Risk Assessment Revision for
40 CFR Part 61 Subpart W –
Radon Emissions from Operating Mill Tailings

Task 4 – Detailed Risk Estimates

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In accordance with the *Quality Assurance Project Plan: Risk Assessment Revision for 40 CFR Part 61 Subpart W – Radon Emissions from Operating Mill Tailings*, this document has been reviewed and approved by the following individuals:

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ACRONYMS AND ABBREVIATIONS

CBR	Crow Butte Resources, Inc.
CFR	Code of Federal Regulations
Ci	Curie
CCD	Counter-Current Decantation
CofA	Court of Appeals
CPP	Central Processing Plant
Dir	Direction
E	East
EA	Environmental Assessment
ENE	East Northeast
ESE	East Southeast
EPA	Environmental Protection Agency
FEIS	Final Environmental Impact Statement
FGR	Federal Guidance Report
HRI	Hydro Resources, Inc.
HUP	Highland Uranium Project
ICRP	International Commission on Radiological Protection
ISL	in-situ leach
km	kilometer
KUC	Kennecott Uranium Company
LCF	Latent Cancer Fatalities
lbs	pounds
m	meter
N	North
NE	North East
NNE	North Northeast
NNW	North Northwest
NW	North West
NESAPS	National Emission Standards for Hazardous Air Pollutants
NMELC	New Mexico Environmental Law Center
NNW	North Northwest
NRC	Nuclear Regulatory Commission
NUREG	NUclear REGulatory report
NW	North West
NWS	National Weather Service
ORIA	Office of Radiation and Indoor Air
ORNL	Oak Ridge National Laboratory
Pb-210	Lead-210
ppm	parts per million
Ra-226	Radium-226
RAI	Request of Additional Information
RMEI	Reasonably Maximally Exposed Individual

ACRONYMS AND ABBREVIATIONS (Continued)

Rn-222	Radon-222
R&D	Research and Development
s	second
S	South
SAG	semi-autogenous grinding
SE	South East
SR	Smith Ranch
SR-HUP	Smith Ranch-Highland Uranium Project
SSE	South Southeast
sq	square
SSW	South Southwest
SW	Southwest
SX	Solvent Extraction
TCEQ	Texas Commission on Environmental Quality
TDH	Texas Department of Health
TDSHS	Texas Department of State Health Services
TEDE	Total Effective Dose Equivalent
TNRCC	Texas Natural Resource Conservation Commission
TRRC	Texas Railroad Commission
U-238	Uranium-238
U_3O_8	Triuranium octoxide (yellow cake)
URI	Uranium Resources, Inc.
V_2O_5	vanadium pentoxide
W	West
WNW	West Northwest
WSW	West Southwest
yr	year

EXECUTIVE SUMMARY

The Office of Radiation and Indoor Air (ORIA) promulgated National Emissions Standards for Hazardous Air Pollutants (NESHAPs) for radon emissions from operating uranium mill tailings impoundments (Subpart W) on December 15, 1989 (FR 1989). In support of Subpart W, as well as other portions of radiolonuclide NESHAPs, ORIA published a three volume Environmental Impact Statement (EIS) that provided: 1) a detailed description of the Agency's procedures and methods for estimating radiation dose and risk due to radionuclide emissions to the air (EPA 1989a), 2) detailed risk estimates for each source of emissions (EPA 1989b, EPA 1989c), and 3) detailed economic assessments for each source of emissions (EPA 1989d).

The purpose of this Work Assignment is to revise the risk assessment for the NESHAPs for radionuclides from uranium facilities. The information developed in this Work Assignment will be used by the Environmental Protection Agency (EPA or the Agency) in the determination of whether the existing standards for Subpart W need revising, and, if so, what may represent reasonable revisions to the standard.

The uranium facilities that were analyzed are listed in Table ES-1 and include three existing conventional mines/mills, five in-situ leach mines, and two generic sites assumed to be the location of conventional mines/mills.

Table ES-1: Uranium Sites Analyzed

Mill / Mine	Type	State	Regulator	Latitude			Longitude		
				deg	min	sec	deg	min	sec
Cañon City Mill	Conventional	CO	State	38	23	46	-105	13	45
Crow Butte	In-Situ Leach	NE	NRC	42	38	41	-103	21	8
Western Generic	Conventional	NM	NRC	35	31	37	-107	52	52
Alta Mesa 1, 2, 3	In-Situ Leach	TX	State	26	53	59	-98	18	29
Kingsville Dome 1,3	In-Situ Leach	TX	State	27	24	54	-97	46	51
White Mesa Mill	Conventional	UT	State	37	34	26	-109	28	40
Eastern Generic	Conventional	VA	NRC	38	36	0	-78	1	11
Smith Ranch - Highland	In-Situ Leach	WY	NRC	43	3	12	-105	41	8
Christensen / Irigaray	In-Situ Leach	WY	NRC	43	48	15	-106	2	7
Sweetwater Mill	Conventional	WY	NRC	42	3	7	-107	54	41

In Task 3 of this Work Assignment, an evaluation of existing computer models that could be used to perform this dose/risk assessment was performed. As a result of that evaluation, it was determined to use the CAP88 computer program, which is based on the AIRDOS and RADRISK computer programs (Trinity 2007) that were used in the original 1989 Subpart W evaluation (EPA 1989a). Discussion on why CAP88 was selected for this assessment can be found in SC&A 2010.

In order to perform the dose/risk analysis, three types of data were necessary: 1) the distribution of the population living within 80 kilometers of each site, 2) the meteorological data at each site, particularly the wind speed, wind direction, and stability class, and 3) the amount of radon annually released from the site.

Normally, the population doses and risks are calculated out to a distance of 80 kilometers (50 miles) from the site. Therefore, it was necessary to know the population to a distance of 80 kilometers from each site in each of the 16 compass directions. This information is not normally available from U.S. Census Bureau data. However, in 1973, the EPA wrote a computer program, SECPOP (Sandia 2003), which would convert census block data into the desired 80-kilometer population estimates for any specific latitude and longitude within the continental United States. The Nuclear Regulatory Commission (NRC) adopted this program to perform citing reviews for license applications, and has updated the program to use the 2000 census data. The SECPOP program was used to estimate the population distribution around each site; that population was then modified to account for changes in the population from 2000 to 2010.

For those sites where site-specific meteorological data were identified, those site-specific data were used. For other sites, CAP88 is provided with a weather library of meteorological data from over 350 National Weather Service (NWS) stations. For sites without site-specific meteorological data, data from the NWS station nearest the site were used.

Annual radon release estimates were determined for each site based on the available documentation for the site. For example, some sites reported their estimated radon release in their semi-annual release reports, while other sites calculated their radon release as part of their license application or renewal application. Finally, for some sites, the annual radon release estimates were obtained from the NRC-produced site-specific Environmental Assessment. If multiple documents provided radon release estimates for a particular site, the estimate from the most recent document was used. Likewise, if both theoretical and actual radon release values were identified for a site, the actual radon release value was given preference.

Table ES-2 presents the reasonably maximally exposed individual (RMEI) and population doses and risks due to the maximum radon releases estimated for each uranium site. The maximum radon releases were used to calculate the doses in order to be able to compare the results to regulatory criteria. For example, 10CFR § 20.1301 "Dose limits for individual members of the public" restricts the total effective dose equivalent (TEDE) to individual members of the public from the licensed operation to less than 100 mrem per year. 10CFR § 20.1301 (e) additionally stipulates a licensee must also comply with the, "provisions of EPA's generally applicable environmental radiation standards in 40 CFR part 190 shall comply with those standards." However, discharges of radon and its daughters are specifically excepted from compliance with the dose criteria of 40 CFR § 190.10(a).

Table ES-2: Calculated Maximum Total Annual RMEI, Population Dose and Risk

Uranium Site	Maximum Radon Release (Ci/yr)	Annual Dose		LCF[(a)] Risk (yr^{-1})	
		Population (person-rem)	RMEI (mrem)	Population	RMEI
Sweetwater	2,075	0.5	1.2	2.9E-06	6.0E-07
White Mesa	1,750	5.2	12.0	3.4E-05	6.4E-06
Cañon City	269	49.2	10.3	3.1E-04	5.4E-06
Smith Ranch - Highlands	36,500	3.7	1.5	2.3E-05	7.7E-07
Crow Butte	8,885	2.7	3.3	1.7E-05	1.7E-06
Christensen / Irigaray	1,600	3.8	1.9	2.4E-05	9.9E-07
Alta Mesa	740	21.6	11.5	1.3E-04	6.1E-06
Kingsville Dome	6,958	58.0	11.3	3.8E-04	6.1E-06
Eastern Generic	1,750	200.3	28.2	1.4E-03	1.6E-05
Western Generic	1,750	5.1	6.0	2.7E-04	7.7E-06

(a)Latent Cancer Fatalities

Table ES-3 presents the RMEI and population doses and risks due to the average radon releases estimated for each uranium site. The risks were based on average radon releases in order to make it easier to convert these annual risk values into lifetime risk values, by simply multiplying the Table ES-3 values by the number of years that the facility operates for the population risk or by the length of time that the individual lives next to the facility for the RMEI risk.

Table ES-3: Calculated Average Total Annual RMEI, Population Dose and Risk

Uranium Site	Average Radon Release (Ci/yr)	Annual Dose		LCF[(a)] Risk (yr^{-1})	
		Population (person-mrem)	RMEI (rem)	Population	RMEI
Sweetwater	1,204	0.3	0.7	1.7E-06	3.5E-07
White Mesa	1,388	3.0	7.0	2.0E-05	3.7E-06
Cañon City	146	28.6	6.0	1.8E-04	3.1E-06
Smith Ranch - Highlands	21,100	2.2	0.9	1.3E-05	4.5E-07
Crow Butte	4,467	1.6	1.9	1.0E-05	1.0E-06
Christensen / Irigaray	1,040	2.2	1.1	1.4E-05	5.7E-07
Alta Mesa	472	12.5	6.7	7.6E-05	3.6E-06
Kingsville Dome	1,291	33.6	6.6	2.2E-04	3.5E-06
Eastern Generic	1,388	116.3	16.4	7.9E-04	9.2E-06
Western Generic	1,388	3.0	3.5	1.6E-04	4.4E-06

(a)Latent Cancer Fatalities

1.0 INTRODUCTION AND BACKGROUND

The National Emission Standards for Hazardous Air Pollutants (NESHAPs) includes radon emissions for uranium mill tailings (40 CFR Part 61 Subpart W – National Emission Standards for Radon Emissions from Operating Mill Tailings – December 15, 1989). At the time of the standard's promulgation, the overwhelming numbers of uranium processing facilities were conventional acid or alkaline leach mills. Radon emissions from these facilities were primarily from the dried out portions of large (greater than 100-acre) tailings ponds. With the promulgation of Subpart W, this large area source was reduced by the requirements to limit the size of new tailings areas to either 40 acres for phased disposal or 10 acres for continuous disposal (40 CFR 61 Subpart W). Additionally, and more importantly, economic and other considerations have led commercial uranium recovery companies to submit license applications/ amendments to develop, upgrade or restart a significant number of in-situ leach (ISL) facilities (NRC 2009).

Table 1: Uranium Sites Analyzed

Mill / Mine	Type	State	Regulator	Latitude			Longitude		
				deg	min	sec	deg	min	sec
Cañon City Mill	Conventional	CO	State	38	23	46	-105	13	45
Crow Butte	In-Situ Leach	NE	NRC	42	38	41	-103	21	8
Churchrock	In-Situ Leach	NM	NRC	35	31	41	-108	44	33
Crownpoint	In-Situ Leach	NM	NRC	35	40	41	-108	9	4
Western Generic	Conventional	NM	NRC	35	31	37	-107	52	52
Alta Mesa 1, 2, 3	In-Situ Leach	TX	State	26	53	59	-98	18	29
Kingsville Dome 1,3	In-Situ Leach	TX	State	27	24	54	-97	46	51
Vasquez	In-Situ Leach	TX	State	31	58	6	-99	54	6
White Mesa Mill	Conventional	UT	State	37	34	26	-109	28	40
Eastern Generic	Conventional	VA	NRC	38	36	0	-78	1	11
Smith Ranch - Highland	In-Situ Leach	WY	NRC	43	3	12	-105	41	8
Christensen / Irigaray	In-Situ Leach	WY	NRC	43	48	15	-106	2	7
Sweetwater Mill	Conventional	WY	NRC	42	3	7	-107	54	41

In Section 2.0, detailed risk assessments were performed for all but three of the uranium sites listed in Table 1. The reasons for not analyzing three sites (Churchrock, Crownpoint, and Vasquez) are described below.

The Crownpoint and Churchrock uranium deposits, San Juan Basin, New Mexico, are currently being developed by Uranium Resources, Inc. (URI) and its subsidiary Hydro Resources, Inc. (HRI). Both deposits will be developed using advanced ISL mining techniques. URI/HRI currently has about 37.834 million pounds of U_3O_8 (14,583 tonnes U) of estimated recoverable reserves at Crownpoint/Churchrock. In March, 1997, a Final Environmental Impact Statement (FEIS) for the Crownpoint/Churchrock sites was completed by the NRC (NRC 1997), which recommends the issuance of an operating license. In January 1998, HRI was granted Source Material License SUA-1580 by the NRC for uranium production at the Crownpoint/Churchrock Uranium Project. Although the license was granted, the project has been delayed due to depressed uranium prices and litigation. In December 2002, the NRC found that, since the renewal application had been timely filed by HRI, the Crownpoint/Churchrock license would not expire until final action had been taken by the NRC on the SUA-1580 renewal application. Regarding the litigation, in March 2010, the United States Court of Appeals, Tenth Circuit denied the intervener's petition for review and upheld the NRC's licensing decision in all respects (CofA 2010). In September 2010, the New Mexico Environmental Law Center (NMELC) filed an appeal to the U.S. Supreme Court (Docket No. 10-368). On November 15, 2010, the United States Supreme Court denied NMELC's petition to review the Appeal Court's ruling, after which URI indicated that construction of the Crownpoint/Churchrock facilities should begin in 2012, with production in 2013. Since, to date, there have been no radon releases from the Crownpoint/Churchrock Uranium Project, it was determined that a detailed radon risk assessment for this licensed site should not be performed.

The Vasquez uranium site is an ISL mine owned by URI and located in southwestern Duval County in South Texas. For the site, URI holds the Texas Natural Resource Conservation Commission's Underground Injection Control Permit: UR03050. The site is also covered by the Texas Department of Health's radioactive materials license: L06353. The Vasquez ISL mine was commissioned in October 2004, and reached peak production output in 2005. In 2006 and 2007, production at Vasquez declined, with 78,600 pounds of uranium in 2007 and 36,600 pounds in 2008. The last well field at Vasquez was fully depleted of its economically recoverable reserves in October 2008, and the project is now undergoing restoration. Vasquez did not have a processing plant; rather the uranium loaded resin from Vasquez was delivered to the Kingsville Dome central plant for processing. Since the Vasquez ISL mine is no longer active, it was determined that a detailed radon risk assessment for this site should not be performed. (URI 2010a, URI 2010b)

1.1 Dose Calculation Methodology

As part of this Work Assignment, the various computer models that could be used to calculate the doses and risks due to the operation of conventional and ISL uranium mines were evaluated. Seven computer programs were considered to be used for this risk assessment: CAP88, RESRAD-OFFISTE, MILDOS, GENII, MEPAS, AIRDOS, and AERMOD. A detailed selection process was used to select the program from the first five programs listed. AIRDOS was not included in the detailed selection process, since it is no longer an independent program, but has been incorporated into CAP88. Because it only calculates atmospheric dispersion, but not radiological doses or risks, AERMOD was also not included in the detailed selection. Each of the five programs were given a score of between 0 and 5 for each of the 12 following criteria: 1) Exposure Pathways Modeled, 2) Population Dose/Risk Capability, 3) Dose Factors Used, 4) Risk Factors Used, 5) Meteorological Data Processing, 6) Source Term Calculations, 7) Verification and Validation, 8) Ease of Use/User Friendly, 9) Documentation, 10) Sensitivity Analysis Capability, and 12)Probabilistic Analysis Capability. Also, each criterion had a weighting factor of between 1 and 2. The total weighted score was calculated for each code, and CAP88 was selected for use in this evaluation. SC&A 2010 presents the details of this program selection process. CAP88 was developed in 1988 from the AIRDOS, RADRISK, and DARTAB computer programs, which had been developed for the EPA at the Oak Ridge National Laboratory (ORNL) (Trinity 2007).

CAP88, which stands for "Clean Air Act Assessment Package-1988," is used to demonstrate compliance with the National Emission Standards for Hazardous Air Pollutants (NESHAPs) applicable to radionuclides. CAP88 calculates the doses and risk to the reasonably maximally exposed individual (RMEI) and as well as the surrounding population. Exposure pathways evaluated by CAP88 are: inhalation, air immersion, ingestion of vegetables, meat, and milk, and ground surface exposure. CAP88 uses a modified Gaussian plume equation to estimate the average dispersion of radionuclides released from up to six emitting sources. The sources may be either elevated stacks, such as a smokestack, or uniform area sources, such as a pile of uranium mill tailings. Plume rise can be calculated assuming either a momentum or buoyant-driven plume. Assessments are done for a circular grid of distances and directions for a radius of up to 80 kilometers (50 miles) around the facility. The Gaussian plume model produces results that agree with experimental data as well as any model, is fairly easy to work with, and is consistent with the random nature of turbulence. CAP88 incorporates dose and risk factors from Federal Guidance Report 13 (FGR 13, EPA 1999) in place of the RADRISK data that were used in previous versions. The FGR 13 factors are based on the methods in Publication 72 of the International Commission on Radiological Protection (ICRP 1972). A description of the mathematical models used by CAP88 is provided in the CAP88 Users Manual (Trinity 2007).

CAP88 requires the distribution of the population surrounding the site and the characteristics of the local meteorology. The methodology used to estimate the population distributions is described in the following section, Section 1.2, while the estimated distributions are presented in the Section 2.0 site-specific subsections. For those sites where site-specific meteorological data were identified, site-specific data were used. For other sites, CAP88 is provided with a weather library of meteorological data from over 350 National Weather Service (NWS) stations. For sites without site-specific meteorological data, the data from the NWS station nearest the site were used, as described in the Section 2.0 site-specific subsections.

Additionally, CAP88 requires much data that is radionuclide-independent and usually independent of the site being analyzed. Table 2 is a listing of the radionuclide- and site-independent parameters, along with the default values that are provided with CAP88 and that were used for these uranium site dose and risk analyses.

