 Conc. (μCi ml^{-1})	% Effluent Conc.	TEDE (mrem yr^{-1})
AS-1	3.69	7.0E-12 ~~3.4E-12~~	7.0~~3.4~~	0.64
AS-5A	0.05	4.5E-11~~2.5E-11~~	45.0~~25.0~~	3.4
AS-5B	0.012	3.18E-12~~1.4E-12~~	3.1~~1.4~~	0.26
AS-6	5.12	5.1E-12~~2.6E-12~~	5.1~~2.6~~	0.38
IR-1	11.73	5.7E-12~~2.9E-12~~	5.7~~2.9~~	0.7
IR-3	11.61	5.7E-12~~2.9E-12~~	5.7~~2.9~~	0.4
IR-4	12.31	1.3E-12~~6.7E-13~~	1.3~~0.7~~	0.1
IR-5	17.68	2.8E-12~~1.5E-12~~	2.8~~1.5~~	0.2
IR-6	11.24	6.1E-12~~3.2E-12~~	6.1~~3.2~~	0.9

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7.3.3.5 Population Dose

The annual population dose commitment to the population in the region within 80 km of the Facility is also predicted by the MILDOS-AREA code. The results are listed in Table 7.3-6, where TEDE is expressed in units of person-rem/yr. For comparison, the dose to the population within 80 km of the Facility due to background radiation is included in the table. Background radiation doses are based on a North American population of 346 million and an average annual TEDE of 360 mrem (NCRP 1987).

The atmospheric release of radon also results in a dose to the population on the North American continent. This continental dose is calculated by comparison with a previous calculation based on a 1 kilocurie release near Casper, Wyoming. The results of these calculations are included in Table 7.3-6 and combined with dose to the region beyond 80 km of the Facility to arrive at the total radiological effects of one year of operation at the Facility.

The maximum radiological effect of the Facility operation would be to increase the TEDE of the continental population by 0.0000093 percent.

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Table 7.3-6
Total Effective Dose Equivalent to the population from one year's operation at the Christensen Ranch-Irigaray Facility

Criteria	TEDE (person-rem/yr)
Dose received by population within 80 km of the Facility	0.17
Dose received by population beyond 80 km of the Facility	9.2
Total Continental Dose	9.3
Background North American Dose	1.0E+08
Fractional increase to background dose	9.2E-08

7.3.3.6 Exposure to Flora and Fauna

To estimate potential radiological impacts to flora and fauna, the most important pathway for exposure should be identified. The most significant planned atmospheric emissions from the Facility include natural uranium and radon-222; therefore the most important pathway for exposure to flora and fauna is deposition of natural uranium and radon-222 decay products on surface water, surface soils, and vegetation. MILDOS-AREA estimates radionuclide surface deposition rates as a function of distance from the source and at receptor locations and calculates ground surface concentrations. Table 7.3-7 presents the highest surface radionuclide concentrations predicted by MILDOS-AREA over a 5-year period. Soil concentrations were calculated based on a conservative assumption of 1.5 g cm^{-3} bulk soil density and a soil mixing zone of 15 cm.

Table 7.3-7
Highest surface radionuclide concentrations resulting from Christensen Ranch-Irigaray uranium ISR operations.

Radionuclide	Receptor Location	Surface Concentration (pCi/m^2)	Soil Concentration in upper 15 cm (pCi/g)
Uranium-238	15 km Northwest	1233	5E-03
Thorium-230	15 km Northwest	1.3	5E-06
Radium-226	15 km Northwest	0.79	4E-06
Polonium-218	1.5 km Northwest	22.06~~1~~	1E-04~~5~~
Lead-214	1.5 km Northwest	22.06~~1~~	1E-04~~5~~
Bismuth-214	1.5 km Northwest	22.06~~1~~	1E-04~~5~~
Lead-210	25 Meters Northwest	84.2	4E-04

Uranium-238 represents the radionuclide with the highest concentration (5E-03 pCi/g) which is at least an order of magnitude below most analytical laboratory detection limits. Site-specific surface soil (0-15 cm) data show that natural uranium ranges from 1.2 to 7.7 with a mean of 2.6 ± 1.5 pCi/g (COGEMA 2001). The increase in soil radioactivity is insignificant compared to site-specific background concentrations.

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From this evaluation, the impact of operations at the Facility would be minimal and indistinguishable from current conditions.