Table 2: Values for CAP88 Site Independent Parameters

Parameter (Units)	Value
Human Inhalation Rate	
Cubic centimeters/hr	9.17E+05
Soil Parameters	
Effective surface density (kg/sq m, dry weight) (Assumes 15 cm plow layer)	2.15E+02
Buildup Times	
For activity in soil (years)	1.00E+02
For radionuclides deposited on ground/water (days)	3.65E+02

Table 2: Values for CAP88 Site Independent Parameters

Parameter (Units)	Value
Delay Times	
Ingestion of pasture grass by animals (hr)	0.00E+00
Ingestion of stored feed by animals (hr)	2.16E+03
Ingestion of leafy vegetables by man (hr)	3.36E+02
Ingestion of produce by man (hr)	3.36E+02
Transport time from animal feed-milk-man (day)	2.00E+00
Time from slaughter to consumption (day)	2.00E+01
Weathering	
Removal rate constant for physical loss (per hr)	2.90E-03
Crop Exposure Duration	
Pasture grass (hr)	7.20E+02
Crops/leafy vegetables (hr)	1.44E+03
Agricultural Productivity	
Grass-cow-milk-man pathway (kg/sq m)	2.80E-01
Produce/leafy vegetables for human consumption (kg/sq m)	7.16E-01
Fallout Interception Fractions	
Vegetables	2.00E-01
Pasture	5.70E-01
Grazing Parameters	
Fraction of year animals graze on pasture	4.00E-01
Fraction of daily feed that is pasture grass when animal grazes on pasture	4.30E-01
Animal Feed Consumption Factors	
Contaminated feed/forage (kg/day, dry weight)	1.56E+01
Dairy Productivity	
Milk production of cow (L/day)	1.10E+01
Meat Animal Slaughter Parameters	
Muscle mass of animal at slaughter (kg)	2.00E+02
Fraction of herd slaughtered (per day)	3.81E-03
Decontamination	
Fraction of radioactivity retained after washing for leafy vegetables and produce	5.00E-01
Fractions Grown In Garden Of Interest	
Produce ingested	1.00E+00
Leafy vegetables ingested	1.00E+00
Ingestion Ratios:	
Immediate Surrounding Area/Total Within Area	
Vegetables	7.00E-01
Meat	4.40E-01
Milk	4.00E-01
Minimum Ingestion Fractions From Outside Area (Actual fractions of food types from outside area can be greater than the minimum fractions listed below.)	
Vegetables	0.00E+00
Meat	0.00E+00
Milk	0.00E+00

Table 2: Values for CAP88 Site Independent Parameters

Parameter (Units)	Value
Human Food Utilization Factors	
Produce ingestion (kg/y)	1.76E+02
Milk ingestion (L/y)	1.12E+02
Meat ingestion (kg/y)	8.50E+01
Leafy vegetable ingestion (kg/y)	1.80E+01

1.2 Methodology to Estimate 2010 Population

In order to calculate the dose and risk to the population surrounding the uranium site, it is necessary to know the distribution of the surrounding population at each site. Normally, the population doses and risks are calculated out to a distance of 80-kilometers (50-miles) from the site. Therefore, it is necessary to know the population to a distance of 80-kilometers from each site in each of the 16 compass directions. This information is not normally available from census data to the degree of specificity needed in this assessment. However, in 1973, the EPA wrote a computer program, SECPOP, that would convert census block data into the desired 80-kilometer population estimates for any specific latitude and longitude within the continental United States (Sandia 2003). The NRC adopted this program to perform siting reviews for license applications, and has updated the program to use the 2000 census data.

The latitude and longitude for each uranium site listed in Table 1 was entered into SECPOP, which calculated the 80-kilometer, 16-sector 2000 population distribution for each site. The SECPOP-calculated population distributions are provided in the site-specific subsections of Section 2.0.

It was desired to use 2010 population data rather than the 2000 census data available in SECPOP. The U.S. Census Bureau has estimates of the population in every county for each year from 2001 though 2009 (http://www.census.gov/popest/counties/files/CO-EST2009-ALLDATA.csv). For each uranium site, the 2000 census data and 2009 estimate were used to calculate an annual population adjustment factor specific for the county in which the site is located. That annual adjustment factor was then used to calculate an adjustment factor to bring the SECPOP population distribution from 2000 to 2010.

Table 3: 2000 to 2010 Population Adjustment Factors

Site	State	County	Population		Factor	
			2000	2009	Annual	2010
Cañon City Mill	CO	Fremont	46145	47815	0.0040	1.04
Crow Butte	NE	Dawes	9060	8735	-0.0041	0.96
Western Generic	NM	McKinley	74798	70513	-0.0065	0.94
Alta Mesa 1, 2, 3	TX	Brooks	7976	7377	-0.0086	0.92
Kingsville Dome 1,3	TX	Kleberg	31549	30647	-0.0032	0.97
White Mesa Mill	UT	San Juan	14413	15049	0.0048	1.05
Eastern Generic	VA	Culpeper	34262	46502	0.0345	1.40
Smith Ranch – Highland	WY	Converse	12052	13578	0.0133	1.14
Christensen / Irigaray	WY	Campbell	33698	43967	0.0300	1.34
Sweetwater Mill	WY	Sweetwater	37613	41226	0.0102	1.11

2.0 DETAILED RISK ESTIMATES

For each uranium site that is analyzed, this section presents a brief description, including an aerial view of the site, followed by the population distribution surrounding the site and the assumptions made concerning food production. The meteorological data used to analyze each site are presented next. Lastly, the methodology used to estimate the annual radon released from each site is discussed and the radon release presented.

2.1 Sweetwater[1]

The Sweetwater Uranium Project, the only conventional mill remaining in Wyoming, consists of a mill and ancillary structures and is located some 65 km northwest of the Town of Rawlins, in south-central Wyoming's Great Divide Basin. The mill was constructed in 1979 and 1980 and NRC source materials license SUA-1350 (Docket Number: 40-8584) was obtained in February 1979 to permit processing of uranium ore. The mill operated between 1981 and 1983 and has been on standby status since mid-1983. During its three years of operation, the Sweetwater facility produced a total of 1,292,000 lbs of U_3O_8 from a total of 2,340,535 tons of ore (sourced from an adjacent, now depleted ore body which has since been reclaimed), at a reported recovery rate of 90%. Operations at Sweetwater are currently suspended; however, the license has been renewed, and is currently set to expire on November 10, 2014. The Kennecott Uranium Company (KUC) operates and manages the Sweetwater Uranium Project for the Green Mountain Mining Venture. With the continued increase in the price of uranium, KUC may either sell or restart the Sweetwater mill, shown in Figure 1.

1 The description of the Sweetwater site was abstracted from various sources, including KUC 1994, KUC 2004, and Uranium One 2006, while the aerial view of the Sweetwater site was obtained from Google Maps.

Figure 1: Sweetwater – Aerial View

2.1.1 Population and Food Production

The 80-kilometer population distribution in each of the 16 principal compass directions, which was calculated for the Sweetwater site by SECPOP and used in CAP88 for population dose calculations, is shown in Table 4. To adjust the 2000 population data to 2010, the CAP88 Sweetwater population dose was multiplied by 1.11, see Section 1.2 and Table 3.

Table 4: Sweetwater Population Data

Dir	Distance (km)						
	0 to 1	1 to 2	2 to 3	3 to 4	4 to 5	5 to 10	10 to 20
N	0	0	0	0	0	0	0
NNW	0	0	0	0	0	0	0
NW	0	0	0	0	0	3	0
WNW	0	0	0	0	0	0	0
W	0	0	0	0	0	0	0
WSW	0	0	0	0	0	0	0
SW	0	0	0	0	0	0	0
SSW	0	0	0	0	0	0	0
S	0	0	0	0	0	0	0
SSE	0	0	0	0	0	0	0
SE	0	0	0	0	0	0	0
ESE	0	0	0	0	0	0	0
E	0	0	0	0	0	0	0
ENE	0	0	0	0	0	0	0
NE	0	0	0	0	0	0	0
NNE	0	0	0	0	0	0	3

Table 4: Sweetwater Population Data

Dir	Distance (km)					
	20 to 30	**30 to 40**	**40 to 50**	**50 to 60**	**60 to 70**	**70 to 80**
N	0	3	75	26	0	0
NNW	0	0	2	37	0	7
NW	0	0	0	0	0	19
WNW	0	0	0	0	0	0
W	0	2	0	2	0	0
WSW	0	0	0	0	0	0
SW	0	0	0	2	102	1
SSW	2	47	0	3	0	0
S	0	0	256	0	2	0
SSE	0	2	2	0	12	0
SE	0	3	43	0	0	0
ESE	0	5	7	137	9097	430
E	3	11	18	5	0	3
ENE	3	0	19	16	0	5
NE	10	97	3	6	7	13
NNE	3	0	0	29	21	0

The agricultural productivity factors for Wyoming were taken from Appendix C of the CAP88 User's Manual, as shown below, and used in the Sweetwater site population dose calculation.

Beef Cattle Density (cattle/km^2):	5.12
Milk Cattle Density (cow/km^2):	0.0579
Land Cultivated for Vegetable Crops:	0.159%

The distance and direction to the RMEI were identified in the Revised Environmental Report (KUC 1994) as:

> The nearest resident is approximately 17 air miles northeast of the Site and the nearest town is Bairoil, located approximately 22 air miles northeast of the Site. [KUC 1994, page 1-1]

Notice, that the Table 4 SECPOP estimate places the nearest individual at a distance of 5 km to 10 km in the NW direction. To calculate the RMEI dose and risk for this study, the Table 4 RMEI distance and direction were used.

2.1.2 Meteorology

The CAP88 computer program is provided with a weather library of meteorological data from over 350 NWS stations. For the Sweetwater site, the CAP88-provided meteorological data for the period 1983 through 1987 was obtained from the site's Revised Environmental Report (KUC 1994) and the associated MILDOS analysis (EnecoTech 1994). Table 5 shows the directional-dependent average wind speed for each stability class, while Table 6 gives the stability class frequency.

Table 5: Sweetwater Arithmetic Average Wind Speeds (Wind Towards)

Dir	Pasquill Stability Class (m/s)						
	A	B	C	D	E	F	G
N	0.000	1.812	2.477	7.722	5.786	2.497	0.000
NNW	0.000	1.423	2.153	7.706	5.898	2.328	0.000
NW	0.000	1.696	1.780	6.684	6.140	2.475	0.000
WNW	0.000	1.501	1.740	6.256	5.517	2.432	0.000
W	0.000	1.365	1.667	6.705	5.685	2.294	0.000
WSW	0.000	1.918	1.897	7.114	5.984	2.410	0.000
SW	0.000	2.045	2.380	6.838	5.788	2.797	0.000
SSW	0.000	1.825	1.982	7.633	5.820	2.955	0.000
S	0.000	1.042	1.177	7.021	6.227	2.171	0.000
SSE	0.000	1.042	1.026	8.634	7.032	1.384	0.000
SE	0.000	1.822	2.446	8.762	5.876	2.981	0.000
ESE	0.000	1.984	2.553	9.262	6.150	3.028	0.000
E	0.000	1.708	2.681	8.078	5.647	2.606	0.000
ENE	0.000	1.851	2.583	8.400	6.069	2.666	0.000
NE	0.000	1.507	2.422	8.611	6.027	2.714	0.000
NNE	0.000	1.549	2.438	8.144	5.963	2.709	0.000

Table 6: Sweetwater Frequencies of Stability Classes (Wind Towards)

Dir	Pasquill Stability Class (frequency)						
	A	B	C	D	E	F	G
N	0.0000	0.0203	0.1677	0.5699	0.0624	0.1797	0.0000
NNW	0.0000	0.0266	0.1551	0.5723	0.0650	0.1811	0.0000
NW	0.0000	0.0197	0.2033	0.4704	0.0827	0.2240	0.0000
WNW	0.0000	0.0275	0.1880	0.3991	0.0753	0.3100	0.0000
W	0.0000	0.0248	0.1914	0.4613	0.0794	0.2430	0.0000
WSW	0.0000	0.0217	0.1591	0.5108	0.0690	0.2394	0.0000
SW	0.0000	0.0177	0.1398	0.4836	0.0945	0.2644	0.0000
SSW	0.0000	0.0234	0.1128	0.4580	0.1166	0.2893	0.0000
S	0.0000	0.0096	0.1540	0.3018	0.0882	0.4464	0.0000
SSE	0.0000	0.0222	0.0630	0.7737	0.0670	0.0741	0.0000
SE	0.0000	0.0080	0.0269	0.7848	0.0716	0.1087	0.0000
ESE	0.0000	0.0021	0.0542	0.7959	0.0542	0.0935	0.0000
E	0.0000	0.0103	0.0913	0.7018	0.0569	0.1397	0.0000
ENE	0.0000	0.0114	0.0960	0.6874	0.0683	0.1370	0.0000
NE	0.0000	0.0102	0.0859	0.7059	0.0680	0.1301	0.0000
NNE	0.0000	0.0089	0.1197	0.6475	0.0712	0.1527	0.0000
TOTAL	0.0000	0.0156	0.1269	0.6039	0.0713	0.1821	0.0000

2.1.3 Radon Release

Even though KUC provides the NRC with semi-annual effluent reports for the Sweetwater site, as required by 10CFR §40.65, radon releases are not included. Rather, KUC provides the upwind and downwind radon concentrations. Thus, in order to perform the risk assessment, it was necessary to refer to the Revised Environmental Report (KUC 1994) for a Sweetwater site-specific radon source term. The following information on radon releases was taken from Section 3.4 of the Sweetwater Revised Environmental Report (KUC 1994).

Ore Stockpiles, Crushing and Grinding

> A total of 604.6 Ci/year of radon is estimated to be released by ore handling, including both radon release from the mill exhaust stack and the ore loading area at the grizzly. [KUC 1994, page 3-9]

Leaching

> The leach tanks are covered and are also equipped with a vent system. The air in the tanks will have small concentrations of radon-222 and sulfuric acid mist. This air will be vented through a wet scrubber (…). Exhaust from the scrubber will contain traces of radon-222. [KUC 1994, page 3-9]

Counter-Current Decantation (CCD) Thickening

> Some water vapor, acid mist, and minor amounts of radon-222 will escape into the atmosphere from the open thickeners. [KUC 1994, page 3-11]

> In accordance with 40 CFR 61, the tailings impoundments will be 40 acres in area at capacity and no more than two impoundments will be operated at any one time. Radon-222 emissions will be minimized from the tailings impoundment, by keeping the tailings in the operating cell wet. When operations are complete, the final surface area of the six reclaimed impoundments and the original impoundment, to be used as an evaporation pond, is estimated to be approximately 280 acres. Assuming the maximum allowable emission of 20.0 pCi/m^2/sec after reclamation, annual radon-222 emissions can be no more than 714 Ci/year for the six proposed impoundments and the existing impoundment, combined. [KUC 1994, page 3-11]

Solvent Extraction

Section 3.4 of the Revised Environmental Report does not provide any radon source term for the solvent extraction phase.

Precipitation

> Air from the yellowcake precipitators, and thickener area will be passed through a wet scrubber and vented to the atmosphere from stack S-6 (…). The exhaust gases will contain approximately 80 - 120 ppm ammonia and traces of radon-222. [KUC 1994, page 3-12]

In addition to the source term discussion provided in Section 3.4, the Revised Environmental Report provides estimated annual radon releases for the facility during operation at specific release points in Table 5.2-1, which has been reproduced in this report as Table 7. Unlike Section 3.4, which is specific to the mill area, Table 5.2-1 includes the radon releases from "the six proposed [in 1994] 40-acre tailings cells, and the existing [in 1994] tailings cell." From Table 7, it can be seen that including the radon contribution from the tailing cells results in a time-dependent annual radon release.

Table 7: Sweetwater Radon Release

Source		Radon Release (Ci/yr)
Dryer		—
Ore Receiving		604.6
Leaching		—
Ore Handling and Storage		—
Ore Dust		—
Tailings	Yr. 1-3	1001
	Yr. 4-6	2861
	Yr. 7-9	2963
	Yr. 10-12	3065
	Yr. 13-15	3167
	Yr. 16-18	3269
	Yr. 19-21	2370
	Yr. 22-24	714

Source: KUC 1994, Table 5.2-1

It should also be noted that the tailing cell radon releases shown in Table 7 were based on an assumed radon flux of 20 pCi/m^2-s from each of the covered cells or impoundments. To demonstrate compliance with 40CFR Part 61, Subpart W, KUC has annually conducted testing on the facility's tailings impoundment for radon emissions (KUC 2004). The results of that testing are shown in Table 8. In addition to showing the measured radon flux, Table 8 also shows what the largest annual radon tailing release would be, based on the measured flux, as opposed to using the 40CFR §61.252 standard of 20 pCi/m^2-s.

Table 8: Sweetwater Radon Flux Testing Results

Test Date	Radon Flux (pCi/m^2-s)	Yr. 16-18 Tailings Release (Ci/yr)
7-Aug-90	9.00	1471
13-Aug-91	5.10	834
5-Aug-92	5.60	915
24-Aug-93	5.00	817
23-Aug-94	5.00	817
15-Aug-95	3.59	587
13-Aug-96	5.47	894
26-Aug-97	4.23	691
11-Aug-98	2.66	435
10-Aug-99	1.27	208

Table 8: Sweetwater Radon Flux Testing Results

Test Date	Radon Flux (pCi/m^2-s)	Yr. 16-18 Tailings Release (Ci/yr)
8-Aug-00	4.05	662
15-Aug-01	6.98	1141
14-Aug-02	4.10	670
13-Aug-03	7.11	1162

Source: KUC 2004, Appendix 6, Page 1

Based on the radon release data provided in Table 7 and Table 8, several annual radon releases may be calculated:

§61.252 Standard, Maximum	3,874	Ci/yr
§61.252 Standard, Average	3,031	Ci/yr
Measured, Maximum	2,075	Ci/yr
Measured, Average	1,204	Ci/yr

2.1.4 Risk Estimates

The RMEI and population doses and risks calculated by CAP88 for the Sweetwater site are shown in Table 9.

Table 9: Sweetwater Risk Assessment Results

Receptor / Impact		Radon Release (Ci/yr)		
		Unitized	Maximum	Average
		1	2075	1204
RMEI (7500m NW)	Dose (mrem/yr)	5.6E-04	1.2E+00	6.7E-01
	LCF Risk (yr^{-1})	2.9E-10	6.0E-07	3.5E-07
Population	Dose (person-rem/yr)	2.3E-04	4.9E-01	2.8E-01
	LCF Risk (yr^{-1})	1.4E-09	2.9E-06	1.7E-06

2.2 White Mesa[2]

The White Mesa mill is a fully licensed, conventional uranium processing mill with a vanadium co-product recovery circuit, shown in Figure 2. Located six miles south of Blanding, Utah, in the southeastern part of the state, White Mesa is the only conventional uranium mill currently operating in the United States. The White Mesa mill is licensed by the state of Utah (Radioactive Materials License: UT1900479), and is owned and operated by Denison Mines (USA). Construction of the White Mesa mill started in 1979, and conventionally mined

[2] The description of the White Mesa site was abstracted from various sources, including Denison 2007 and Melbye 2008, while the aerial view of the White Mesa site was obtained from Google Maps.

uranium/vanadium ore was first processed in May 1980. To date, White Mesa has produced over 30 million pounds of U_3O_8 and 33 million pounds of V_2O_5.

Figure 2: White Mesa – Aerial View

Operations at White Mesa begin with weighting, receiving, sampling, and stockpiling of conventional ore and other feed materials from various offsite sources. Mine ore, as well as stockpiled crushed ore, is fed into the semi-autogenous grinding (SAG) mill. The ground feed material, stored as a wet slurry in one of two agitated tanks, is then fed to the first stage of leach. The two-stage acid leach is followed by the recovery of uranium bearing pregnant solution in a CCD system. Once the pregnant solution is clarified, it is pumped to the solvent extraction (SX) circuit. Vanadium, when recovered, is stripped from the barren uranium raffinate, also using a solvent extraction circuit. Both uranium and vanadium are precipitated in their respective circuits, followed by drying and packaging.

2.2.1 Population and Food Production

The 80-kilometer population distribution in each of the 16 principal compass directions, which was calculated for the White Mesa site by SECPOP and used in CAP88 for population dose calculations, is shown in Table 10. To adjust the 2000 population data to 2010, the CAP88 White Mesa population dose was multiplied by 1.05, see Section 1.2 and Table 3.

Table 10: White Mesa Population Data

Dir	Distance (km)						
	0 to 1	1 to 2	2 to 3	3 to 4	4 to 5	5 to 10	10 to 20
N	0	0	3	69	567	2813	73
NNW	0	0	0	0	0	24	0
NW	0	0	52	0	0	0	0
WNW	0	0	0	0	0	0	0
W	0	0	0	0	0	0	0
WSW	0	0	0	0	0	1	0
SW	0	0	0	0	0	0	0
SSW	0	0	0	0	0	0	0
S	0	0	0	0	0	7	247
SSE	0	5	0	0	0	0	40
SE	0	0	0	0	0	0	12
ESE	0	0	0	0	0	0	0
E	0	0	0	0	0	0	0
ENE	0	14	0	0	0	0	0
NE	0	0	0	0	180	0	1
NNE	0	0	0	79	0	25	16

Dir	Distance (km)					
	20 to 30	30 to 40	40 to 50	50 to 60	60 to 70	70 to 80
N	0	0	6	4	0	28
NNW	0	0	0	0	16	0
NW	0	0	0	0	0	0
WNW	0	0	0	0	0	0
W	0	8	8	2	0	2
WSW	0	0	0	0	0	0
SW	0	2	0	88	352	195
SSW	0	195	163	19	175	367
S	1	307	105	264	488	617
SSE	62	710	431	116	159	539
SE	83	232	860	340	14	5
ESE	3	8	22	140	231	3045
E	0	2	135	130	463	1361
ENE	7	26	88	1046	168	6
NE	10	100	91	165	66	6
NNE	61	2035	51	9	8	1

The agricultural productivity factors for Utah were taken from Appendix C of the CAP88 User's Manual, as shown below, and used in the White Mesa site population dose calculation.

Beef Cattle Density (cattle/km^2): 2.84
Milk Cattle Density (cow/km^2): 0.446
Land Cultivated for Vegetable Crops: 0.183%

The distance and direction to the RMEI were identified in the Cell 4B dose assessment (SENES 2008) as:

> … the nearest "potential" resident is approximately 1.2 miles (1.9 km) north of the Mill, near the location of air monitoring station BHV-I. The nearest actual resident is located approximately 1.6 miles (2.5 km) north of the mill. [SENES 2008, page 5-3]

Notice that the Table 10 SECPOP estimate places the nearest individuals to White Mesa at a distance of 1 to 2 km in the SSE and ENE directions. To calculate the RMEI dose and risk for this study, the Table 10 RMEI distances and directions were used, since they are closer than the nearest actual resident.

2.2.2 Meteorology

The White Mesa mill has an onsite meteorological monitoring station that records wind speed, wind direction, and stability class. This onsite meteorological data were used by Denison to formulate a joint frequency distribution for the dose calculations performed as part of their White Mesa license renewal application. For this risk assessment, the meteorological data from the license renewal application was reformatted so that it could be processed by the CAP88 auxiliary program, WINDGET (Trinity 2007), which generated a meteorological data file in the format required by CAP88 (i.e., a .WND file). Table 11 shows the directional-dependent average wind speed for each stability class that was used in this risk assessment, while Table 12 gives the stability class frequency.

Table 11: White Mesa Arithmetic Average Wind Speeds (Wind Towards)

Dir	Pasquill Stability Class (m/s)						
	A	B	C	D	E	F	G
N	2.727	4.293	5.984	7.051	3.651	1.924	0.000
NNW	2.670	4.234	5.430	5.673	3.186	1.857	0.000
NW	2.495	4.375	5.509	6.080	2.818	1.793	0.000
WNW	2.341	3.914	4.958	5.741	3.011	1.650	0.000
W	2.065	3.635	5.898	5.238	2.980	1.684	0.000
WSW	2.086	3.598	5.089	5.043	2.779	1.745	0.000
SW	1.833	3.217	4.058	4.495	3.280	1.956	0.000
SSW	2.130	3.399	3.697	4.366	4.326	2.229	0.000
S	1.993	3.388	4.827	5.115	4.516	2.343	0.000
SSE	2.245	4.794	6.375	7.140	4.766	2.429	0.000
SE	2.384	4.103	6.302	7.199	4.302	2.289	0.000
ESE	2.378	4.104	5.912	5.791	3.457	2.178	0.000
E	2.381	4.290	6.150	7.401	3.951	2.222	0.000
ENE	2.571	4.617	6.414	7.725	4.031	1.915	0.000
NE	2.773	4.565	6.196	7.945	4.018	1.957	0.000
NNE	2.910	4.580	6.102	8.225	4.523	2.077	0.000

Table 12: White Mesa Frequencies of Stability Classes (Wind Towards)

Dir	Pasquill Stability Class (m/s)						
	A	B	C	D	E	F	G
N	0.2581	0.2125	0.1837	0.2509	0.0372	0.0576	0.0000
NNW	0.3351	0.2376	0.1578	0.1507	0.0319	0.0869	0.0000
NW	0.3286	0.1690	0.1314	0.2253	0.0282	0.1174	0.0000
WNW	0.3637	0.1318	0.0727	0.1545	0.0500	0.2273	0.0000
W	0.3938	0.0933	0.0622	0.1088	0.0778	0.2642	0.0000
WSW	0.3098	0.1059	0.0784	0.1726	0.0588	0.2745	0.0000
SW	0.1223	0.0526	0.0782	0.3912	0.1579	0.1977	0.0000
SSW	0.0334	0.0193	0.0405	0.4585	0.3331	0.1151	0.0000
S	0.0473	0.0164	0.0327	0.4064	0.3273	0.1700	0.0000
SSE	0.0595	0.0280	0.0653	0.5449	0.1272	0.1750	0.0000
SE	0.0794	0.0451	0.1155	0.4567	0.1119	0.1913	0.0000
ESE	0.1575	0.0822	0.1575	0.3390	0.0788	0.1849	0.0000
E	0.1749	0.0933	0.1399	0.3907	0.0787	0.1224	0.0000
ENE	0.1885	0.1195	0.1747	0.3839	0.0529	0.0805	0.0000
NE	0.1781	0.1557	0.2380	0.3383	0.0359	0.0539	0.0000
NNE	0.1888	0.1958	0.2118	0.3247	0.0380	0.0410	0.0000
TOTAL	0.1560	0.0999	0.1161	0.3595	0.1397	0.1287	0.0000

2.2.3 Radon Release

SENES 2008 presents the results of a dose assessment that was performed to quantify the dose impact from the proposed development of new tailings Cell 4B. Two sources of uranium ore are considered for processing by the White Mesa mill: Colorado Plateau (0.25% U_3O_8 and 1.5% V_2O_5) and Arizona Strip (0.637% U_3O_8 and no V_2O_5). For both ores, Section 4 of SENES 2008 documents the source term, including radon, from each area of the White Mesa mill, and is summarized below.

Grinder

> The Rn-222 concentration in the ore was assumed to be equal to the U-238 concentration. The Rn-222 released during wet grinding is 92.7 and 236 Ci/yr for Colorado Plateau and Arizona Strip ore, respectively. [SENES 2008, page 4-3]

Ore Dump to Grizzly

SENES 2008 does not indicate any radon release from the grizzly (i.e., screener).

Yellowcake Stacks

> Since the ore processing steps reject nearly all the radium to the tailings, very little radon is released during the production of yellowcake. No significant radon releases occur during yellowcake drying and packaging, since only about 0.1% of the original Ra-226 in the ore is found in yellowcake. Therefore, the amount of Rn-222 emitted from the yellowcake stack was assumed to be negligible. [SENES 2008, page 4-4]

Vanadium Stack

> …, the emissions from the remaining radionuclides [including radon] were assumed to be negligible and in any event would likely be discharged to the tailings cells. [SENES 2008, page 4-4]

Ore Pads

> Rn-222 will be produced in the ore pads from the decay of Ra-226. The estimated annual radon release rate from the ore pads is 375 and 956 Ci/yr for Colorado Plateau and Arizona Strip ore, respectively. [SENES 2008, page 4-5]

Active Tailings Cells

> …, the total annual radon release rates for active tailings cell 3 and 4A and 4B were estimated to be 179 Ci/yr for tailings cell 3 and 102 Ci/yr for each of tailings cells 4A and 4B. These estimates are extremely conservative because it was assumed that the radon release rate of 20 pCi/m^2s (…) occurred over the entire area of each cell. [SENES 2008, page 4-7]

Inactive Tailings Cells

> …, the total annual radon release from the tailings cells 2 and 3 with interim soil covers were 85.3 and 89.4 Ci/yr, respectively. [SENES 2008, page 4-7]

Table 13 summarizes the SENES 2008 annual radon release from the White Mesa uranium mill.

Table 13: White Mesa Radon Release

Source	Radon Release (Ci/yr)	
	Colorado Plateau	Arizona Strip
Grinding	92.7	236
Ore Dump to Grizzly	—	
Ore Pads	375	956
North Yellowcake Stack	—	
South Yellowcake Stack	—	
Tailing Cell 2: Interim Soil Cover	85.3	
Tailing Cell 3: Interim Soil Cover	89.4	
Tailing Cell 3: Active	179	
Tailing Cell 4A: Active	102	
Tailing Cell 4B: Active	102	
Vanadium Stack	—	N/A
Total	1,025	1,750

Source: SENES 2008, Tables 4.5-1 and 4.5-2

2.2.4 Risk Estimates

The RMEI and population doses and risks calculated by CAP88 for the White Mesa site are shown in Table 14.

Table 14: White Mesa Risk Assessment Results

Receptor / Impact		Radon Release (Ci/yr)		
		Unitized	**Maximum**	**Average**
		1	1750	1388
RMEI (1500m SSE)	Dose (mrem/yr)	5.8E-03	1.2E+01	7.0E+00
	LCF Risk (yr^{-1})	3.1E-09	6.4E-06	3.7E-06
Population	Dose (person-rem/yr)	2.5E-03	5.2E+00	3.0E+00
	LCF Risk (yr^{-1})	1.6E-08	3.4E-05	2.0E-05

2.3 Cañon City[3]

The Cañon City mill, shown in Figure 3, is located approximately two miles south of downtown Cañon City in Fremont County, Colorado. The community of Lincoln Park borders the site to the north and the housing developments of Dawson Ranch, Wolf Park, and Eagle Heights are located along the mill's western boundary. The 2,500-acre site includes two inactive mills, ore stockpile areas, a partially reclaimed tailings pond disposal area (i.e., the old ponds area), and a current tailings pond disposal area (i.e., the lined "main impoundment area"). A large portion of the site is used to store waste products in the impoundment area.

[3] The description of the Cañon City site was abstracted from various sources, including CDPHE 2007, Cotter 2010, and ATSDR 2010, while the aerial view of the Cañon City site was obtained from Google Maps.

Figure 3: Cañon City – Aerial View

The Cañon City mill, which is owned by the Cotter Corporation, began operations in 1958, extracting uranium ore using an alkaline leach process. At that time, the mill was licensed by the U.S. Atomic Energy Agency; currently it is licensed by the state of Colorado (Radioactive Materials License: Colo. 369-01). In 1979, the facility switched to an acid leach process for extracting uranium. Cotter suspended primary operations in 1987, and only limited and intermittent processing occurred until the facility resumed operations in 1999 with a modified alkaline-leaching capability until 2001. Cotter refabricated the mill circuits between 2002 and 2005 to operate using an acid process, since March 2006 the mill has been in storage. Current accelerated efforts to close down contaminated facilities at the Cañon City site may be aimed at clearing a path for possible uranium processing in the future and do not indicate that Cotter plans to leave the 2,600-acre site. There is indication that Cotter is planning a $200-million rebuild of the mill by 2014, when it expects to treat ore from the Mount Taylor mine in New Mexico.

2.3.1 Population and Food Production

The 80-kilometer population distribution in each of the 16 principal compass directions, which was calculated for the Cañon City site by SECPOP and used in CAP88 for population dose calculations, is shown in Table 15. To adjust the 2000 population data to 2010, the CAP88 Cañon City population dose was multiplied by 1.04, see Section 1.2 and Table 3.

Table 15: Cañon City Population Data

Dir	Distance (km)					
	0 to 1	**1 to 2**	**2 to 3**	**3 to 4**	**4 to 5**	**5 to 10**
N	0	18	37	915	1198	9911
NNW	0	0	20	114	1699	1663
NW	0	0	105	0	20	0
WNW	0	16	38	0	0	0
W	0	71	27	0	0	0
WSW	0	0	0	0	30	0
SW	0	0	0	0	0	7
SSW	0	0	0	0	0	0
S	0	0	0	0	0	0
SSE	0	0	0	9	0	8
SE	0	0	0	0	0	32
ESE	0	0	0	0	0	1484
E	0	0	0	0	0	2040
ENE	0	0	0	106	52	2961
NE	0	0	31	679	295	1939
NNE	0	0	138	942	1046	4365
Dir	**Distance (km)**					
	20 to 30	**30 to 40**	**40 to 50**	**50 to 60**	**60 to 70**	**70 to 80**
N	4	1310	1083	2224	5576	450
NNW	4	46	369	347	251	132
NW	93	61	43	102	55	117
WNW	0	39	41	41	6061	1261
W	196	225	315	996	290	901
WSW	637	136	169	32	249	152
SW	205	812	106	13	726	134
SSW	341	737	261	0	98	15
S	145	5	253	145	180	155
SSE	295	56	699	1683	754	160
SE	107	236	506	513	1104	36
ESE	16	1688	8507	90006	10649	1976
E	1350	1081	6010	14530	20	84
ENE	733	12	43	3498	203	578
NE	7	215	1369	111270	191995	52423
NNE	38	627	99	15816	66131	34794

The agricultural productivity factors for Colorado were taken from Appendix C of the CAP88 User's Manual, as shown below, and used in the Cañon City site population dose calculation.

Beef Cattle Density (cattle/km^2):	1.13
Milk Cattle Density (cow/km^2):	0.35
Land Cultivated for Vegetable Crops:	1.39%

The distance and direction to the RMEI were identified in the Agency for Toxic Substances and Disease Registry's public health assessment (ATSDR 2010) as:

> The nearest residence is about 0.25 miles from the mill [ATSDR 2010, page 1].

Notice that the Table 15 SECPOP estimate places the nearest individuals to Cañon City at a distance of 1 to 2 km in the North, West, and WNW directions. Through analysis using CAP88 the RMEI was found to be located 1 to 2 km North. To calculate the RMEI dose and risk for this study, the Table 15 RMEI distances and directions were used, since the public health assessment did not specify the direction to the nearest resident.

2.3.2 Meteorology

The CAP88 computer program is provided with a weather library of meteorological data from over 350 NWS stations. For the Cañon City site, the CAP88-provided weather data for Colorado Springs, CO (CAP88 File: 93037.WND) were used. The period of record for this data included the years 1988 through 1992. Table 16 shows the directional dependent average wind speed for each stability class, while Table 17 gives the stability class frequency, used in the Cañon City analysis.

Table 16: Cañon City Arithmetic Average Wind Speeds (Wind Towards)

Dir	Pasquill Stability Class (m/s)						
	A	**B**	**C**	**D**	**E**	**F**	**G**
N	1.900	2.710	4.450	5.320	3.570	1.950	0.000
NNW	1.830	2.880	4.610	5.480	3.760	2.030	0.000
NW	1.950	2.980	4.310	5.200	3.760	2.070	0.000
WNW	1.850	2.820	3.760	4.690	3.700	2.020	0.000
W	1.880	2.360	3.450	4.390	3.650	2.030	0.000
WSW	1.640	2.190	3.490	4.660	3.550	2.020	0.000
SW	1.880	2.440	3.220	4.960	3.740	2.230	0.000
SSW	1.850	2.120	3.970	5.170	3.960	2.300	0.000
S	2.030	2.030	4.200	6.540	4.010	2.250	0.000
SSE	1.480	2.340	3.790	7.000	3.940	2.150	0.000
SE	2.030	2.120	3.590	6.710	3.740	2.080	0.000
ESE	2.020	2.200	3.320	6.500	3.570	1.930	0.000
E	1.880	1.870	3.750	6.120	3.470	1.840	0.000
ENE	1.880	2.330	3.730	6.030	3.470	1.860	0.000
NE	2.030	2.400	3.480	6.020	3.450	1.840	0.000
NNE	1.780	2.720	4.200	5.960	3.410	1.860	0.000

Table 17: Cañon City Frequencies of Stability Classes (Wind Towards)

Dir	Pasquill Stability Class (m/s)						
	A	B	C	D	E	F	G
N	0.0116	0.1188	0.2367	0.4935	0.0654	0.0741	0.0000
NNW	0.0071	0.0907	0.2116	0.5325	0.0851	0.0730	0.0000
NW	0.0123	0.0988	0.2017	0.4892	0.1146	0.0833	0.0000
WNW	0.0164	0.1108	0.1983	0.3762	0.1622	0.1362	0.0000
W	0.0154	0.1102	0.1597	0.3290	0.1767	0.2090	0.0000
WSW	0.0085	0.0823	0.1231	0.3181	0.1974	0.2706	0.0000
SW	0.0044	0.0474	0.0783	0.2728	0.2647	0.3324	0.0000
SSW	0.0021	0.0220	0.0577	0.2310	0.3668	0.3204	0.0000
S	0.0021	0.0190	0.0658	0.4320	0.2807	0.2004	0.0000
SSE	0.0023	0.0226	0.0603	0.6097	0.1893	0.1159	0.0000
SE	0.0017	0.0307	0.0855	0.5660	0.1750	0.1410	0.0000
ESE	0.0045	0.0585	0.1043	0.5250	0.1552	0.1525	0.0000
E	0.0108	0.0861	0.1416	0.4909	0.1250	0.1457	0.0000
ENE	0.0204	0.1346	0.1629	0.4512	0.0858	0.1451	0.0000
NE	0.0180	0.1876	0.1914	0.4188	0.0725	0.1118	0.0000
NNE	0.0149	0.1415	0.2149	0.4723	0.0712	0.0852	0.0000
TOTAL	0.0074	0.0678	0.1321	0.4401	0.1863	0.1664	0.0000

2.3.3 Radon Release

Cotter Corporation does not include the site's radon release in its semi-annual effluent reports that are prepared for the Colorado Department of Public Health and Environment. However, until recently, the reports did include the results of radon flux measurements for the Primary and Secondary Impoundments in their semi-annual effluent reports. The radon flux measurements can be used to calculate an annual radon release following the guidance provided in Quinn 2010. This was done, and the resulting annual radon releases from 1999 through 2009 are tabulated in Table 18 and shown graphically in Figure 4.