7.3 REFERENCES

COGEMA 2001. COGEMA Mining Company, *Decommissioning Plan for Irigaray and Christensen Ranch Projects.*

Malapai Resources 1988. Application for In Situ Permit to Mine for Christensen Ranch, Wyoming Department of Environmental Quality, Approved Permit to Mine No. 478, 1977 (Amendment No. 2, 1988), Section D4, Meteorology.

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

NRC, 2003. U.S. Nuclear Regulatory Commission (NRC) NUREG-1569, *Standard Review Plan for In-Situ Leach Uranium Extraction License Applications-Final Report, Appendix D, MILDOS-AREA:*

An Update with Incorporation of In-Situ Leach Uranium Recovery Technologies

NCRP, 1987. National Council on Radiation Protection and Measurements (NCRP) Report No. 93, *Ionizing Radiation Exposure of the Population of the United States.*

WEST, 2005. Western Environmental Services Testing, Inc (WEST), *Cogema Resources Company, Yellow Cake Dryer Stack Test Report.*

7.3 RADIOLOGICAL EFFECTS

Uranium One USA, Inc. (Uranium One) is proposing to increase the wellfield production for Willow Creek Christensen Ranches operating uranium in-situ recovery facility to a production and restoration flow of approximately 9000 and 1000 gallons per minute (gpm), respectively. An assessment of the radiological effects of the Christensen Ranch-Irigaray facility (the Facility) must consider the types and potential consequences of radiological emissions and potential pathways present.

The Facility will use fixed-bed pressurized down flow ion exchange columns to separate uranium from the pregnant production fluid and treat restoration solutions. The uranium contained in the regenerant from the production ion exchange columns will be precipitated and subsequently vacuum dried.

In addition to ion exchange treatment, the groundwater restoration process will use reverse osmosis to remove the dissolved solids. Liquid and solid waste disposal will occur via direct deep well injection, placement into new or existing surface impoundments, or offsite disposal at an appropriate licensed disposal facility.

The Facility will consist of a main processing plant (Irigaray) and a satellite facility (Christensen Ranch), where an ion exchange system similar to the one described above will operate. The resin from the satellite facility will be transferred to the main processing plant for elution. An average of 1 resin transfer per day from the satellite facility is anticipated. Uranium precipitation, drying, and packaging operations will be conducted at the main processing plant.

The drying and packaging operation at Irigaray will be conducted using a propane-fired multi-hearth dryer with emissions controlled by a high efficiency water scrubber. Atmospheric radon-222 is expected to be the predominant pathway for impacts on human and environmental media with smaller potential impacts form long lived radionuclides emitted from the yellowcake dryer stack. Plans are being considered to add an additional vacuum drying system to the current operations which under vacuum; as such, the only significant routine emission at the Facility will be radon-222 gas. Radon-222, a decay product of radium-226, is dissolved in the lixiviant as it travels through the ore to a production well where it is brought to the surface. The concentration of radon-222 in the production solution and estimated releases were calculated using the methods found in US NRC Regulatory Guide 3.59, "Methods for Estimating Radioactive and Toxic Airborne Source Terms for Uranium Milling Operations" (NRC 1987) and NUREG 1569 "Standard Review Plan for In Situ Leach Uranium Extraction License Applications" (NRC 2003). The details of and assumptions used in these calculations are found in Section 7.3.3

MILDOS-AREA (ANL 1997) (see Appendix D for the MILDOS printout) was used to model radiological impacts on human and environmental receptors (e.g., air and soil) using site-specific release estimates, meteorological and population data, and other parameters. All of the pathways related to air emissions of radon-222 and airborne particulates are evaluated by MILDOS-AREA. The estimated radiological impacts resulting from routine site activities are compared to applicable public dose limits as well as naturally occurring background levels.

7.3.1 Exposure Pathways

Figure 7.3-1 presents exposure pathways from all potential sources at the Facility. The

predominant pathways for planned and unplanned releases are identified. Atmospheric radon-222 is expected to be the predominant pathway for impacts on human and environmental media with smaller potential impacts from long lived radionuclides emitted from the yellowcake dryer stack. Potential impacts of releases can be expected in all quadrants surrounding the Facility, the magnitude of which is driven predominantly by wind direction and atmospheric stability. As a noble gas, radon-222 itself has very little radiological impact on human health or the environment. Rather, it is the radon-222 decay products that are of concern. Radon-222 has a relatively short half-life (3.82 days) and its decay products are short-lived, alpha-emitting, nongaseous radionuclides. Figure 7.3-1 shows that all exposure pathways, with the possible exception of skin absorption, can be important depending on the environmental media impacted.