Table 18: Cañon City Annual Radon Release

Year	Radon Flux (pCi/m^2-s)	Radon Release (Ci/y)
1999	13.2	180
2000	7.7	105
2001	7.9	108
2002	15.9	217
2003	5.8	79
2004	6.2	85
2005	7.6	104
2006	6.1	83
2007	14	191
2008	19.7	269
2009	13.4	183

Sources: Cotter 2007, Figure 4-19; Cain 2008, page 47; Cain 2010, page 50

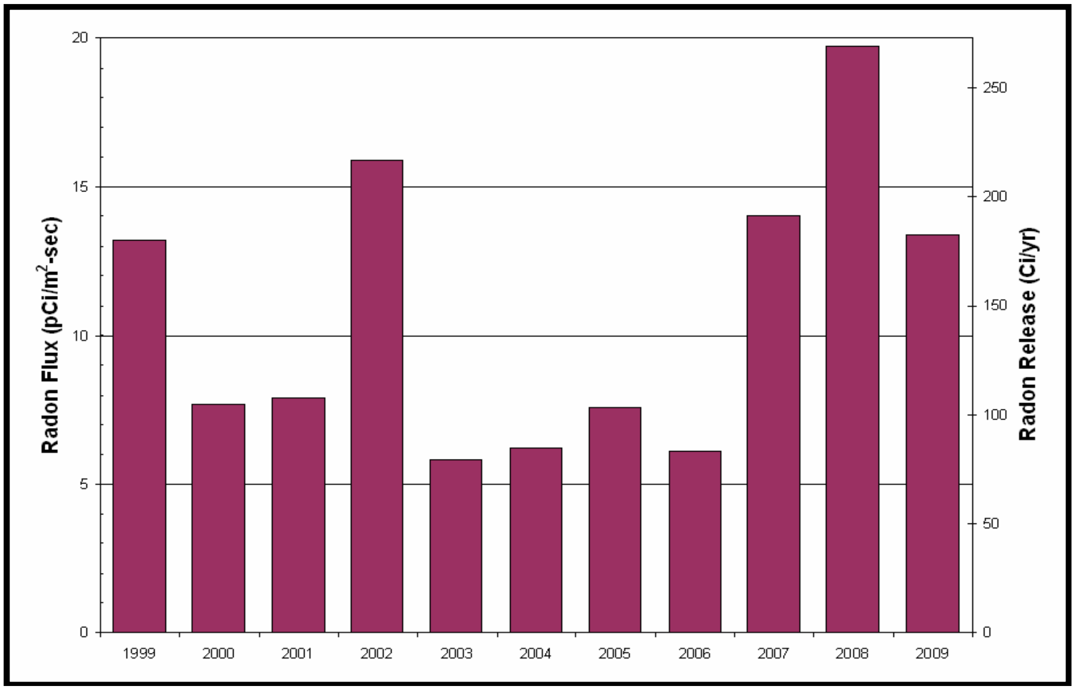

Figure 4: Cañon City Radon Flux and Annual Release

Although the radon releases given in Table 18 and Figure 4 are only from the impoundments, it is assumed that other onsite sources of radon would be small by comparison. The basis for this assumption is that no milling operations have occurred at Cañon City since 2005, and there is not likely much uranium onsite to act as a source of radon. This is supported by the monthly release rates for uranium, thorium, and radium, which are very low. Finally, Cotter 2010 points out that the offsite radon daughter (i.e., ^{210}Pb) concentrations (which are measured and reported in the semiannual effluent reports) are consistent with what would be expected from non-Cañon City Milling Facility radon:

> Results for ^{210}Pb at all monitoring locations are controlled by regional ^{222}Rn concentrations and do not exhibit discernible effects from milling facility activities. [Cotter 2010, page 5-4]

2.3.4 Risk Estimates

The RMEI and population doses and risks calculated by CAP88 for the Cañon City site are shown in Table 19.

Table 19: Cañon City Risk Assessment Results

Receptor / Impact		Radon Release (Ci/yr)		
		Unitized	Maximum	Average
		1	269	146
RMEI (1500m N)	Dose (mrem/yr)	5.0E-03	1.0E+01	6.0E+00
	LCF Risk (yr^{-1})	2.6E-09	5.4E-06	3.1E-06
Population	Dose (person-rem/yr)	2.4E-02	4.9E+01	2.9E+01
	LCF Risk (yr^{-1})	1.5E-07	3.1E-04	1.8E-04

2.4 Smith Ranch – Highland[4]

Power Resources Incorporated (PRI), a wholly owned subsidiary of the Cameco Corporation, operates the Highland and Smith Ranch ISL uranium mines located in eastern Wyoming, approximately 16 miles north of Glenrock in Converse County. In 1987, ISL facilities were constructed at the Highland mine, and commercial production began a year later. Cameco acquired PRI in 1997. The first ISL pilot operation began in 1981 at the Smith Ranch; the second operation began in 1984. Commercial ISL facilities were constructed in 1996 and began producing a year later. Cameco then acquired the Smith Ranch from Rio Algom Mining Corporation in 2002 and consolidated the Highland and Smith Ranch operations (the Highland license, SUA-1511, was integrated into the license: SUA-1548). The Highland and Smith Ranch mines are currently the largest operated uranium production facilities in the United States, with lifetime production capacities of two million pounds of uranium from each facility. Proven and probable reserves total 5.9 million pounds of U_3O_8, and in 2009, production was 1.8 million pounds of U_3O_8.

The permit area for the combined Smith Ranch – Highland properties contains 30,760 acres. The main facilities at the Smith Ranch – Highland Uranium Project (SR-HUP), besides the well fields, include the two yellowcake processing plant sites and related facilities that are located within the former Bill Smith Mine site (Smith Ranch Main Office Central Processing Plant [CPP] Complex) and the former Exxon Highland Mine site (HUP Central Plant/Office Complex). Since 2002, the HUP facilities have been on stand-by status, although in the future it may be used as a resin stripping, elution, and precipitation facility. All yellowcake processing, office, and related activities currently are occurring at Smith Ranch, shown in Figure 5. In association with the Smith Ranch CPP is a lined, two-celled evaporation pond to assist with wastewater disposal. Additional lined evaporation ponds consisting of 5- to 15-acre cells may be constructed as needed. Waste water is also disposed at two deep disposal wells at Smith Ranch and one deep disposal well at Highland.

4 The description of the Smith Ranch – Highland site was abstracted from various sources, including RAMC 1999, Trihydro 2005, Melbye 2008, Cameco 2009, and Cameco 2010b, while the aerial view of the Smith Ranch – Highland site was obtained from Google Maps.

Figure 5: Smith Ranch – Aerial View

2.4.1 Population and Food Production

The 80-kilometer population distribution in each of the 16 principal compass directions, which was calculated for the Smith Ranch – Highland site by SECPOP and used in CAP88 for population dose calculations, is shown in Table 20. To adjust the 2000 population data to 2010, the CAP88 Smith Ranch – Highland population dose was multiplied by 1.14, see Section 1.2 and Table 3.

Table 20: Smith Ranch – Highland Population Data

Dir	Distance (km)						
	0 to 1	1 to 2	2 to 3	3 to 4	4 to 5	5 to 10	10 to 20
N	0	0	0	0	0	0	10
NNW	0	0	0	0	0	0	0
NW	0	0	0	0	0	0	0
WNW	0	0	0	0	0	0	0
W	0	0	0	0	0	0	0
WSW	0	0	0	0	0	0	6
SW	0	0	0	0	0	0	33
SSW	0	0	0	0	0	0	133
S	0	0	0	0	0	0	19
SSE	0	0	0	0	0	0	0
SE	0	0	0	0	0	0	9
ESE	0	0	0	0	0	0	0
E	0	0	0	0	0	2	0
ENE	0	0	0	0	0	0	0
NE	0	0	0	0	0	0	4
NNE	0	0	0	0	0	0	6

Table 20: Smith Ranch – Highland Population Data

Dir	Distance (km)					
	20 to 30	30 to 40	40 to 50	50 to 60	60 to 70	70 to 80
N	7	5	13	30	4	172
NNW	2	3	14	10	10	11
NW	0	0	0	17	590	31
WNW	0	0	13	3	6	2
W	0	0	2	304	24	123
WSW	37	216	926	42155	20374	756
SW	2418	137	179	63	66	32
SSW	893	25	27	5	0	0
S	80	37	33	6	5	4
SSE	77	388	586	88	35	63
SE	19	1234	5161	78	106	54
ESE	16	5	21	29	22	44
E	5	8	5	16	20	13
ENE	0	21	30	3	21	12
NE	9	0	14	14	4	19
NNE	4	14	9	3	33	1299

The agricultural productivity factors for Wyoming were taken from Appendix C of the CAP88 User's Manual, as shown below, and used in the Smith Ranch – Highland site population dose calculation.

Beef Cattle Density (cattle/km^2):	5.12
Milk Cattle Density (cow/km^2):	0.0579
Land Cultivated for Vegetable Crops:	0.159%

The distance and direction to the RMEI were identified in the Smith Ranch – Highland license application (PRI 2003) as:

> … the Sundquist (Smith) Ranch located approximately 2.6 miles southwest of the Smith Ranch Main Office/CPP site, the Vollman Ranch well located approximately 1.5 miles east of Satellite No. 3 and the Fowler Ranch well located just north of the permit area approximately 2.5 miles north of the Highland Central Plant. [PRI 2003, page 2-3]

Notice, that the Table 20 SECPOP estimate places the nearest individual to Smith Ranch – Highland at a distance of 5 to 10 km in the East direction. This location was found through analysis using CAP88 to be the location of the RMEI. To calculate the RMEI dose and risk for this study, the Table 20 RMEI distance and direction were used.

2.4.2 Meteorology

The CAP88 computer program is provided with a weather library of meteorological data from over 350 NWS stations. For the Smith Ranch – Highland site, the CAP88-provided weather data for Casper, WY (CAP88 File: CPR0335.WND) were used. The period of record for this data included the years 1967 through 1971. Table 21 shows the directional dependent average wind speed for each stability class, while Table 22 gives the stability class frequency used in the Smith Ranch – Highland analysis.

Table 21: Smith Ranch – Highland Arithmetic Average Wind Speeds (Wind Towards)

Dir	Pasquill Stability Class (m/s)						
	A	B	C	D	E	F	G
N	1.372	2.360	3.774	5.971	3.088	1.804	0.000
NNW	1.855	2.243	3.408	4.058	3.145	1.862	0.000
NW	1.972	2.493	3.522	4.613	3.354	2.059	0.000
WNW	1.991	2.361	3.922	5.109	3.762	1.924	0.000
W	1.585	2.354	3.613	5.489	3.668	2.019	0.000
WSW	1.178	2.558	3.731	4.958	3.653	2.147	0.000
SW	1.991	2.901	3.740	5.331	3.461	2.056	0.000
SSW	1.725	2.656	3.756	5.648	3.423	2.160	0.000
S	1.972	2.687	3.938	5.565	3.384	1.943	0.000
SSE	1.991	2.699	4.561	4.794	3.367	2.064	0.000
SE	0.772	3.216	3.909	6.086	3.344	2.104	0.000
ESE	1.972	2.827	4.075	6.414	3.521	2.041	0.000
E	1.837	2.846	4.651	6.724	3.865	2.010	0.000
ENE	1.725	2.973	4.670	7.288	4.105	2.073	0.000
NE	1.178	2.691	5.089	8.261	4.040	1.959	0.000
NNE	1.672	2.809	4.477	8.494	3.971	1.924	0.000

Table 22: Smith Ranch – Highland Frequencies of Stability Classes (Wind Towards)

Dir	Pasquill Stability Class (frequency)						
	A	B	C	D	E	F	G
N	0.0093	0.1614	0.1547	0.4633	0.0849	0.1264	0.0000
NNW	0.0904	0.1825	0.1474	0.3184	0.1325	0.1289	0.0000
NW	0.0115	0.1378	0.1499	0.4327	0.1466	0.1214	0.0000
WNW	0.0109	0.0631	0.1201	0.5322	0.1641	0.1095	0.0000
W	0.0067	0.0608	0.1044	0.5708	0.1438	0.1135	0.0000
WSW	0.0092	0.0366	0.0886	0.5864	0.1417	0.1376	0.0000
SW	0.0072	0.0404	0.0644	0.6413	0.1314	0.1152	0.0000
SSW	0.0084	0.0388	0.0585	0.6700	0.1046	0.1197	0.0000
S	0.0037	0.0385	0.0691	0.5697	0.1331	0.1860	0.0000
SSE	0.0084	0.0694	0.0792	0.4323	0.1598	0.2509	0.0000
SE	0.0061	0.0442	0.0914	0.4621	0.1687	0.2275	0.0000
ESE	0.0109	0.0439	0.0937	0.4982	0.1641	0.1892	0.0000
E	0.0081	0.0372	0.0843	0.4802	0.2302	0.1600	0.0000
ENE	0.0031	0.0175	0.0636	0.6527	0.1984	0.0647	0.0000
NE	0.0017	0.0165	0.0400	0.8454	0.0730	0.0233	0.0000
NNE	0.0044	0.0224	0.0438	0.8422	0.0546	0.0327	0.0000
TOTAL	0.0066	0.0389	0.0717	0.6385	0.1394	0.1049	0.0000

2.4.3 Radon Release

Tables 3 and 4 of Savignac 2007 provide the data necessary to use NUREG-1569 (NRC 2003), Appendix D to calculate the radon released from the various Smith Ranch – Highland well fields during both production and restoration, respectively. Using the Savignac 2007 data, Table 23 presents the calculated well field annual radon releases during both production and restoration. The reason that the annual restoration radon release is greater than the production release for all the well fields, except well field SW, is because the restoration purge rate is greater. Thus, there is less time for radiological decay to reduce the amount of radon prior to its release.

Table 23: Smith Ranch – Highland Well Field Annual Radon Release

Well Field	Radon Release (Ci/yr)						
	Production				Restoration		
	Purge	Vent	IX	Total	Purge	Vent	Total
C	19	1,544	2.3	1,565	157	1,537	1,694
D	6	257	2.3	266	26	256	282
Dext	4	772	2.3	779	79	768	848
E	2	1,011	2.3	1,016	103	1,006	1,109
F	8	4,230	2.3	4,241	455	4,207	4,662
H	1	2,207	2.3	2,210	225	2,195	2,420
I	28	2,206	2.3	2,236	225	2,195	2,420
1	185	983	8.7	1,177	794	952	1,745
2	126	674	3.4	803	217	669	886
3	237	1,275	6.9	1,518	806	1,245	2,051
4/4A	185	1,001	8.2	1,195	334	994	1,328
(SR)15	62	2,572	2.3	2,636	239	2,562	2,801
(SR)15A	58	2,388	2.2	2,448	206	2,380	2,586
(HUP)J	40	2,389	2.2	2,431	245	2,378	2,624
(HUP)K	41	844	2.4	887	94	841	935
SW	4,727	3,615	1.1	8,343	311	3,846	4,157

Cameco 2009 presents a revised estimated schedule for Smith Ranch – Highland well field activities, which has been reproduced below as Figure 6.

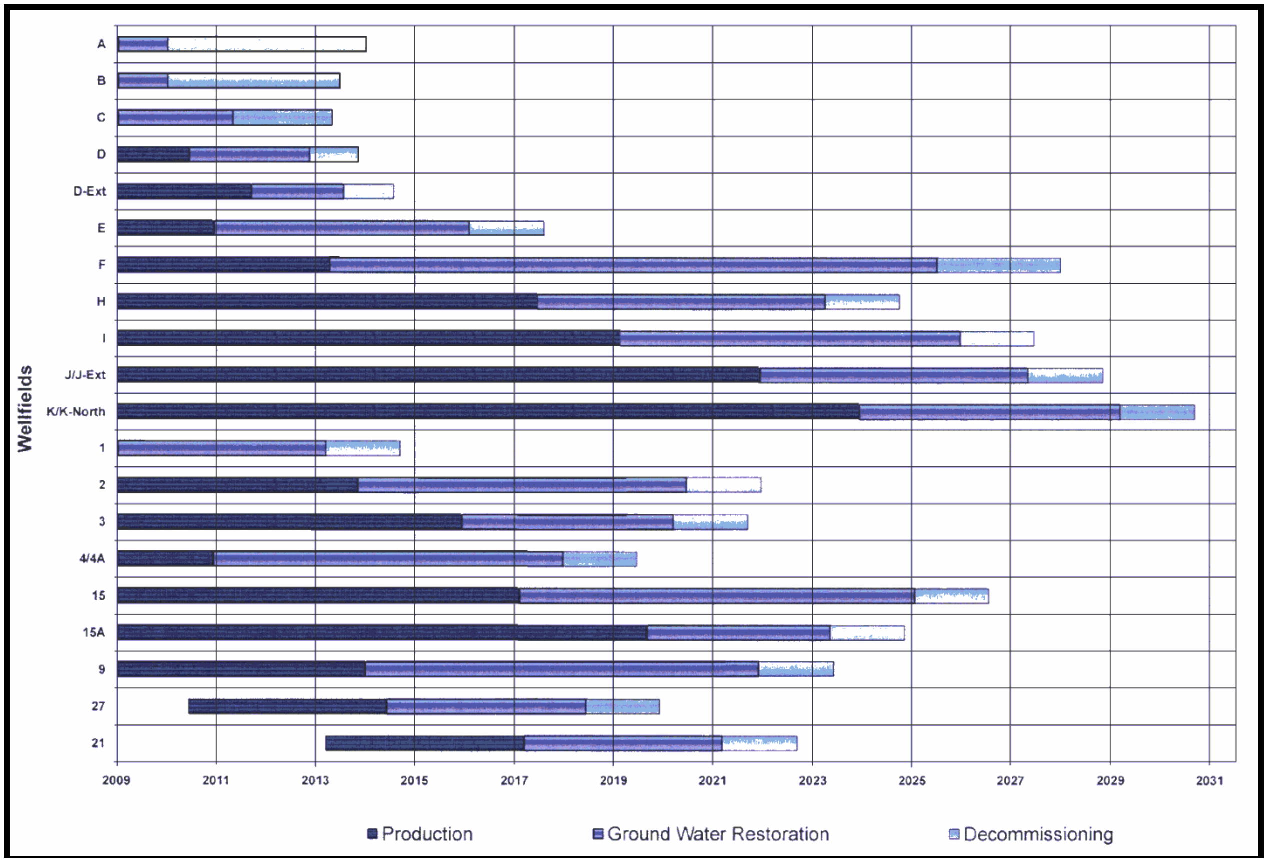

Figure 6: Smith Ranch – Highland – Estimated Time Table of Mining Related Activities

Figure 6 is used in conjunction with Table 23 to calculate the site-wide annual radon release over the Smith Ranch – Highlands estimated operating life. Figure 7 shows these calculated Smith Ranch – Highland radon releases.

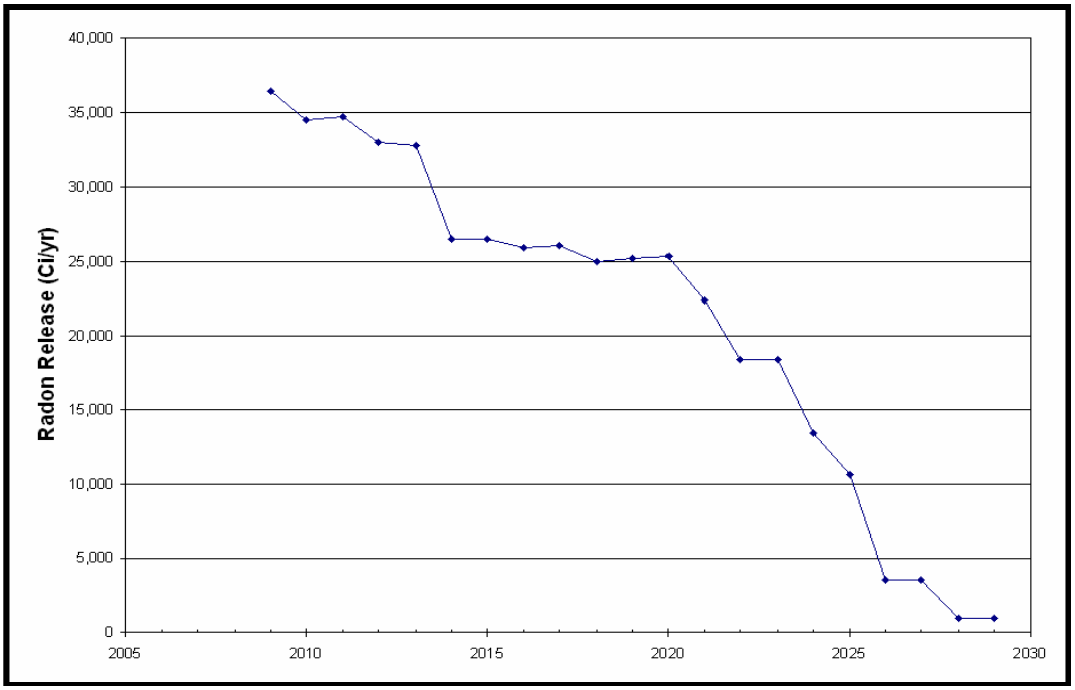

Figure 7: Smith Ranch – Highland – Total Estimated Radon Release by Year

The calculated maximum Smith Ranch – Highland annual radon release from all well fields either in production or restoration occurs in 2009 and is 36,500 Ci, while the average annual radon release from 2009 to 2029 is 21,100 Ci.

2.4.4 Risk Estimates

The RMEI and population doses and risks calculated by CAP88 for the Smith Ranch – Highland site are shown in Table 24.

Table 24: Smith Ranch – Highland Risk Assessment Results

Receptor / Impact		Radon Release (Ci/yr)		
		Unitized	Maximum	Average
		1	36,500	21,100
RMEI (7500m E)	Dose (mrem/yr)	7.2E-04	1.5E+00	8.6E-01
	LCF Risk (yr^{-1})	3.7E-10	7.7E-07	4.5E-07
Population	Dose (person-rem/yr)	1.8E-03	3.7E+00	2.2E+00
	LCF Risk (yr^{-1})	1.1E-08	2.3E-05	1.3E-05

2.5 Crow Butte[5]

The Crow Butte Project site is located in west central Dawes County, Nebraska, just north and west of the Pine Ridge Area. The Crow Butte Project site, shown in Figure 8, is about 4.0 miles southeast of the City of Crawford via Squaw Creek Road. What is now the Crow Butte Project was originally developed by Wyoming Fuel Corporation, which constructed a R&D facility at the site in 1986; commercial operations began in 1991. The project was subsequently acquired and is now owned and operated by Crow Butte Resources, Inc. (CBR), known as the Ferret Exploration Company of Nebraska until May 1994. It is the first uranium mine in Nebraska and has reserves of 5.9 million pounds of U_3O_8 (2,270 tonnes U), resources of 8.5 million pounds of U_3O_8 (3,270 tonnes U), and an annual capacity of 2 million pounds of U_3O_8.

Figure 8: Crow Butte – Aerial View

Most of the following description of the Crow Butte ISL process was taken from the license renewal application (CBR 2007). Uranium is recovered by ISL from the Chadron Sandstone at a depth that varies from 400 feet to 900 feet. The overall width of the mineralized area varies from 1000 feet to 5000 feet. The ore body ranges from less than 0.05 percent to greater than 0.5 percent U_3O_8, with an average grade estimated at 0.26 percent equivalent U_3O_8. The ISL process at Crow Butte uses gaseous oxygen or hydrogen peroxide to oxidize the uranium, and bicarbonate for dissolution. The uranium-bearing solution that results from the leaching of uranium underground is recovered from the well field and the uranium is extracted in the process plant. The plant process consists of the following steps:

- Loading of uranium complexes onto ion exchange resin;
- Reconstitution of the solution by the addition of carbonate and an oxidizer;

[5] The description of the Crow Butte site was abstracted from various sources, including CBR 2007, Melbye 2008, CBR 2009, and Cameco 2010a, while the aerial view of the Crow Butte site was obtained from Google Maps.

- Elution of the uranium complexes from the resin; and
- Drying and packaging of the uranium.

The radon-222 is contained in the pregnant lixiviant that comes from the well field to the process plant. The majority of this radon is released in the ion exchange columns and process tanks. These vessels are covered and vented to a manifold, which are in turn exhausted to atmosphere outside the building through stacks.

2.5.1 Population and Food Production

The 80-kilometer population distribution in each of the 16 principal compass directions, which was calculated for the Crow Butte site by SECPOP and used in CAP88 for population dose calculations, is shown in Table 25. To adjust the 2000 population data to 2010, the CAP88 Crow Butte population dose was multiplied by 0.96, see Section 1.2 and Table 3.

Table 25: Crow Butte Population Data

Dir	Distance (km)						
	0 to 1	1 to 2	2 to 3	3 to 4	4 to 5	5 to 10	10 to 20
N	0	0	0	0	0	19	20
NNW	0	0	0	1	0	34	39
NW	0	0	0	1	0	1140	33
WNW	0	0	4	0	0	20	12
W	0	3	0	0	0	24	20
WSW	0	2	0	5	0	7	21
SW	0	0	0	6	0	0	25
SSW	0	0	0	0	1	10	18
S	0	0	0	0	0	0	41
SSE	0	0	0	0	12	0	22
SE	0	0	0	0	0	10	12
ESE	0	1	0	0	0	0	43
E	0	0	0	0	0	0	6
ENE	0	0	0	15	0	9	32
NE	0	0	0	0	0	7	42
NNE	0	0	0	0	0	5	147

Table 25: Crow Butte Population Data

Dir	Distance (km)					
	20 to 30	30 to 40	40 to 50	50 to 60	60 to 70	70 to 80
N	0	3	22	88	187	232
NNW	3	7	13	22	37	80
NW	26	24	4	23	0	51
WNW	25	35	22	22	28	37
W	27	26	295	35	72	25
WSW	22	8	9	29	35	34
SW	13	7	46	14	14	26
SSW	17	14	22	12	88	355
S	29	42	40	34	8	239
SSE	37	80	1148	209	268	5496
SE	14	94	134	182	495	3841
ESE	43	60	35	178	131	70
E	70	263	101	889	162	1193
ENE	203	598	101	86	109	3858
NE	59	5588	55	29	166	1904
NNE	1	17	11	17	81	103

The agricultural productivity factors for Nebraska were taken from Appendix C of the CAP88 User's Manual, as shown below, and used in the Crow Butte site population dose calculation.

Beef Cattle Density (cattle/km^2): 35.
Milk Cattle Density (cow/km^2): 0.878
Land Cultivated for Vegetable Crops: 2.39%

The distance and direction to the RMEI were identified in the CBR's response to NRC's request for additional information (RAI) (CBR 2009) regarding the Crow Butte license renewal application as:

> Two dwelling units are within 0.62 mile [ENE and ESE], and another five dwelling units are within 1.24 miles of the center point of the License Area. [CBR 2009, Section 2.2.3.4]

Notice that the Table 25 SECPOP estimate places the nearest individuals to Crow Butte at a distance of 1 to 2 km in the West, WSW, and ESE directions. Through analysis using CAP88 the RMEI was found to be located 1 to 2 km in the WSW direction. To calculate the RMEI dose and risk for this study, the Table 25 RMEI distances and directions were used, since they are consistent with the RAI response information (i.e., 0.62 mile is equal to 1 km in the ESE direction, and 1.24 miles is about 2 km).

2.5.2 Meteorology

The Crow Butte ISL site has a meteorological monitoring station that records wind speed, wind direction, and stability class. This onsite meteorological data were used by CBR to formulate a joint frequency distribution for the dose calculations performed as part of the Crow Butte license renewal application. For this risk assessment, the meteorological data from the license renewal application were reformatted so that it could be processed by the CAP88 auxiliary program, WINDGET (Trinity 2007), which generated a meteorological data file in the format required by CAP88 (i.e., a .WND file). Table 26 shows the directional-dependent average wind speed for each stability class that was used in this risk assessment for the Crow Butte site, while Table 27 gives the stability class frequency.

Table 26: Crow Butte Arithmetic Average Wind Speeds (Wind Towards)

Dir	Pasquill Stability Class (m/s)						
	A	B	C	D	E	F	G
N	3.702	5.309	5.269	8.323	3.824	2.504	0.000
NNW	4.259	5.031	7.395	7.497	3.340	2.364	0.000
NW	3.890	5.313	6.946	6.680	3.971	2.243	0.000
WNW	3.251	4.099	6.033	5.610	3.801	1.897	0.000
W	3.208	4.558	6.026	6.968	3.559	1.643	0.000
WSW	3.400	4.658	6.596	6.267	3.786	1.869	0.000
SW	3.381	4.672	6.051	6.886	3.936	2.446	0.000
SSW	3.594	4.399	5.726	7.469	3.882	2.095	0.000
S	3.844	5.053	5.848	6.572	3.401	1.826	0.000
SSE	3.898	5.988	5.852	8.053	3.356	1.682	0.000
SE	4.106	5.996	5.821	9.384	4.293	2.160	0.000
ESE	4.322	4.833	5.447	8.553	4.029	2.311	0.000
E	4.296	5.217	5.643	8.225	3.246	2.105	0.000
ENE	4.024	5.198	4.985	7.496	4.094	2.192	0.000
NE	3.804	4.493	5.118	6.580	4.179	2.347	0.000
NNE	4.550	4.719	4.820	7.136	3.594	2.568	0.000

Table 27: Crow Butte Frequencies of Stability Classes (Wind Towards)

Dir	Pasquill Stability Class (frequency)						
	A	B	C	D	E	F	G
N	0.0229	0.0336	0.0608	0.5833	0.1758	0.1236	0.0000
NNW	0.0349	0.0462	0.0908	0.5105	0.2089	0.1087	0.0000
NW	0.0885	0.1017	0.1610	0.3487	0.1788	0.1213	0.0000
WNW	0.0605	0.1256	0.1596	0.2897	0.1589	0.2058	0.0000
W	0.1169	0.0716	0.4700	0.1658	0.0878	0.0879	0.0000
WSW	0.1062	0.1419	0.2329	0.3233	0.1250	0.0708	0.0000
SW	0.0833	0.1149	0.1570	0.4925	0.1229	0.0294	0.0000
SSW	0.1098	0.0898	0.1157	0.5296	0.1157	0.0395	0.0000
S	0.1463	0.1528	0.1463	0.3110	0.1425	0.1010	0.0000
SSE	0.0825	0.1194	0.1369	0.5582	0.0695	0.0335	0.0000
SE	0.0332	0.0615	0.0780	0.7436	0.0521	0.0315	0.0000
ESE	0.0677	0.1026	0.0720	0.5913	0.1089	0.0574	0.0000
E	0.0823	0.1161	0.1263	0.4623	0.1055	0.1075	0.0000
ENE	0.0372	0.0696	0.1450	0.5163	0.1518	0.0801	0.0000
NE	0.0281	0.0439	0.0930	0.5189	0.1994	0.1166	0.0000
NNE	0.0244	0.0400	0.0874	0.4574	0.2123	0.1785	0.0000
TOTAL	0.0559	0.0730	0.1152	0.5100	0.1510	0.0948	0.0000

2.5.3 Radon Release

Regarding radon release from the Crow Butte site, the application for license renewal (CBR 2007) stated:

> The only radioactive airborne effluent at the Crow Butte Project is radon-222 gas. As yellowcake drying and packaging is carried out using a vacuum dryer, there are no airborne effluents from that system.
>
> The radon-222 is contained in the pregnant lixiviant that comes from the wellfield to the process plant. The majority of this radon is released in the ion exchange columns and process tanks. These vessels are covered and vented to a manifold, which are in turn exhausted to atmosphere outside the building through stacks. The manifolds are equipped with an exhausting fan. [CBR 2007, Section 1.8.1]

As required by 10 CFR § 40.65 and License SUA-1534 Condition Number 12.1, the estimated release of radon from process operations is reported in the semi-annual reports. Table 28 contains annual calculated radon releases from the Crow Butte Project Facility since 1994, as does Figure 9.

Table 28: Crow Butte Radon Release to the Environment

Year	Release (Ci/yr)	Year	Release (Ci/yr)
1995	3,537	2001	4,633
1996	3,997	2002	4,675
1997	4,175	2003	4,615
1998	4,740	2004	4,671
1999	4,674	2005	4,517
2000	4,760	2006	4,607

Source: CBR 2009, Table 5.8-8

Table 29: Crow Butte Modeled Radon Release

Source	Release (Ci/yr)
Plant Vent	4,603
Satellite Plant Vent	342
MU-2-4 (restoration)	350
MU-5	454
MU-6&8	908
MU 7&9	908
North Trend Well Field	1,320
Total	8,885

Source: CBR 2007, Table 7.12-5

CBR 2007 used MILDOS-Area to model the emission rate of radon from the Crow Butte Project, including the North Trend Well Field. Those modeled radon emission rates are shown in Table 29, which consists of a flow of 5000 gpm in the up-flow ion exchange columns in the existing plant, along with the proposed 4000 gpm of flow treated in the pressurized down-flow ion exchange columns. Notice that the modeled radon release rate is about twice as that reported as the estimated radon release rate.

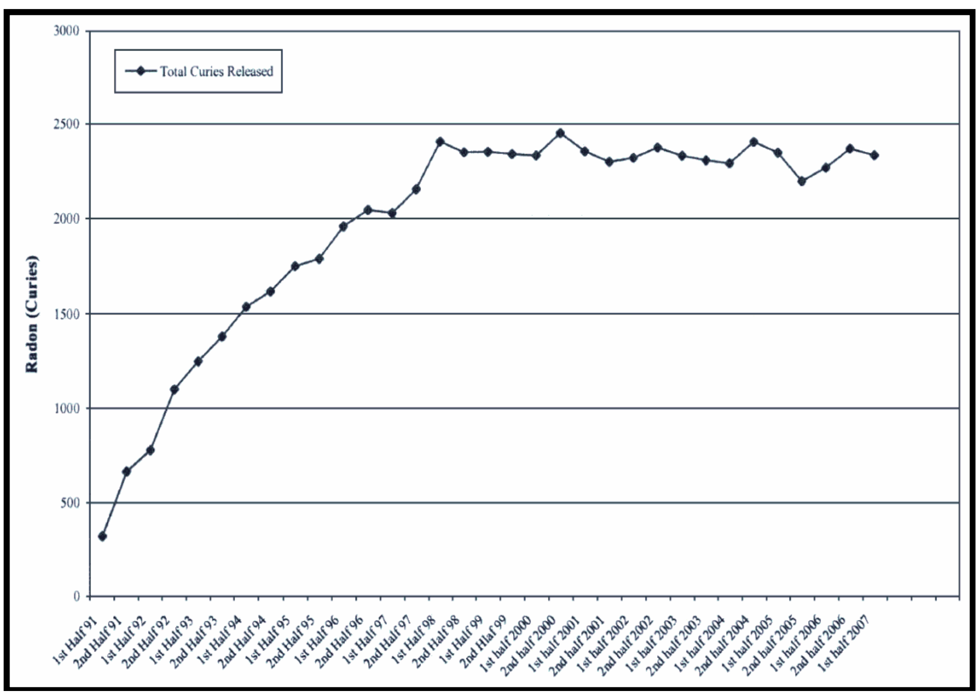

Figure 9: Crow Butte Total Estimated Semi-Annual Radon Release (1991-2007)

For the Crow Butte Project, the maximum annual radon release rate was assumed to be 8,885 Ci, while the average annual release rate is 4,467 Ci.

2.5.4 Risk Estimates

The RMEI and population doses and risks calculated by CAP88 for the Crow Butte site are shown in Table 30.

Table 30: Crow Butte Risk Assessment Results

Receptor / Impact		Radon Release (Ci/yr)		
		Unitized	**Maximum**	**Average**
		1	8,885	4,467
RMEI (1500m WSW)	Dose (mrem/yr)	1.6E-03	3.3E+00	1.9E+00
	LCF Risk (yr^{-1})	8.4E-10	1.7E-06	1.0E-06
Population	Dose (person-rem/yr)	1.3E-03	2.7E+00	1.6E+00
	LCF Risk (yr^{-1})	8.4E-09	1.7E-05	1.0E-05

2.6 Christensen / Irigaray[6]

The Christensen / Irigaray Ranch project is an ISL uranium mining operation located approximately 55 miles southeast of Buffalo, Wyoming, and 51 miles northeast of Midwest, Wyoming. The project is actually composed of two ISL sites (7 miles apart) containing well fields or facilities within approximately 687 acres. The first area, generally referred to as the Irigaray site or the Irigaray CPP, is located in southeast Johnson County, Wyoming (see Figure 10). The uranium deposit is one of many located in the Powder River Basin in northeast Wyoming. The property consists of approximately twenty-eight square miles. The second area is the Christensen Ranch well field and satellite operation (ion exchange plant), shown in Figure 11, which is located approximately 13 miles southeast of the Irigaray site. The Christensen Ranch operations consist of approximately 14,000 acres in Johnson and Campbell Counties, Wyoming.

In August 1978, the NRC issued one license, SUA-1341, which covers both areas of the Christensen / Irigaray Ranch project. The site operated intermittently until June 2000, when all mining activities were suspended due to low uranium prices. In April 2007, the mine owner, Cogema Mining, Inc., requested an amendment to the license to return the facility to an operating status. The NRC subsequently approved the licensee's request by a license amendment dated September 30, 2008. In December 2009, Cogema Mining was sold to Uranium One, Inc.

In anticipation of plant startup, the licensee began implementing operations-related environmental monitoring during October 2008. When the plant resumes operation, the first mine unit that will be placed into service will be Christensen Ranch mine unit 7. At the time of the inspection, the well field data package for this mine unit was being reviewed by the State of Wyoming. The construction of the mine unit was approximately half complete. The monitor

[6] The description of the Christensen / Irigaray site was abstracted from various sources, including Melbye 2008, NRC 2008, and NRC 2010, while the aerial views of the Christensen / Irigaray site were obtained from Google Maps.

well ring and some of the main trunk lines had been installed. In the near future, the licensee plans to develop Christensen Ranch mine units 8-9. Future well fields may include Christensen Ranch mine units 10-12.