7.3.2 Exposures from Water Pathways

The mining solutions in the ore zone will be controlled and adequately monitored to ensure that migration does not occur. The overlying and underlying aquifers, if present, will also be monitored.

The primary method of waste disposal at the Facility will be by deep well injection or placement in surface impoundments. Two licensed deep injection well exists at the Facility. Uranium One anticipates the need to add a third deep injection well by January 2016.

The uranium ion exchange, precipitation, drying and packaging facilities will be located on curbed concrete pads to prevent any liquids from entering the environment. Solutions used to wash down equipment will drain to a sump and either be pumped back into the processing circuit or disposal well. The pads will be of sufficient size to contain the contents of the largest tank in the event of a rupture.

No routine liquid environmental discharges, other than waste disposal via deep well injection or lined surface impoundment, are planned and as such, no definable water-related pathways for routine operations exist. There is a surface discharge permit for Christensen Ranch, but any such discharge would be limited in volume and consist of very clean permeate water from reverse osmosis treatment.

7.3.3 Exposures from Air Pathways

The only significant sources of radionuclide emission are radon-222 released into the atmosphere through a vent system in the satellite plant, releases from the wellfields and long lived radionuclides released into the atmosphere through the yellowcake stack at the Irigaray Plant. As shown in Figure 7.3-1, atmospheric releases of radon-222 can result in radiation exposure via three pathways: inhalation, ingestion, and external exposure. The Total Effective Dose Equivalent (TEDE) to a hypothetical person living at receptor locations surrounding the facility as well as actual residences was estimated using MILDOS-Area.

7.3.3.1 Source Term Estimates

The source terms used to estimate radon-222 releases from the Facility include two well fields in production, two restoration well fields, one new well field, and the satellite processing facility. The radon-222 releases from these source terms are calculated using methods described in Sections 7.3.3.1.1 through 7.3.3.1.4 below. For the Christensen Ranch area, mine units 10-12 and 7 were chosen based on their proximity to site boundaries and predominant wind directions. The parameters used to characterize and estimate releases are provided in Table 7.3-1.

Table 7.3-1
Parameters used to estimate and characterize source terms at the Christensen Ranch - Irigaray uranium in-situ recovery facility.

Parameter	Value	Unit	Source
Average ore grade	0.094	%	Application
Ore radium-226 concentration	265	$pCi\ g^{-1}$	Reg. Guide 3.59
Mined area	1.6E+05	$m^2\ y^{-1}$	Application
Average lixiviant flow	2.65E+04	$L\ m^{-1}$	Application
Average restoration flow	1.89E+03	$L\ m^{-1}$	Application
Operating days per year	365	days	Full-time operation assumed
Ore formation thickness	3.7	meters	Application
Ore formation porosity	0.28		Application
Ore formation rock density	1.91	$g\ cm^{-3}$	Estimated
Average residence time for lixiviant	8.7	days	Application
Average residence time for restoration solutions	30	days	Application
Average mass of ore material in mud pit	5.2E+05	g	Estimate based on planned activities
Number of mud pits generated per year	300		Estimate based on planned activities

Storage time in mud pits	14	days	Estimate based on planned activities
Radon-222 emanating power	0.2		Reg. Guide 3.59
Radon-222 release rates	0.1	y^{-1}	Estimate based on process
Resin porosity	0.4		NUREG 1569
Ion exchange column volume	1.42E+04	L	Estimate based on planned activities
Number of resin transfers per day (Christensen Ranch only)	2		Estimate based on planned activities
Stack height	16	m	Application
Stack diameter	0.3	m	Application
Stack velocity	11	$m\ s^{-1}$	Application
Radon-222 decay constant	0.181	d^{-1}	NUREG 1569

7.3.3.1.1 Production Releases

Currently, plans are to have up to two wellfield areas that potentially could be mined concurrently. The potential radon-222 releases from the production well fields were estimated using methods described in NRC Regulatory Guide 3.59 as follows:

Radon-222 released (equilibrium condition) to production fluid from leaching is calculated using Equation 1:

$$G = R\rho E \frac{(1-p)}{p} x10^{-6} \qquad \text{(Equation 1)}$$

Where:

G	=	radon-222 released (Ci m^{-3})
R	=	radium content of ore (pCi/g)
E	=	emanating power
ρ	=	rock density (g cm^{-3})
p	=	formation porosity

The yearly radon-222 released to the production fluid is calculated using Equation 2:

$$Y = 1.44GMD(1-e^{-\lambda t}) \qquad \text{(Equation 2)}$$

Where:

Y	=	yearly radon-222 released to production fluid (Ci yr^{-1})

G	=	radon-222 released at equilibrium (Ci m^{-3})
M	=	lixiviant flow rate (L min^{-1})
D	=	production days per year (d)
λ	=	radon-222 decay constant (d^{-1})
t	=	lixiviant residence time
1.44	=	unit conversion factor

Using Equations 1 and 2 and the parameters in Table 7.3-1, the radon-222 release rate to production fluid is 3709 Ci yr^{-1}. NRC Regulatory Guide 3.59 assumes all radon-222 that is released to the production fluid is ultimately released to the atmosphere, which in the case of ion exchange columns operating at atmospheric pressure in an open system is an appropriate, conservative assumption. In cases where pressurized ion exchange columns are used and wellfields are operated under pressure, the majority of radon released to the production fluid stays in solution and is not released. Fugitive radon-222 is released from occasional well field venting for sampling events, small unavoidable leaks in well field and ion exchange equipment, and maintenance of well field and ion exchange equipment. For this reason, an annual release of 10% of the radon-222 from the production fluid is assumed to occur in the well fields. An additional 10% release in the ion exchange circuit is assumed. This release includes any releases from the worst case bleed stream (125 gallons per minute). Given these assumptions, the annual radon-222 released from production in the wellfields and the satellite facility is 372 and 334 Ci yr^{-1}, respectively. In the MILDOS-AREA model simulations, the wellfield release of 374 Ci yr^{-1} was distributed equally among Mine Areas 7 and 10-12.

7.3.3.1.2 Restoration Releases

Radon-222 releases resulting from wellfield restoration activities were estimated in the same manner as the production activities above (i.e. using Equation 2) but modified for the lower restoration flow rate and longer restoration fluid residence time, both of which are listed in Table 7.3-1. A 10% release in the wellfield, as in the production release, was assumed. A 100% release was assumed at the treatment facility since it is not known whether the restoration water treatment will be under pressure. These assumptions yield a radon-222 release rate of 26 Ci yr^{-1} in the wellfield and 231 Ci yr^{-1} at the satellite facility. In the MILDOS-AREA model simulations, the wellfield release of 26 Ci yr^{-1} was distributed equally among Mine Area 7 and 10-12.

7.3.3.1.3 New Well Field Releases

Radon-222 releases resulting from new wellfield development activities were estimated using methods described in NUREG-1569 as follows:

$$Rn_{nw} = E\lambda[Ra]TmNx10^{-12} \qquad \text{(Equation 3)}$$

Where:

Rn_{nw}	=	Radon-222 release rate from new well field (Ci yr^{-1})
E	=	emanating power
[Ra]	=	concentration of radium-226 in ore (pCi g^{-1})
λ	=	decay constant of radon-222
T	=	storage time in mud pit (d)
m	=	average mass of ore material in the pit (g)
N	=	number of mud pits generated per year
10^{-12}	=	unit conversion factor (Ci pCi^{-1})

Using Equation 3 and the parameters in Table 7.3-1, the yearly radon released from new well field development is 0.02 Ci yr^{-1}. In the MILDOS-AREA model simulations, the new wellfield release was assumed to occur at Mine Areas 7 and 10-12.

7.3.3.1.4 Resin Transfer Releases

The radon-222 release resulting from resin transfers from the Christensen Ranch satellite facility was estimated using methods described in NUREG-1569 as follows:

$$Rn_x = 3.65x10^{-10} F_i C_{Rn} \qquad \text{(Equation 4)}$$

Where:

Rn_x	=	Radon-222 release rate from resin transfers (Ci yr^{-1})
F_i	=	water discharge rate from resin unloading (L d^{-1})
C_{Rn}	=	Steady state radon-222 concentration in process water (pCi L^{-1})
$3.65x10^{-10}$	=	unit conversion factor (Ci pCi^{-1})(d yr^{-1})

The steady state radon-222 concentration in process water (C_{Rn}) was estimated from the following expression:

$$C_{Rn} = \frac{Y * 1.9x10^6}{M} \qquad \text{(Equation 5)}$$

Where:

C_{Rn}	=	Steady state radon-222 concentration in process water (pCi L^{-1})
Y	=	yearly radon-222 released to production fluid (Ci yr-^{1})
M	=	lixiviant flow rate (L min^{-1})
$1.9x10^6$	=	unit conversion factor (pCi Ci^{-1})(yr min^{1})

The water discharge rate from resin unloading (Fi) was estimated from the following expression:

$$F_i = N_i * V_i * P_i \qquad \text{(Equation 6)}$$

Where:

F_i	=	water discharge rate from resin unloading (L d^{-1})
N_i	=	Number of resin transfers per day
V_i	=	volume of resin in transfer (L)
P_i	=	porosity of resin

Using Equations 4 through 6 and the parameters in Table 7.3-1, the radon-222 released from resin transfers from the Christensen Ranch satellite facility is 0.86 Ci yr^{-1}. In the MILDOS-AREA model simulations, the resin transfer release was assumed to occur only at the Christensen Ranch satellite plant site.

7.3.3.1.5 Radon-222 Release Summary

A summary of estimated radon-222 releases from the Facility is presented in Table 7.3-2. The source coordinates in Table 7.3-2 and 7.3-3 are relative to the Christensen Ranch satellite facility.

Table 7.3-2
Estimated Radon-222 releases (Ci yr^{-1}) from Christensen Ranch-Irigaray Facility.

			Radon-222 Releases (Ci yr^{-1})				
Location	**X (km)**	**Y (km)**	**Production**	**Restoration**	**Drilling**	**Resin Transfer**	**Total**
CR Mine Area 7	0.66	1.71	186	13	0.02	0	199.02
CR Mine Area 10-12	-1.16	-0.74	186	13	0.02	0	199.02
CR Satellite Plant	0	0	334	231	0	0.86	565.86
Irigaray Thermal Dryer	-7.09	9.22	0	0	0	0	0
Total			706	257	0.04	0.86	963.90

Notes:
CR = Christensen Ranch

7.3.3.1.6 Other Airborne Radionuclide Releases

The yellow cake dryer stack at the Irigaray location will have minimal releases of long lived radionuclides including natural uranium, radium-226, thorium-230, and lead-210. The yellow cake dryer is a propane-fired multi-hearth with emissions controlled by a high efficiency water scrubber; resulting in minimal particulate emissions. The emission quantities of these radionuclides were taken from monthly release rates reported in "*Cogema Resources Company Yellow Cake Dryer Stack Test Report*" (WEST 2005) and scaled to reflect annual emission quantities. These quantities are summarized in Table 7.3-3.

Table 7.3-3
Estimated long-lived radionuclide releases (Ci yr^{-1}) from Irigaray Facility.

			Long-Lived Radionuclide Releases (Ci yr^{-1})			
Location	**X (km)**	**Y (km)**	**Natural Uranium**	**Radium-226**	**Thorium-230**	**Lead-210**
Irigaray Thermal Dryer	-7.09	9.22	0.009	2.6E-06	4.4E-06	1.1E-04

7.3.3.2 Receptors

Two types of receptors were used in the MILDOS-AREA simulation. First, arbitrary receptors were identified based on an approximate 0.5 km grid system across the site. The grid system was established using a random staring point. A total of 1050 arbitrary receptors were modeled to develop iso-dose curves in and around the permit boundary using a kriging method described in ArcMap GIS software. Second, potential receptor locations were identified and modeled. The receptors used in the MILDOS-AREA simulations are presented in Appendix D and represent directional and residential receptors. The estimated annual exposure hours for receptors in Table

7.3.5 are based on 24 hours per day for one year. Some of the receptors in Table 7.3.5 are within the permit area so the residence scenario may be unrealistic but is a conservative estimate.