Since the site was returned to operational status September 30, 2008, with the intent of returning to uranium production, plans to decommission the CPP at Irigaray were stopped, and, instead, the plant will be refurbished for a return to operation. Surface reclamation of the well fields at Irigaray will continue, as there is no intent to reopen them for production. The satellite processing plant at Christensen Ranch will be used for operations, as uranium production has not occurred at several permitted well fields at Christensen Ranch. The Irigaray CPP may also be used for final processing of uranium from the Moore Ranch and Uranium One's other uranium projects in the Powder River Basin.

Figure 10: Irigaray – Aerial View

Figure 11: Christensen – Aerial View

2.6.1 Population and Food Production

The 80-kilometer population distribution in each of the 16 principal compass directions, which was calculated for the Christensen / Irigaray site by SECPOP and used in CAP88 for population dose calculations, is shown in Table 31. To adjust the 2000 population data to 2010, the CAP88 Christensen / Irigaray population dose was multiplied by 1.34, see Section 1.2 and Table 3.

Table 31: Christensen / Irigaray Population Data

Dir	Distance (km)						
	0 to 1	1 to 2	2 to 3	3 to 4	4 to 5	5 to 10	10 to 20
N	0	0	0	0	0	0	0
NNW	0	0	0	0	0	0	0
NW	0	0	0	0	0	0	6
WNW	0	0	0	0	0	0	7
W	0	0	0	0	0	0	0
WSW	0	0	0	0	0	0	30
SW	0	0	0	0	0	0	0
SSW	0	0	0	0	0	0	0
S	0	0	0	0	0	0	0
SSE	0	0	0	0	0	1	10
SE	0	0	0	1	0	0	0
ESE	0	0	0	0	0	3	5
E	0	0	0	0	0	0	1
ENE	0	0	0	0	0	0	7
NE	0	0	0	0	0	0	0
NNE	0	0	0	0	0	0	7

Table 31: Christensen / Irigaray Population Data

Dir	Distance (km)					
	20 to 30	30 to 40	40 to 50	50 to 60	60 to 70	70 to 80
N	0	0	12	18	17	8
NNW	0	0	3	5	24	16
NW	0	0	0	26	151	2135
WNW	0	0	0	16	36	34
W	0	24	109	39	23	27
WSW	54	24	277	55	19	13
SW	4	0	11	0	21	8
SSW	34	3	600	2	13	0
S	14	4	0	3	8	0
SSE	2	0	20	5	4	25
SE	0	8	29	9	17	14
ESE	13	7	77	7	5	49
E	3	0	1417	91	20	8
ENE	31	2	39	52	16	28
NE	38	11	150	459	23517	5049
NNE	0	8	66	407	403	118

The agricultural productivity factors for Wyoming were taken from Appendix C of the CAP88 User's Manual, as shown below, and used in the Christensen / Irigaray site population dose calculation.

Beef Cattle Density (cattle/km^2):	5.12
Milk Cattle Density (cow/km^2):	0.0579
Land Cultivated for Vegetable Crops:	0.159%

The distance and direction to the RMEI were identified in Cogema's response to NRC's RAI (Cogema 2010) regarding the Christensen / Irigaray license renewal application as:

> The nearest residence to the IR site is 4 miles to the north (the Brubaker ranch) and the nearest residence to CR is the John Christensen ranch located 3 miles southeast of the CR plant site. Both are ranch housing with a population of 5 or less. [Cogema 2010, Section 5.2]

Notice that the Table 31 SECPOP estimate places the nearest individual to Christensen / Irigaray at a distance of 3 to 4 km in the SE direction. This location was found to be the location of the RMEI through analysis using CAP88. Since it is slightly closer, the Table 31 RMEI distance and direction were used to calculate the RMEI dose and risk for this study.

2.6.2 Meteorology

The CAP88 computer program is provided with a weather library of meteorological data from over 350 NWS stations. For the Christensen / Irigaray site, the CAP88-provided weather data for Casper, WY (CAP88 File: 24089.WND) were used. The period of record for this data included the years 1988 through 1992. Table 32 shows the directional-dependent average wind speed for each stability class, while Table 33 gives the stability class frequency, used in the Christensen / Irigaray analysis.

Table 32: Christensen / Irigaray Arithmetic Average Wind Speeds (Wind Towards)

Dir	Pasquill Stability Class (m/s)						
	A	B	C	D	E	F	G
N	2.070	2.820	4.040	5.620	3.160	1.960	0.000
NNW	2.080	2.760	3.260	4.620	3.160	1.920	0.000
NW	1.990	2.920	3.340	4.670	3.160	1.820	0.000
WNW	2.210	2.650	4.080	5.340	3.580	2.150	0.000
W	1.940	2.680	4.100	5.730	3.780	2.080	0.000
WSW	2.070	3.020	4.050	5.110	3.520	2.120	0.000
SW	1.930	2.990	3.830	5.190	3.410	2.170	0.000
SSW	2.060	2.870	3.750	5.830	3.520	2.180	0.000
S	1.770	2.900	3.970	5.510	3.450	2.150	0.000
SSE	2.190	2.520	3.530	5.120	3.270	2.150	0.000
SE	2.270	3.030	4.100	5.560	3.470	2.200	0.000
ESE	2.070	3.110	4.560	6.220	3.450	2.190	0.000
E	2.020	2.890	4.720	6.500	3.820	2.150	0.000
ENE	1.970	3.100	5.200	7.080	4.100	2.200	0.000
NE	2.170	2.980	5.500	8.420	4.010	2.210	0.000
NNE	1.970	2.990	5.000	8.290	3.740	2.110	0.000

Table 33: Christensen / Irigaray Frequencies of Stability Classes (Wind Towards)

Dir	Pasquill Stability Class (frequency)						
	A	B	C	D	E	F	G
N	0.0135	0.2097	0.1742	0.3958	0.0973	0.1095	0.0000
NNW	0.0276	0.2452	0.2063	0.2690	0.1188	0.1331	0.0000
NW	0.0302	0.1927	0.2094	0.3469	0.1073	0.1134	0.0000
WNW	0.0083	0.1102	0.1352	0.4937	0.1515	0.1010	0.0000
W	0.0036	0.0671	0.1110	0.5846	0.1395	0.0943	0.0000
WSW	0.0088	0.0549	0.0995	0.5699	0.1414	0.1254	0.0000
SW	0.0061	0.0557	0.0861	0.5939	0.1350	0.1232	0.0000
SSW	0.0056	0.0431	0.0616	0.6628	0.1138	0.1130	0.0000
S	0.0061	0.0469	0.0886	0.5403	0.1474	0.1707	0.0000
SSE	0.0046	0.0541	0.0913	0.3999	0.2038	0.2462	0.0000
SE	0.0015	0.0535	0.0963	0.4190	0.1955	0.2343	0.0000
ESE	0.0063	0.0391	0.1045	0.4612	0.1511	0.2379	0.0000
E	0.0028	0.0336	0.0921	0.4964	0.2166	0.1586	0.0000
ENE	0.0013	0.0178	0.0720	0.6031	0.2275	0.0783	0.0000
NE	0.0008	0.0099	0.0444	0.8381	0.0813	0.0254	0.0000
NNE	0.0028	0.0318	0.0732	0.7946	0.0614	0.0361	0.0000
TOTAL	0.0041	0.0424	0.0820	0.6227	0.1437	0.1051	0.0000

2.6.3 Radon Release

Table 34 presents annual calculated radon release estimates for the Christensen / Irigaray site for the period 1995 to 2000, the last production run prior to entering exclusively into restoration. Table 34 summarizes the information presented in the semi-annual effluent reports over that time period. Calculation of the semi-annual radon release was suspended after year 2000 (Cogema 2008).

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 similar to those described in NUREG-1569, Appendix D. For the Christensen Ranch area, mine units 10-12 and 7 were chosen based on their proximity to site boundaries and predominant wind directions. A summary of estimated radon-222 releases from the Facility is presented in Table 35.

Table 34: Christensen / Irigaray Environmental Radon Release Summary

Year	Radon Release (Ci/yr)	
	Irigaray	Christensen Ranch
1995	58.5	739.8
1996	63.9	1125.1
1997	71.0	1231.7
1998	69.6	1384.4
1999	132.8	711.4
2000	214.5	434.0

Source: Cogema 2008, Table 5.13

Table 35: Christensen / Irigaray Estimated Radon Release

Source	Release (Ci/yr)
Production	281
Restoration	257
Drilling	0.04
Resin Transfer	0.42
Total	538.46

Source: Cogema 2008, Table 7.3-2

For the Christensen / Irigaray site, the maximum annual radon release rate was assumed to be 1,600 Ci, while the average annual release rate is 1,040 Ci.

2.6.4 Risk Estimates

The RMEI and population doses and risks calculated by CAP88 for the Christensen / Irigaray site are shown in Table 36.

Table 36: Christensen / Irigaray Risk Assessment Results

Receptor / Impact		Radon Release (Ci/yr)		
		Unitized	Maximum	Average
		1	1,600	1,040
RMEI (3500m SE)	Dose (mrem/yr)	9.1E-04	1.9E+00	1.1E+00
	LCF Risk (yr^{-1})	4.8E-10	9.9E-07	5.7E-07
Population	Dose (person-rem/yr)	1.8E-03	3.8E+00	2.2E+00
	LCF Risk (yr^{-1})	1.2E-08	2.4E-05	1.4E-05

2.7 Alta Mesa 1,2,3[7]

The Alta Mesa Project uranium deposits, located in southern Brooks County, Texas, were discovered in the mid-1970s, and some exploration drilling and monitor well installation were started in the 80s and early 90s. However, due to low uranium prices, the project was not developed. When Uranium Resources Inc. began licensing the Alta Mesa Project, the Texas Natural Resource Conservation Commission (TNRCC) was the regulatory agency. In 1998, Uranium Resources Inc. received permit number UR03060 from the TNRCC. Due to the depressed uranium market, URI abandoned the project in 1999, which was then continued by Mesteña Uranium LLC. Licensing and permitting effort proceeded to 2002. In 2002, the Texas Department of Health, Bureau of Radiation Control issued material license number L05360 for the operation of the Alta Mesa in situ uranium mine to Mesteña Uranium. Development activities began in late 2004, and construction of the production facilities began in January 2005. Despite challenges due to three hurricanes, and short supplies of materials, equipment, and trained personnel, the Alta Mesa Project started, as planned, in October 2005. The Alta Mesa Project produced 480,000 lbs of U_3O_8 in 2009, and plans to produce about 650,000 lbs of U_3O_8 in 2010.

In 2007, the responsibility for source material recovery (i.e., uranium surface mining activities) licensing was transferred to the Texas Department of State Health Services (TDSHS) to the Texas Commission on Environmental Quality (TCEQ). The Texas Railroad Commission (TRRC) retains responsibility for permitting for exploration wells for uranium mining.

The uranium mineralization occurs at depths from 150 to 500+ feet deep in different sandstone units of the Pliocene Goliad Formation, with an average thickness of 14.3 feet. The majority of the mineable reserves as of 1994 had been found in a sandstone unit designated the Middle C Sand Unit, with ore quality mineralization ranging from 420 to 480 feet deep. The uranium occurs along multiple, relatively continuous oxidation-reduction fronts that range in width from 50 to 200+ feet wide. The Alta Mesa uranium deposit has an average ore grade of 0.096% U_3O_8. The Alta Mesa Project, shown in Figure 12, uses conventional ion exchange precipitation processes and a low-temperature, zero-emission rotary vacuum dryer. The facility and well fields are designed for flexibility of operations.

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7 The description of the Alta Mesa site was abstracted from various sources, including Tanner and Goranson 2007, Melbye 2008, and McNeill 2010, while the aerial view of the Alta Mesa site was obtained from Google Maps.

Figure 12: Alta Mesa – Aerial View

2.7.1 Population and Food Production

The 80-kilometer population distribution in each of the 16 principal compass directions, which was calculated for the Alta Mesa site by SECPOP and used in CAP88 for population dose calculations, is shown in Table 37. To adjust the 2000 population data to 2010, the CAP88 Alta Mesa population dose was multiplied by 0.92, see Section 1.2 and Table 3.

Table 37: Alta Mesa 1,2,3 Population Data

Dir	Distance (km)						
	0 to 1	1 to 2	2 to 3	3 to 4	4 to 5	5 to 10	10 to 20
N	0	0	0	0	0	2	0
NNW	0	0	6	0	0	0	0
NW	0	0	0	0	0	0	0
WNW	0	0	0	0	0	0	0
W	0	0	6	0	0	0	0
WSW	0	0	0	0	0	0	9
SW	0	0	0	0	0	0	0
SSW	0	0	0	0	0	0	51
S	0	0	0	0	0	10	38
SSE	0	0	0	0	0	0	0
SE	0	0	0	0	0	41	0
ESE	0	0	0	0	0	14	0
E	0	0	69	0	0	79	198
ENE	0	0	0	0	0	6	112
NE	0	0	0	0	0	0	0
NNE	0	0	0	0	0	0	0

Dir	Distance (km)					
	20 to 30	30 to 40	40 to 50	50 to 60	60 to 70	70 to 80
N	11	17	197	577	184	2454
NNW	6	0	73	106	309	41
NW	7	13	0	4748	339	482
WNW	0	14	5	25	28	30
W	22	3	0	26	16	84
WSW	0	114	21	44	78	19
SW	239	149	155	47	502	20610
SSW	462	13	38	33	2458	17761
S	81	56	103	2305	65220	201974
SSE	3	56	1058	6732	41029	66913
SE	25	60	34	69	7733	9454
ESE	6	0	0	65	26	404
E	18	0	8	48	0	0
ENE	18	4	3	8	8	24
NE	3	42	201	36	1542	5971
NNE	5	4518	2862	3377	48	3089

The agricultural productivity factors for Texas were taken from Appendix C of the CAP88 User's Manual, as shown below, and used in the Alta Mesa site population dose calculation.

Beef Cattle Density (cattle/km^2):	19
Milk Cattle Density (cow/km^2):	0.53
Land Cultivated for Vegetable Crops:	0.577%

According to Mestena 2000, Table 3.2, the nearest resident to the Alta Mesa site is located about 2.5 km in the WSW direction. Table 37 also shows the nearest resident as being 2 to 3 km from the site, but in the NNW, West, and East directions. Through analysis using CAP88, the RMEI was identified to be located 2 to 3 km in the NNW direction.

2.7.2 Meteorology

The U.S. Naval Air Base in Kingsville, which is much closer to the site than any of the NWS stations (45miles northeast), collects meteorological data, including wind speed, wind direction, and stability class. Meteorological data from the Kingsville Naval Air Base were used by Mestena Uranium to formulate a joint frequency distribution for the dose calculations performed as part of the Alta Mesa license application. For this risk assessment, the meteorological data from the Alta Mesa license application were reformatted so that they could be processed by the CAP88 auxiliary program, WINDGET (Trinity 2007), which generated a meteorological data file in the format required by CAP88 (i.e., a .WND file). Table 38 shows the directional-dependent average wind speed for each stability class that was used in this risk assessment for the Alta Mesa site, while Table 39 gives the stability class frequency.

Table 38: Alta Mesa / Kingsville Dome Arithmetic Average Wind Speeds (Wind Towards)

Dir	Pasquill Stability Class (m/s)						
	A	B	C	D	E	F	G
N	2.012	3.266	5.985	7.300	4.983	2.017	0.000
NNW	1.743	3.518	5.521	7.872	5.115	2.003	0.000
NW	2.000	3.566	6.077	7.482	5.107	1.975	0.000
WNW	1.823	3.648	5.834	7.200	4.799	1.659	0.000
W	1.680	2.995	5.338	5.648	4.244	1.533	0.000
WSW	1.488	2.699	4.844	5.468	3.866	1.341	0.000
SW	1.439	2.713	4.849	5.512	4.025	1.601	0.000
SSW	1.300	2.720	4.888	6.149	4.340	1.624	0.000
S	2.208	2.618	4.761	6.445	4.705	1.633	0.000
SSE	1.826	2.395	5.180	6.390	4.763	1.659	0.000
SE	2.556	2.373	5.205	6.202	4.782	1.642	0.000
ESE	2.556	2.924	4.545	6.220	4.388	1.695	0.000
E	1.027	1.982	4.278	4.734	4.203	1.542	0.000
ENE	1.029	1.762	3.991	3.652	6.112	1.462	0.000
NE	1.826	3.573	4.278	5.487	3.962	1.344	0.000
NNE	1.814	2.600	5.346	6.672	4.431	1.945	0.000

Table 39: Alta Mesa / Kingsville Dome Frequencies of Stability Classes (Wind Towards)

Dir	Pasquill Stability Class (frequency)						
	A	B	C	D	E	F	G
N	0.0162	0.0700	0.1047	0.4226	0.1090	0.2775	0.0000
NNW	0.0146	0.0529	0.0762	0.4792	0.1186	0.2585	0.0000
NW	0.0091	0.0354	0.0771	0.4761	0.1313	0.2710	0.0000
WNW	0.0060	0.0474	0.1093	0.4900	0.0947	0.2526	0.0000
W	0.0201	0.0745	0.1079	0.3680	0.0769	0.3526	0.0000
WSW	0.0176	0.0876	0.1120	0.4117	0.0694	0.3017	0.0000
SW	0.0092	0.0676	0.1025	0.5021	0.0816	0.2370	0.0000
SSW	0.0085	0.0756	0.1033	0.5325	0.0657	0.2144	0.0000
S	0.0084	0.0471	0.0879	0.5084	0.0913	0.2568	0.0000
SSE	0.0040	0.0493	0.0830	0.4447	0.0741	0.3448	0.0000
SE	0.0045	0.0523	0.0751	0.3448	0.0726	0.4507	0.0000
ESE	0.0081	0.0724	0.1158	0.2966	0.0553	0.4517	0.0000
E	0.0242	0.1773	0.0492	0.1892	0.0375	0.5226	0.0000
ENE	0.0244	0.1323	0.0997	0.1670	0.0082	0.5683	0.0000
NE	0.0189	0.1679	0.1463	0.3258	0.0619	0.2792	0.0000
NNE	0.0389	0.1298	0.1531	0.3888	0.0518	0.2377	0.0000
TOTAL	0.0121	0.0617	0.0949	0.4520	0.0945	0.2848	0.0000

2.7.3 Radon Release

The only information identified regarding radon release from the Alta Mesa Project was contained within the June 2000 radiological assessment performed for the project (Mestena 2000). The following is the radiological assessment's description of the Alta Mesa radon release.