Table 7.3-4
Christensen Ranch-Irigaray receptor names and locations

Receptor	X (km)	Y (km)	Distance (km)
1. AS-1	-3.66	-0.46	3.69
2. AS-5A	0.01	-0.05	0.05
3. AS-5B	-0.01	0.01	0.01
4. AS-6	3.51	-3.73	5.12
23. IR-1	-7.18	9.28	11.73
24. IR-3	-7.05	9.22	11.61
25. IR-4	-7.09	10.06	12.31
26. IR-5	-9.22	15.09	17.68
27 IR-6	-6.02	8.50	11.24

Notes:
AS = Air monitoring station IR = Irigaray

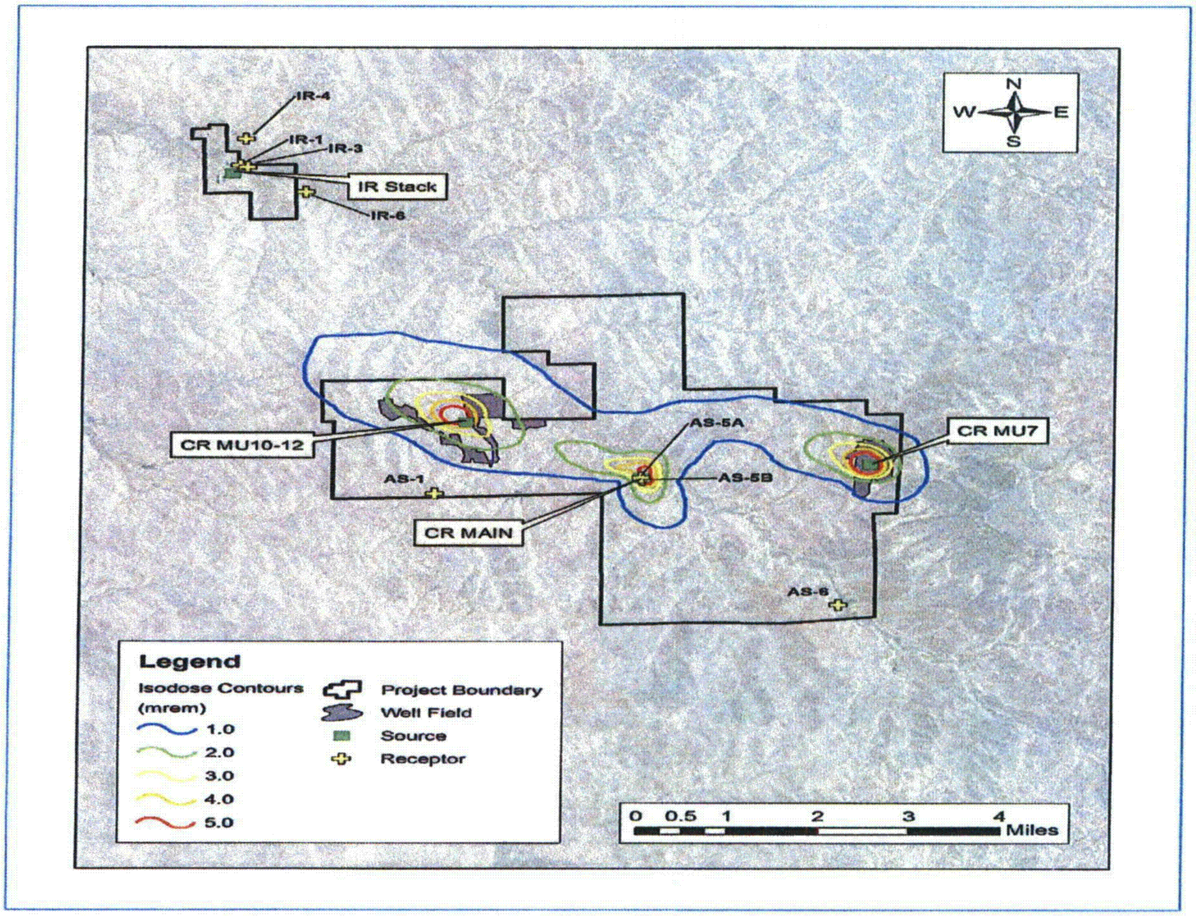

Figure 7.3-2 Iso-Dose Map of Willow Creek ISR Project

7.3.3.3 Miscellaneous Parameters

The meteorological data used in the MILDOS-AREA model is from the Joint Frequency Distribution data presented in Appendix D4 of the Mine Permit No. 478 Christensen Ranch amendment application (1988).

The population distribution used in the MILDOS-AREA model to estimate population doses is from the demographic information presented in Section 2.0 of this amendment application.

7.3.3.4 Total Effective Dose Equivalent (TEDE) to Individual Receptors

In order to show compliance with the annual dose limit found in 10 CFR 20.1301, COGEMA has demonstrated by calculation that the TEDE to the individual most likely to receive the highest dose from the Facility operation is less than 100 mrem per year. The results of the MILDOS-AREA simulation for each potential receptor location in Table 7.3-5 are presented in Table 7.3-6.