> Radon gas will be emitted at the central facility when the circulating fluids are brought into equilibrium with the ambient atmosphere. The emission points will be all open tankage, resin columns and processing equipment.
>
> Two centralized discharge areas of radon gas were modeled, one centered on the production area of the process pad (Production Pad) and one centered on the restoration area of the process pad (Restoration Pad). An additional point source for radon was modeled based on the center of the pond receiving purge water (Purge Pond).
>
> Additional radon gas will be emitted at the wellfields because of well field venting and other small releases. These sites were modeled as small area sources centered on points within each wellfield which represented a one year production element. [Mestena 2000, Appendix 1]

The Alta Mesa annual radon release, as presented in the radiological assessment (Mestena 2000), is shown in Table 40.

Table 40: Alta Mesa Annual Radon Source Term

Source	Release (Ci/yr)
Well field 1a	5.2
Well field 1b	6.05
Well field 2a	4.81
Well field 2b	5.09
Well field 3a	1.67
Well field 3b	2.5
Well field 4	2.09
Process Pad	617.5
Restoration Pad	88.35
Purge Pond	6.5
Total	739.8

Source: Mestena 2000, Attachment 1

The radon releases given in Table 40 are design basis values; and, as such, are based on the Alta Mesa uranium production capacity of 1,500,000 lbs per year. As stated above, the amount of uranium produced at Alta Mesa has been somewhat less than its production capacity. Table 41 gives the Alta Mesa annual radon release as a function of the amount of uranium produced.

Table 41: Alta Mesa Radon Release by Uranium Production

Year	Uranium Production (lbs/yr)	Radon Release (Ci/yr)
2007	956,000	471
2009	480,000	237
2010	650,000	321
Capacity	1,500,000	740

2.7.4 Risk Estimates

The RMEI and population doses and risks calculated by CAP88 for the Alta Mesa site are shown in Table 42.

Table 42: Alta Mesa Risk Assessment Results

Receptor / Impact		Radon Release (Ci/yr)		
		Unitized	Maximum	Average
		1	740	472
RMEI (2500m NNW)	Dose (mrem/yr)	5.6E-03	1.2E+01	6.7E+00
	LCF Risk (yr^{-1})	3.0E-09	6.1E-06	3.6E-06
Population	Dose (person-rem/yr)	1.0E-02	2.2E+01	1.3E+01
	LCF Risk (yr^{-1})	6.3E-08	1.3E-04	7.6E-05

2.8 Kingsville Dome 1,3[8]

Uranium Resources, Inc.'s (URI's) Kingsville Dome property consists of mineral leases from private landowners on about 2,354 acres located in central Kleberg County, Texas. An aerial view of the Kingsville Dome site is shown in Figure 13. For the Kingsville Dome site, URI holds the TNRCC's Underground Injection Control Permit: UR02827; the site is also covered by the Texas Department of Health's radioactive materials license: L06353. At Kingsville Dome, multiple satellites feed a central processing plant at a rate of 400,000 pounds of U_3O_8 (154 tonnes U) per year (targeting between 1 and 2 million pounds of U_3O_8 (385-770 tonnes U) annually). Initial production commenced in May 1988 and continued until July 1999, when depressed uranium prices led to the suspension of production. URI resumed production at Kingsville Dome in April 2006 and produced 94,100 pounds of uranium in 2006, 338,100 pounds in 2007, 254,000 pounds in 2008, and 56,000 pounds in 2009. In the second quarter of 2009, due to depressed pricing, production at Kingsville Dome was shut-down to conserve the in-place reserve base until higher prices could be realized.

Figure 13: Kingsville Dome – Aerial View

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8 The description of the Kingsville Dome site was abstracted from various sources, including Melbye 2008, URI 2010a, and URI 2010b while the aerial view of the Kingsville Dome site was obtained from Google Maps.

2.8.1 Population and Food Production

The 80-kilometer population distribution in each of the 16 principal compass directions, which was calculated for the Kingsville Dome site by SECPOP and used in CAP88 for population dose calculations, is shown in Table 43. To adjust the 2000 population data to 2010, the CAP88 Kingsville Dome population dose was multiplied by 0.97, see Section 1.2 and Table 3.

Table 43: Kingsville Dome 1,3 Population Data

Dir	Distance (km)						
	0 to 1	1 to 2	2 to 3	3 to 4	4 to 5	5 to 10	10 to 20
N	0	0	0	0	0	54	3796
NNW	0	0	0	0	0	0	21
NW	0	0	0	0	0	0	0
WNW	0	0	0	0	0	0	0
W	0	0	0	0	0	0	0
WSW	0	0	82	0	0	0	0
SW	0	0	3	0	0	87	393
SSW	0	0	0	0	0	37	189
S	0	0	0	0	0	41	248
SSE	0	0	0	0	0	240	512
SE	0	0	0	0	138	0	0
ESE	0	0	66	0	0	461	288
E	0	0	0	39	27	677	409
ENE	0	0	0	91	30	369	265
NE	0	0	0	0	0	537	18252
NNE	0	0	7	0	0	74	7920

Dir	Distance (km)					
	20 to 30	30 to 40	40 to 50	50 to 60	60 to 70	70 to 80
N	1134	1242	2185	3921	2450	8983
NNW	330	1026	19092	24698	4509	14441
NW	276	296	60486	159467	14418	15036
WNW	0	77	2009	29018	305	181
W	0	0	6	0	0	0
WSW	0	0	0	0	0	0
SW	0	0	0	0	0	0
SSW	30	0	0	0	0	0
S	148	5	0	51	5	30
SSE	80	6	4	0	172	8
SE	25	613	68	8	160	235
ESE	0	1724	6133	99	26	22
E	0	2495	503	189	301	276
ENE	0	26	469	259	2036	125
NE	0	649	23849	6994	1116	52
NNE	126	302	1209	1430	3988	750

The agricultural productivity factors for Texas were taken from Appendix C of the CAP88 User's Manual, as shown below, and used in the Kingsville Dome site population dose calculation.

Beef Cattle Density (cattle/km^2):	19
Milk Cattle Density (cow/km^2):	0.53
Land Cultivated for Vegetable Crops:	0.577%

According to TBRC 1988, Table S6.9-2, the nearest downwind resident to the Kingsville Dome site is located about 1.35 km in the West direction, and the nearest resident is located 0.44 km in the East direction. Table 43 also shows the nearest residents to the Kingsville Dome site as being about 2 to 3 km from the site, but in the WSW, ESE, and NNE directions. Through analysis using CAP88, the RMEI was found to be located 2 to 3 km in the NNW direction.

2.8.2 Meteorology

Because of the close proximity of the Kingsville Dome site to the Alta Mesa site (less than 50 miles) and because Kingsville Naval Air Base is the closest meteorological station to both, the meteorological data used for the Kingsville Dome site are the same as that used for the Alta Mesa site. Table 38 shows the directional-dependent average wind speed for each stability class that was used in this risk assessment for the Kingsville Dome site, while Table 39 gives the stability class frequency.

2.8.3 Radon Release

The only information identified regarding radon release from the Kingsville Dome site was in the Environmental Assessment (EA) prepared by the Texas Department of Health (TDH 1988). In the Kingsville Dome EA, the TDH estimated the annual radon release to be 6,958 Ci. If this radon release rate is assumed to correspond to the Kingsville Dome uranium production capacity, then the reported uranium production rates may be used to estimate the radon released for other years. This has been done, with the results shown in Table 44.

Table 44: Kingsville Dome Radon Release by Uranium Production

Year	Uranium Production (lbs/yr)	Radon Release (Ci/yr)
2006	94,100	655
2007	338,100	2,352
2008	254,000	1,767
2009	56,000	390
Capacity	1,000,000	6,958

The maximum annual radon release from the Kingsville Dome site is assumed to be 6,958 Ci, while the average annual release is 1,291 Ci.

2.8.4 Risk Estimates

The RMEI and population doses and risks calculated by CAP88 for the Kingsville Dome site are shown in Table 45.

Table 45: Kingsville Dome Risk Assessment Results

Receptor / Impact		Radon Release (Ci/yr)		
		Unitized	Maximum	Average
		1	6958	1291
RMEI (2500 NNW)	Dose (mrem/yr)	5.5E-03	1.1E+01	6.6E+00
	LCF Risk (yr^{-1})	2.9E-09	6.1E-06	3.5E-06
Population	Dose (person-rem/yr)	2.8E-02	5.8E+01	3.4E+01
	LCF Risk (yr^{-1})	1.8E-07	3.8E-04	2.2E-04

2.9 Eastern Generic Site – Virginia

Due to its many uranium deposits, as shown in Figure 14, the state of Virginia was selected for the location of the Eastern Generic site. In the early 1980s, uranium mining leases were obtained for 40,000 uranium-rich acres in Pittsylvania County and 16,000 acres in Fauquier, Madison, Culpeper, and Orange counties. Additionally, uranium deposits were discovered in Nelson County (UFV 2010). Because of its high population density and its past experience as a uranium mine lease site, Culpeper County was selected as the Eastern Generic site location within Virginia.

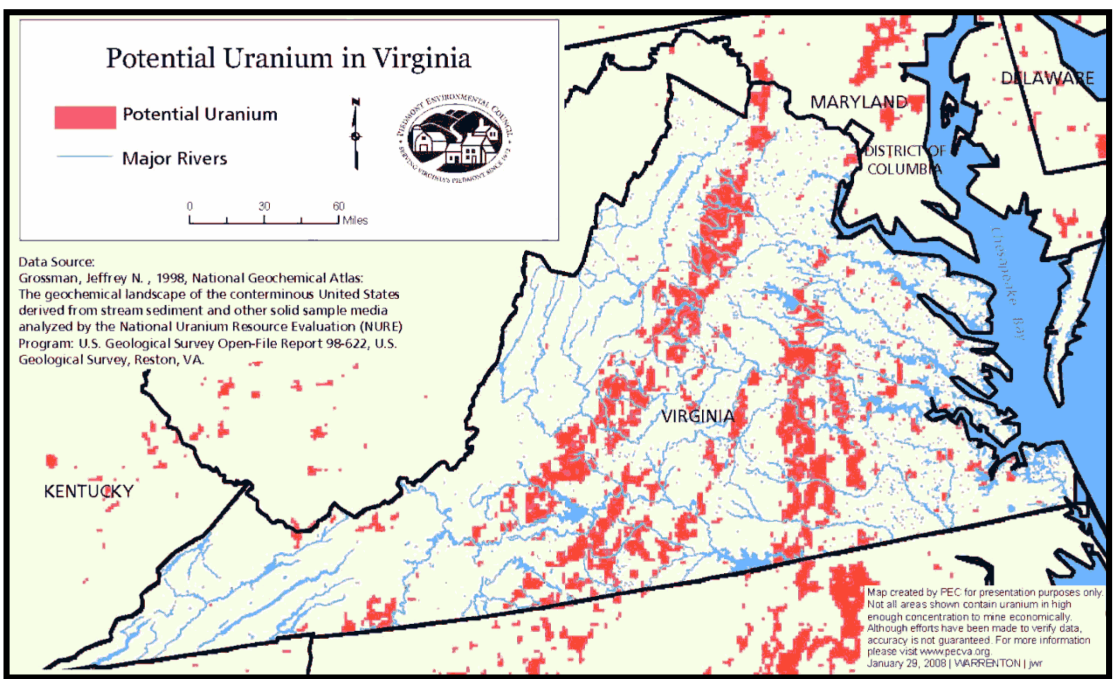

Figure 14: Potential Uranium in Virginia

The actual Eastern Generic site location within Culpeper County was selected so that there would be no population located within 1 km of the site. Figure 15 shows the approximate location of the Eastern Generic site, located in the northern portion of Virginia's Culpeper County.

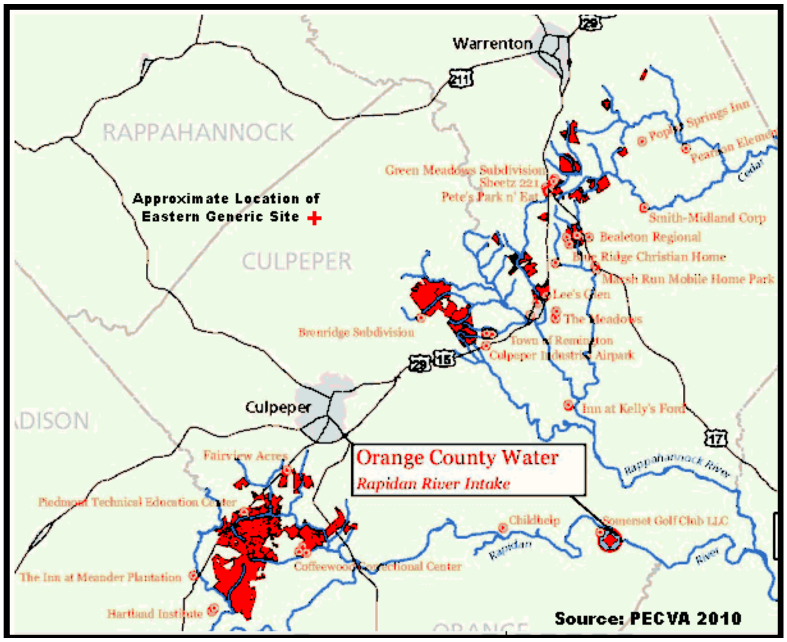

Figure 15: Approximate Location of the Eastern Generic Site

As shown in Figure 15, the Eastern Generic site is located north of the city of Culpeper and southwest of the city of Warrenton in an uninhabited area. Also, the areas in red on Figure 15 denote areas that have had uranium mine leases in the past.

2.9.1 Population and Food Production

The 80-kilometer population distribution in each of the 16 principal compass directions, which was calculated for the Eastern Generic site by SECPOP and used in CAP88 for population dose calculations, is shown in Table 46. To adjust the 2000 population data to 2010, the CAP88 Eastern Generic population dose was multiplied by 1.40, see Section 1.2 and Table 3.

Table 46: Eastern Generic Site (Virginia) Population Data

Dir	Distance (km)						
	0 to 1	1 to 2	2 to 3	3 to 4	4 to 5	5 to 10	10 to 20
N	0	0	0	5	160	442	588
NNW	0	11	154	0	2	816	1072
NW	0	0	0	125	76	741	2358
WNW	0	0	0	0	38	457	2105
W	0	0	0	38	0	367	2077
WSW	0	0	8	28	2	159	1608
SW	0	0	10	0	0	730	953
SSW	0	0	0	332	55	623	4037
S	0	0	0	0	0	841	10192
SSE	0	0	0	0	0	542	2474
SE	0	0	213	0	0	545	1393
ESE	0	0	143	0	130	187	598
E	0	0	197	38	35	135	349
ENE	0	0	147	1	31	176	711
NE	0	0	0	0	30	175	938
NNE	0	0	9	16	63	91	523

Dir	Distance (km)					
	20 to 30	30 to 40	40 to 50	50 to 60	60 to 70	70 to 80
N	931	3140	2718	5208	36454	23280
NNW	1714	3578	3065	5089	16570	12798
NW	8464	4721	9451	11662	114035	115934
WNW	7907	8202	55966	135173	247760	367208
W	5161	2433	4498	69279	132991	40611
WSW	2868	4336	17263	58995	13734	5773
SW	1204	6574	9500	66863	23680	4796
SSW	651	3098	2808	4588	5366	7093
S	1947	3289	2997	2925	6611	4356
SSE	2407	4923	3356	6393	6092	41432
SE	2420	2990	5214	11763	17293	45571
ESE	1026	176	1095	10894	6452	50227
E	287	5893	7017	4870	11750	10706
ENE	446	3733	1566	8154	4049	1475
NE	542	2114	1487	13550	1098	1816
NNE	1160	17008	8288	19156	18827	6533

The agricultural productivity factors for Virginia were taken from Appendix C of the CAP88 User's Manual, as shown below, and used in the Eastern Generic site population dose calculation.

Beef Cattle Density (cattle/km^2):	13.1
Milk Cattle Density (cow/km^2):	1.84
Land Cultivated for Vegetable Crops:	0.87%

The Eastern Generic site was selected so that there would be no population within 1 km of the site. Thus, the RMEI at the Eastern Generic site is located 1 to 2 km from the site in the NNW direction, as shown in Table 46.

2.9.2 Meteorology

The CAP88 computer program is provided with a weather library of meteorological data from over 350 NWS stations. For the Eastern Generic site, the CAP88-provided weather data for Gordonsville, VA (CAP88 File: GVE0824.WND) were used. The period of record for this data includes the years 1956 through 1960. Table 47 shows the directional-dependent average wind speed for each stability class, while Table 48 gives the stability class frequency, used in the Eastern Generic analysis.

Table 47: Eastern Generic Site (Virginia) Arithmetic Average Wind Speeds (Wind Towards)

Dir	Pasquill Stability Class (m/s)						
	A	B	C	D	E	F	G
N	1.184	1.737	2.755	2.990	2.955	1.102	0.000
NNW	1.132	1.852	2.758	2.860	2.878	1.108	0.000
NW	1.170	1.542	2.067	2.420	2.704	1.070	0.000
WNW	1.172	1.433	2.263	2.400	3.093	1.049	0.000
W	1.141	1.473	2.120	2.163	2.678	1.028	0.000
WSW	1.177	1.876	2.622	2.463	2.935	1.086	0.000
SW	1.076	1.740	2.839	2.819	2.949	1.089	0.000
SSW	1.177	1.975	3.334	3.646	3.384	1.138	0.000
S	1.174	1.912	2.781	3.343	3.210	1.098	0.000
SSE	1.278	2.144	3.260	3.730	3.479	1.116	0.000
SE	1.204	1.990	3.147	4.179	3.569	1.133	0.000
ESE	1.238	2.327	3.518	5.455	4.076	1.164	0.000
E	1.197	1.917	3.220	4.912	3.887	1.140	0.000
ENE	1.201	2.030	3.276	4.479	3.784	1.131	0.000
NE	1.196	1.871	3.054	3.468	3.330	1.099	0.000
NNE	1.197	2.102	3.273	3.985	3.333	1.114	0.000

Table 48: Eastern Generic Site (Virginia) Frequencies of Stability Classes (Wind Towards)

Dir	Pasquill Stability Class (frequency)						
	A	B	C	D	E	F	G
N	0.0224	0.0863	0.1225	0.3226	0.0791	0.3672	0.0000
NNW	0.0238	0.0788	0.1438	0.3242	0.0874	0.3421	0.0000
NW	0.0424	0.1049	0.1395	0.3309	0.0502	0.3321	0.0000
WNW	0.1047	0.1644	0.1440	0.3753	0.0276	0.1840	0.0000
W	0.0709	0.1887	0.1336	0.3718	0.0215	0.2134	0.0000
WSW	0.0528	0.1127	0.1576	0.4373	0.0502	0.1893	0.0000
SW	0.0206	0.0857	0.1223	0.4187	0.0629	0.2898	0.0000
SSW	0.0132	0.0509	0.0951	0.5464	0.0594	0.2350	0.0000
S	0.0108	0.0397	0.0722	0.4681	0.0522	0.3570	0.0000
SSE	0.0091	0.0519	0.0728	0.2914	0.0626	0.5122	0.0000
SE	0.0179	0.0404	0.0862	0.2618	0.0774	0.5163	0.0000
ESE	0.0159	0.0619	0.1244	0.4009	0.1222	0.2748	0.0000
E	0.0292	0.0641	0.1222	0.3285	0.1067	0.3492	0.0000
ENE	0.0290	0.1081	0.1642	0.3326	0.0826	0.2835	0.0000
NE	0.0288	0.0982	0.1551	0.3305	0.0670	0.3203	0.0000
NNE	0.0198	0.0820	0.1513	0.4027	0.0777	0.2664	0.0000
TOTAL	0.0231	0.0767	0.1219	0.3784	0.0716	0.3282	0.0000

2.9.3 Radon Release

It is assumed that a conventional uranium mine and mill would be located at the Eastern Generic site, and that the annual radon release from the Eastern Generic site would be similar to the radon released from the conventional mill located at White Mesa (see Section 2.2.3). Thus, the Eastern Generic site annual radon release was estimated to range from 1,025 to 1,750 Ci.