An evaluation of the TEDE follows:

1) The maximum TEDE of 3.4 mrem/yr, located 200 meters south of the Christensen Ranch satellite facility, is 3.4 percent of the public dose limit of 100 mrem/yr. Occupationally exposed workers would be expected to be at this location for a fraction of their work time.

2) The TEDE to the site's nearest residents ranged from 0.14 to 3.4 mrem/yr.

3) All dose rates outside the permit boundary are less than 3 mrem per year and in most instances all dose rates outside the permit boundary are less than 1 mrem/yr as demonistrated in Figure 7.3-2. These estimates are based on 100% occupancy for a year.

4) The effect of the Facility operation at any potential resident is less than or equal to 3.4 mrem/yr TEDE.

5) The contributions from long-lived radionuclide emissions from the thermal dryer stack at Irigaray were not significant and ranged from 0.003 to 0.5 mrem/yr to an adult. The highest dose estimate was 200 meters south of the Irigaray thermal dryer, which is within the permit boundary. This is well below public dose requirements in 40 CFR Part 190 and the 10 mrem/yr constraint rule in 10 CFR 20.1101, both of which exclude doses from radon-222.

6) Even if 100% of the radon-222 contained in production fluids were released to the atmosphere (i.e. 100% released instead of 10%), the TEDE at receptor locations surrounding the Facility would be less than the 100 mrem/yr public dose limit and the radon-222 air concentrations would be less than the radon-222 Effluent Concentration at boundary locations.

7) The air concentrations for long-lived radionuclides (uranium-228, thorium-230, radium-226, and lead-210) are well below their respective Effluent Concentrations at all receptor locations.

Table 7.3-5
MILDOS-Area predicted radon-222 concentrations and estimated TEDE at directional receptors surrounding the Christensen Ranch-Irigaray uranium processing facility.

Receptor	Distance (km)	Rn-222 Conc. (μCi ml^{-1})	% Effluent Conc.	TEDE (mrem yr^{-1})
AS-1	3.69	7.0E-12	7.0	0.64
AS-5A	0.05	4.5E-11	45.0	3.4
AS-5B	0.01	3.18E-12	3.1	0.26
AS-6	5.12	5.1E-12	5.1	0.38
IR-1	11.73	5.7E-12	5.7	0.7
IR-3	11.61	5.7E-12	5.7	0.4
IR-4	12.31	1.3E-12	1.3	0.1
IR-5	17.68	2.8E-12	2.8	0.2
IR-6	11.24	6.1E-12	6.1	0.9

7.3.3.5 Population Dose

The annual population dose commitment to the population in the region within 80 km of the Facility is also predicted by the MILDOS-AREA code. The results are listed in Table 7.3-6, where TEDE is expressed in units of person-rem/yr. For comparison, the dose to the population within 80 km of the Facility due to background radiation is included in the table. Background radiation doses are based on a North American population of 346 million and an average annual TEDE of 360 mrem (NCRP 1987).

The atmospheric release of radon also results in a dose to the population on the North American continent. This continental dose is calculated by comparison with a previous calculation based on a 1 kilocurie release near Casper, Wyoming. The results of these calculations are included in Table 7.3-6 and combined with dose to the region beyond 80 km of the Facility to arrive at the total radiological effects of one year of operation at the Facility.

The maximum radiological effect of the Facility operation would be to increase the TEDE of the continental population by 0.0000093 percent.

Table 7.3-6
Total Effective Dose Equivalent to the population from one year's operation at the Christensen Ranch-Irigaray Facility

Criteria	TEDE (person-rem/yr)
Dose received by population within 80 km of the Facility	0.17
Dose received by population beyond 80 km of the Facility	9.2
Total Continental Dose	9.3
Background North American Dose	1.0E+08
Fractional increase to background dose	9.2E-08

7.3.3.6 Exposure to Flora and Fauna

To estimate potential radiological impacts to flora and fauna, the most important pathway for exposure should be identified. The most significant planned atmospheric emissions from the Facility include natural uranium and radon-222; therefore the most important pathway for exposure to flora and fauna is deposition of natural uranium and radon-222 decay products on surface water, surface soils, and vegetation. MILDOS-AREA estimates radionuclide surface deposition rates as a function of distance from the source and at receptor locations and calculates ground surface concentrations. Table 7.3-7 presents the highest surface radionuclide concentrations predicted by MILDOS-AREA over a 5-year period. Soil concentrations were calculated based on a conservative assumption of 1.5 g cm^{-3} bulk soil density and a soil mixing zone of 15 cm.