2.9.4 Risk Estimates

The RMEI and population doses and risks calculated by CAP88 for the Eastern Generic site are shown in Table 49.

Table 49: Eastern Generic Site Risk Assessment Results

Receptor / Impact		Radon Release (Ci/yr)		
		Unitized	Maximum	Average
		1	1750	1388
RMEI (500m SSE)	Dose (mrem/yr)	1.4E-02	2.8E+01	1.6E+01
	LCF Risk (yr^{-1})	7.6E-09	1.6E-05	9.2E-06
Population	Dose (person-rem/yr)	9.7E-02	2.0E+02	1.2E+02
	LCF Risk (yr^{-1})	6.6E-07	1.4E-03	7.9E-04

2.10 Western Generic Site – New Mexico[9]

The Grants Uranium Region in New Mexico is a world premier uranium mining district, having produced over 350 million pounds of uranium. During the 1970s, a conventional uranium mine and mill were developed by a joint venture between Long Island Lighting Company, a New York utility, and Bokum Resources Corporation. In addition to deposit development drilling, a shaft was sunk to a depth of 1,842 feet, a 2,200 ton-per-day uranium processing mill was constructed on site, and a tailings disposal site was excavated, all fully permitted. Due to the collapse in the uranium market in the early 1980s, development was halted, the deposit remains un-mined, and the mill was dismantled in 2001. According to Nuclear Regulatory Commission records, the source material license was terminated in 1988 following multiple inspections, which confirmed that no ore was ever produced or processed at the site. Although the mill has been removed, much of the infrastructure remains in place, including electric power, 1,800+ acre-feet of industrial-use water rights, the 1,842 shaft, and the previously permitted and partially completed tailings disposal site. The site is currently being considered for redevelopment as a conventional uranium mine and mill.

The Bokum mill was designed to accommodate 2,200 tons of ore feed per day. Metallurgical studies and yearly production were based on an average mill feed of 0.12% U_3O_8. Grinding was to be accomplished by a semi-autogenous mill and a rod mill. A two-stage sulfuric acid leach circuit was to be utilized. Liquid-solid separation was to use six stages of counter-current decantation, with clarification of overflows from inter-stage thickening. Solvent extraction and stripping for solubilization and removal of uranium was to be employed, and ammonia was to be used to precipitate the U_3O_8 as yellowcake.

The site of the former Bokum mine and mill was selected as the Western Generic site. It was assumed that a conventional mine and mill similar to the mine and mill previously proposed and partially constructed, but updated to reflect current 2010 technology, would be constructed.

2.10.1 Population and Food Production

The 80-kilometer population distribution in each of the 16 principal compass directions, which was calculated for the Western Generic site by SECPOP and used in CAP88 for population dose calculations, is shown in Table 50. To adjust the 2000 population data to 2010, the CAP88 Western Generic population dose was multiplied by 0.94, see Section 1.2 and Table 3.

[9] The description of the Western Generic site was abstracted from various sources, including Alief 2010, NE 2008a, and NE 2008b.

Table 50: Western Generic Site (New Mexico) Population Data

Dir	Distance (km)						
	0 to 1	1 to 2	2 to 3	3 to 4	4 to 5	5 to 10	10 to 20
N	0	0	0	0	0	0	0
NNW	0	0	0	0	0	0	0
NW	0	0	0	0	0	0	0
WNW	0	0	0	0	0	0	0
W	0	0	0	0	0	0	0
WSW	0	0	0	0	0	0	2
SW	0	0	0	0	0	0	0
SSW	0	0	0	0	0	0	0
S	0	0	0	0	0	0	24
SSE	0	0	0	0	0	2	341
SE	0	0	0	0	0	8	45
ESE	0	0	0	0	0	2	298
E	0	0	0	0	2	12	259
ENE	0	0	0	0	0	49	163
NE	0	0	0	7	1	43	365
NNE	0	0	0	4	4	14	36

Dir	Distance (km)					
	20 to 30	30 to 40	40 to 50	50 to 60	60 to 70	70 to 80
N	0	4	0	1	65	206
NNW	38	294	108	468	177	693
NW	77	0	18	228	555	588
WNW	4	0	95	254	1311	308
W	0	0	0	0	7	7
WSW	0	0	0	5	3	74
SW	169	0	0	724	1951	1215
SSW	28	618	23	2285	1226	44
S	116	2674	10176	449	17	1
SSE	274	617	18	29	125	126
SE	1126	643	1	0	489	815
ESE	534	2110	269	77	15	756
E	700	511	982	2009	2928	19973
ENE	177	162	550	836	314	1318
NE	1302	1683	425	230	22	35
NNE	96	0	32	19	377	254

The agricultural productivity factors for New Mexico were taken from Appendix C of the CAP88 User's Manual, as shown below, and used in the Western Generic site population dose calculation.

Beef Cattle Density (cattle/km^2):	4.13
Milk Cattle Density (cow/km^2):	0.114
Land Cultivated for Vegetable Crops:	0.138%

As indicated in Table 50, for the Western Generic site, the nearest individual is located between 3 and 4 km in the NE and NNE directions, which is consistent with NEI 2008, which states that the nearest downwind resident is at about 2.5 miles. Through analysis with CAP88, the RMEI was identified to be located 2 to 3 km in the NNW direction.

2.10.2 Meteorology

The CAP88 computer program is provided with a weather library of meteorological data from over 350 NWS stations. For the Western Generic site, the CAP88-provided weather data for Grants, NM (CAP88 File: GNT1246.WND) were used. The period of record for this data is limited to the year 1954. Table 51 shows the directional-dependent average wind speed for each stability class, while Table 52 gives the stability class frequency, used in the Western Generic analysis.

Table 51: Western Generic Site (New Mexico) Arithmetic Average Wind Speeds (Wind Towards)

Dir	Pasquill Stability Class (m/s)						
	A	B	C	D	E	F	G
N	1.324	2.175	3.366	4.871	3.773	1.202	0.000
NNW	0.772	1.518	3.561	5.734	3.664	1.368	0.000
NW	1.271	1.951	3.733	5.719	3.751	1.278	0.000
WNW	1.183	2.088	4.141	5.835	3.697	1.337	0.000
W	0.772	1.792	2.944	3.982	3.155	0.888	0.000
WSW	0.772	4.373	4.373	4.008	4.373	1.372	0.000
SW	0.772	1.410	1.610	2.594	3.299	1.149	0.000
SSW	0.772	2.347	3.163	4.907	3.933	1.176	0.000
S	1.088	1.772	3.251	5.126	4.035	1.286	0.000
SSE	1.104	1.537	3.505	5.737	4.217	1.497	0.000
SE	1.099	1.526	3.142	5.306	4.213	1.393	0.000
ESE	1.246	1.954	3.378	6.231	4.191	1.515	0.000
E	1.324	1.732	3.819	6.684	4.040	1.419	0.000
ENE	1.183	2.174	5.214	7.451	4.189	1.496	0.000
NE	0.993	1.938	3.978	6.664	3.800	1.294	0.000
NNE	1.141	2.658	4.743	6.129	3.630	1.255	0.000

Table 52: Western Generic Site (New Mexico) Frequencies of Stability Classes (Wind Towards)

Dir	Pasquill Stability Class (frequency)						
	A	B	C	D	E	F	G
N	0.0277	0.0653	0.1118	0.2731	0.1517	0.3705	0.0000
NNW	0.0169	0.0555	0.0852	0.3901	0.1569	0.2954	0.0000
NW	0.0367	0.1338	0.1667	0.3783	0.0887	0.1959	0.0000
WNW	0.0179	0.1259	0.1877	0.4097	0.0661	0.1926	0.0000
W	0.0650	0.2801	0.1804	0.2975	0.0295	0.1474	0.0000
WSW	0.1381	0.0410	0.2127	0.1866	0.0410	0.3806	0.0000
SW	0.0875	0.2602	0.0852	0.1832	0.0665	0.3174	0.0000
SSW	0.0754	0.1447	0.1156	0.3106	0.0452	0.3085	0.0000
S	0.0464	0.1383	0.1320	0.2285	0.1295	0.3254	0.0000
SSE	0.0290	0.1021	0.1406	0.2746	0.1637	0.2899	0.0000
SE	0.0103	0.0722	0.1104	0.1905	0.2485	0.3682	0.0000
ESE	0.0188	0.0387	0.0695	0.2171	0.3169	0.3391	0.0000
E	0.0111	0.0827	0.0998	0.3827	0.1368	0.2869	0.0000
ENE	0.0238	0.0680	0.1257	0.4770	0.1423	0.1633	0.0000
NE	0.0486	0.1099	0.1260	0.4649	0.0564	0.1943	0.0000
NNE	0.0437	0.1148	0.1547	0.4117	0.0758	0.1992	0.0000
TOTAL	0.0258	0.0932	0.1243	0.3070	0.1679	0.2817	0.0000

2.10.3 Radon Release

It was assumed that a conventional uranium mill would be located at the Western Generic site, as that was the type of mill that was licensed to operate there in the 1990s. As such, it was decided to use the annual radon release from the White Mesa site for the Western Generic site (see Section 2.2.3). Thus, the Western Generic site annual radon release was estimated to range from 1,025 to 1,750 Ci.

2.10.4 Risk Estimates

The RMEI and population doses and risks calculated by CAP88 for the Western Generic site are shown in Table 53.

Table 53: Western Generic Site Risk Assessment Results

Receptor / Impact		Radon Release (Ci/yr)		
		Unitized	Maximum	Average
		1	1,750	1,388
RMEI (3500m NNW)	Dose (mrem/yr)	2.9E-03	6.0E+00	3.5E+00
	LCF Risk (yr^{-1})	3.7E-09	7.7E-06	4.4E-06
Population	Dose (person-rem/yr)	2.5E-03	5.1E+00	3.0E+00
	LCF Risk (yr^{-1})	1.3E-07	2.7E-04	1.6E-04

3.0 SUMMARY OF RESULTS

Table 54 shows the cumulative population within 80 kilometers of each site. Table 54 reveals a difference between the least populated site, Sweetwater, and the most populated site, the Eastern Generic site, of more than a factor of 200. If all other factors were equal (e.g., meteorology, radon release), this population difference would be directly reflected in the CAP88-calculated population doses. It is also interesting to note that while the Cañon City site has only about a third of the 80-km population of the Eastern Generic site, the Cañon City site has the largest population living within 10 km.

Table 54: Cumulative 2000 Population Data

Uranium Site	Distance (km)						
	0 to 1	0 to 5	0 to 10	0 to 20	0 to 40	0 to 60	0 to 80
Sweetwater	0	0	3	6	197	885	10,604
White Mesa	0	969	3,839	4,228	8,080	12,363	20,675
Crow Butte	0	51	1,336	1,869	9,324	13,251	32,676
Christensen / Irigaray	0	1	5	78	362	4,366	36,192
Western Generic	0	18	148	1,681	15,638	35,949	71,944
Smith Ranch – Highlands	0	0	2	222	5,882	55,739	79,694
Kingsville Dome	0	483	3,060	35,353	45,963	388,110	457,735
Alta Mesa	0	81	233	641	6,606	29,610	478,440
Cañon City	0	7,606	32,016	41,028	52,485	313,574	691,284
Eastern Generic	0	2,097	9,124	41,100	156,443	727,294	2,129,665

Table 54 also shows that for all of the sites analyzed, there are no people living within one kilometer of any site, and for the Sweetwater and Smith Ranch – Highland sites, the closest resident (i.e., the RMEI) is located about 7.5 km away. Table 55 compares the current actual location of the nearest resident (as determined by SECPOP) to the hypothetical worst case location (i.e., the nearest location in the most prevalent wind direction). As expected, if the distant RMEI's were to be relocated nearer the site (e.g., Sweetwater and Smith Ranch – Highland), their doses would increase significantly. In addition, changing the direction of the RMEI can have a significant effect on the dose. For example, moving the Sweetwater RMEI to the worst-case location means changing both his/her distance and direction and results in an increase of about a factor of 250, but moving the Smith Ranch – Hignland RMEI to the worst-case location means only changing his/her distance, and the dose increase is much less at only a factor of about 80.

Table 55: Comparison of Current RMEI Location Dose/Risk to Worst-Case Location Dose/Risk

Uranium Site	Current RMEI Location			Worst Case Location		Increase
	Distance (km)	Direction	Dispersion (sec/m^3)	Direction	Dispersion (sec/m^3)	
Sweetwater	7.5	NW	6.63E-08	ENE	1.65E-05	248.9
White Mesa	1.5	SSE	1.19E-06	SSW	1.73E-05	14.5
Cañon City	1.5	N	9.29E-07	S	1.63E-05	17.6
Smith Ranch - Highlands	7.5	E	1.46E-07	E	1.18E-05	81.2
Crow Butte	1.5	WSW	3.08E-07	N	1.34E-05	43.4
Christensen / Irigaray	3.5	SE	1.80E-07	ENE	1.02E-05	57.0
Alta Mesa	2.5	NNW	1.28E-06	NW	2.38E-05	18.5
Kingsville Dome	2.5	NNW	1.28E-06	NW	2.38E-05	18.5
Eastern Generic	1.5	NNE	3.76E-06	NE	3.35E-05	8.9
Western Generic	3.5	NW	2.11E-07	SE	4.52E-05	70.5

For each of the 10 uranium sites analyzed in this report, Table 56 presents the CAP88-calculated RMEI and population dose and risk, normalized to the radon release. To estimate the annual dose or risk for a site, simply multiply the normalized dose or risk from Table 56 by the site's annual radon release. For example, if the radon release at the Sweetwater site was 2,075 Ci/yr, then the annual RMEI dose at Sweetwater would be 2,075 Ci/yr × 5.6E-04 mrem/Ci = 1.16 mrem/yr.

Table 56: Calculated RMEI and Population Dose and Risk Normalized to the Radon Release

Uranium Site	Dose (Ci^{-1})		LCF Risk (Ci^{-1})	
	Population (person-rem)	RMEI (mrem)	Population	RMEI
Sweetwater	2.3E-04	5.6E-04	1.4E-09	2.9E-10
White Mesa	2.5E-03	5.8E-03	1.6E-08	3.1E-09
Cañon City	2.4E-02	5.0E-03	1.5E-07	2.6E-09
Smith Ranch - Highlands	1.8E-03	7.2E-04	1.1E-08	3.7E-10
Crow Butte	1.3E-03	1.6E-03	8.4E-09	8.4E-10
Christensen / Irigaray	1.8E-03	9.1E-04	1.2E-08	4.8E-10
Alta Mesa	1.0E-02	5.6E-03	6.3E-08	3.0E-09
Kingsville Dome	2.8E-02	5.5E-03	1.8E-07	2.9E-09
Eastern Generic	9.7E-02	1.4E-02	6.6E-07	7.6E-09
Western Generic	2.5E-03	2.9E-03	1.3E-07	3.7E-09

Presenting the normalized doses and risks allows analysis of the effect that siting has on dose and risk without the complications posed by the different mining and/or milling operations. From Table 56, it can be seen that the RMEI dose/risk can vary by up to about a factor of 50, depending on the site where the radon release occurs, while the population dose/risk can vary by up to a factor of 450, depending on the site. This population factor is consistent with the factor of 200 difference in the 80 km cumulative population difference identified in Table 54, plus another factor to account for meteorological differences between the sites and the actual location of the population (e.g., if a large fraction of the population is located in a predominant wind direction at one site, that site will have a larger population dose/risk than a similar population located in a minor wind direction at another site).

Table 57 presents the RMEI and population doses and risks due to the maximum radon releases estimated in Section 2.0, for each uranium site. The maximum radon releases were used to calculate the doses in order to be able to compare the results to regulatory criteria. For example, 10CFR § 20.1301 "Dose Limits for Individual Members of the Public" restricts the total effective dose equivalent (TEDE) to individual members of the public from the licensed operation to less than 100 mrem per year.

Table 57: Calculated Maximum Total Annual RMEI, Population Dose and Risk

Uranium Site	Maximum Radon Release (Ci/yr)	Annual Dose		LCF Risk[(a)] (yr^{-1})	
		Population (person-rem)	RMEI (mrem)	Population	RMEI
Sweetwater	2,075	0.5	1.2	2.9E-06	6.0E-07
White Mesa	1,750	5.2	12.0	3.4E-05	6.4E-06
Cañon City	269	49.2	10.3	3.1E-04	5.4E-06
Smith Ranch - Highlands	36,500	3.7	1.5	2.3E-05	7.7E-07
Crow Butte	8,885	2.7	3.3	1.7E-05	1.7E-06
Christensen / Irigaray	1,600	3.8	1.9	2.4E-05	9.9E-07
Alta Mesa	740	21.6	11.5	1.3E-04	6.1E-06
Kingsville Dome	6,958	58.0	11.3	3.8E-04	6.1E-06
Eastern Generic	1,750	200.3	28.2	1.4E-03	1.6E-05
Western Generic	1,750	5.1	6.0	2.7E-04	7.7E-06

[(a)]Latent Cancer Fatalities

Table 58 presents the RMEI and population doses and risks due to the average radon releases estimated in Section 2.0 for each uranium site. The risks were based on average radon releases in order to make it easier to convert these annual risk values into lifetime risk values, by simply multiplying the Table 58 values by the number of years that the facility operates for the population risk or by the length of time that the individual lives next to the facility for the RMEI risk.

Table 58: Calculated Average Total Annual RMEI, Population Dose and Risk

Uranium Site	Average Radon Release (Ci/yr)	Annual Dose		LCF[a] Risk (yr^{-1})	
		Population (person-mrem)	RMEI (rem)	Population	RMEI
Sweetwater	1,204	0.3	0.7	1.7E-06	3.5E-07
White Mesa	1,388	3.0	7.0	2.0E-05	3.7E-06
Cañon City	146	28.6	6.0	1.8E-04	3.1E-06
Smith Ranch - Highlands	21,100	2.2	0.9	1.3E-05	4.5E-07
Crow Butte	4,467	1.6	1.9	1.0E-05	1.0E-06
Christensen / Irigaray	1,040	2.2	1.1	1.4E-05	5.7E-07
Alta Mesa	472	12.5	6.7	7.6E-05	3.6E-06
Kingsville Dome	1,291	33.6	6.6	2.2E-04	3.5E-06
Eastern Generic	1,388	116.3	16.4	7.9E-04	9.2E-06
Western Generic	1,388	3.0	3.5	1.6E-04	4.4E-06

[a]Latent Cancer Fatalities

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