Table 7.3-7
Highest surface radionuclide concentrations resulting from Christensen Ranch-Irigaray uranium ISR operations.

Radionuclide	Receptor Location	Surface Concentration (pCi/m^2)	Soil Concentration in upper 15 cm (pCi/g)
Uranium-238	15 km Northwest	1233	5E-03
Thorium-230	15 km Northwest	1.3	5E-06
Radium-226	15 km Northwest	0.79	4E-06
Polonium-218	1.5 km Northwest	22.06	1E-04
Lead-214	1.5 km Northwest	22.06	1E-04
Bismuth-214	1.5 km Northwest	22.06	1E-04
Lead-210	25 Meters Northwest	84.2	4E-04

Uranium-238 represents the radionuclide with the highest concentration (5E-03 pCi/g) which is at least an order of magnitude below most analytical laboratory detection limits. Site-specific surface soil (0-15 cm) data show that natural uranium ranges from 1.2 to 7.7 with a mean of 2.6 ± 1.5 pCi/g (COGEMA 2001). The increase in soil radioactivity is insignificant compared to site-specific background concentrations.

From this evaluation, the impact of operations at the Facility would be minimal and indistinguishable from current conditions.

7.3 REFERENCES

COGEMA 2001. COGEMA Mining Company, *Decommissioning Plan for Irigaray and Christensen Ranch Projects.*

Malapai Resources 1988. Application for In Situ Permit to Mine for Christensen Ranch, Wyoming Department of Environmental Quality, Approved Permit to Mine No. 478, 1977 (Amendment No. 2, 1988), Section D4, Meteorology.

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

NRC, 2003. U.S. Nuclear Regulatory Commission (NRC) NUREG-1569, *Standard Review Plan for In-Situ Leach Uranium Extraction License Applications-Final Report, Appendix D, MILDOS-AREA:*

An Update with Incorporation of In-Situ Leach Uranium Recovery Technologies

NCRP, 1987. National Council on Radiation Protection and Measurements (NCRP) Report No. 93, *Ionizing Radiation Exposure of the Population of the United States.*

WEST, 2005. Western Environmental Services Testing, Inc (WEST), *Cogema Resources Company, Yellow Cake Dryer Stack Test Report.*

The drying operation at Irigaray is conducted using propane-fired multi-hearth dryer with emissions controlled by a high efficiency water scrubber. As a result, radon-222 and to a lesser degree long lived radionuclides such as natural uranium, thorium-230, and radium-226 are routine airborne emissions from the facility. Radon-222, a decay product of radium-226, is dissolved in the lixiviant as it travels through the ore to a production well where it is brought to the surface. The concentration of radon-222 in the production solution and estimated releases were calculated using the methods found in US NRC Regulatory Guide 3.59, "Methods for Estimating Radioactive and Toxic Airborne Source Terms for Uranium Milling Operations" (NRC 1987) and NUREG 1569 "Standard Review Plan for In Situ Leach Uranium Extraction License Applications" (NRC 2003). The details of and assumptions used in these calculations are found in Section 3.2.1.

MILDOS-AREA (ANL 1997) was used to model radiological impacts on human and environmental receptors (e.g. air and soil) using site specific release estimates, meteorological and population data, and other parameters. All of the pathways related to air emissions of radon-222 and airborne particulates are evaluated by MILDOS-AREA. The estimated radiological impacts resulting from routine site activities are compared to applicable public dose limits as well as naturally occurring background levels.

3.0 Potential Exposure Pathways

Figure 1 depicts conceptually all exposure pathways from all potential sources at the facility. The predominant pathways for planned and unplanned releases are identified. Atmospheric radon-222 is expected to be the predominant pathway for impacts on human and environmental media with smaller potential impacts from long lived radionuclides emitted from the yellowcake dryer stack. Potential impacts of releases can be expected in all quadrants surrounding the facility, the magnitude of which is driven predominantly by wind direction and atmospheric stability. As a noble gas, radon-222 itself has very little radiological impact on human health or the environment. Radon-222 has a relatively short half-life (3.82 days) and its decay products include short lived, alpha-emitting, nongaseous radionuclides. These decay products have the potential for radiological impacts to human health and the environment. As Figure 1 depicts, all

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