Technical Basis for Radiological Release of Grand Junction Office Building 2

Volume 1, Dose Assessment

July 1997

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of Energy

GRAND JUNCTION OFFICE

A stylized, shaded illustration of the Grand Junction Office building, showing its unique stepped profile and multiple windows.

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Grand Junction Office Remedial Action Program
Technical Basis for Radiological Release
of Grand Junction Office Building 2
Volume 1, Dose Assessment

July 1997

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Executive Summary

Building 2 on the U.S. Department of Energy (DOE) Grand Junction Office (GJO) site is part of the GJO Remedial Action Program (GJORAP). During evaluation of Building 2 for determination of radiological release disposition, some inaccessible surface contamination measurements were detected to be greater than the generic surface contamination guidelines of DOE Order 5400.5 (which are functionally equivalent to U.S. Nuclear Regulatory Commission [NRC] Regulatory Guide 1.86). Although the building is nominal in size, it houses the site telecommunications system, that is critical to continued GJO operations, and demolition is estimated at \$1.9 million. Because unrestricted release under generic surface contamination guidelines is cost-prohibitive, supplemental standards consistent with DOE Order 5400.5 are being pursued.

This report describes measurements and dose analysis modeling efforts to evaluate the radiation dose to members of the public who might occupy or demolish Building 2, a 2,480 square-foot (ft²) building constructed in 1944. The north portion of the building was used as a shower facility for Manhattan Project uranium-processing mill workers and the south portion was a warehouse. Many originally exposed surfaces are no longer accessible for contamination surveys because expensive telecommunications equipment have been installed on the floors and mounted on panels covering the walls. These inaccessible surfaces are contaminated above generic contamination limits.

Release criteria were proposed in a data quality objectives (DQO) process. The DQO states that Building 2 may be released for unrestricted use if the predicted dose (excluding radon) to a member of the public occupying the building is less than 15 mrem in a typical year and less than 30 mrem in the year when demolition occurs. The radon exposure must not exceed 4 picocuries per liter (pCi/L), the action level recommended for the public by the U.S. Environmental Protection Agency (EPA).

Data were collected to characterize gamma exposure rates, contamination levels, radon concentrations, and contaminants in subsurface drain lines. When direct measurements of the dose component were not possible, RESRAD-Build, a pathway analysis model developed for DOE, was used to assess the dose potential. Dose related to disposal of demolition debris in a sanitary landfill was modeled with the radionuclide transport code, RESRAD.

Measurements indicate that the net Building 2 external gamma exposure rate is approximately 0.4 microrem per hour ($\mu\text{rem/hr}$) greater than the reference samples from two uncontaminated buildings. This rate is not statistically different than background. For conservatism, the dose analysis was conducted with a value of 0.4 $\mu\text{rem/hr}$. By applying occupancy factors defined in the use scenario, the external gamma dose during normal occupancy is estimated to be 0.8 mrem/yr. All other pathways and use scenarios resulted in lower doses.

Summing all sources, the maximum predicted Total Effective Dose Equivalent (TEDE) from Building 2 during normal occupancy scenarios is 0.9 mrem/yr. During demolition, the predicted dose is 0.7 mrem. For both scenarios, the radon concentrations are predicted to be less than the detection limit of 1 pCi/L. The maximum predicted TEDE from future use scenario of a sanitary landfill site where debris is disposed is 0.2 mrem/yr.

Because unrestricted use of Building 2 will cause insignificant incremental increases of predicted dose to the general public and cost per person-rem avoided is approximately \$14,000,000, Building 2 should be released for unrestricted use under as low as reasonably achievable (ALARA) principles.

1.0 Introduction

Planning, measurements, and dose analysis modeling efforts were used to evaluate the radiation dose to members of the public who might inhabit, might demolish, or could be exposed to demolition debris from Building 2 on the U.S. Department of Energy (DOE) Grand Junction Office (GJO) site in Mesa County, Colorado. Building 2 was a shower and change facility for uranium-processing mill workers during the Manhattan Project. Future use of the building is likely to be as an office facility followed by demolition and disposal of debris in a sanitary landfill. Inaccessible surfaces of this building are now contaminated above the generic contamination guidelines specified in DOE Order 5400.5, *Radiation Protection of the Public and the Environment*.

Constructed in 1944, the north portion of this building was used originally as a shower and change facility and the south portion was a warehouse. Most originally exposed surfaces are no longer accessible for contamination surveys because of new floor slabs, remodeling, and the installation of telecommunications equipment, needed for site operations, on the walls and floors. The cost to duplicate this equipment and demolish the building is estimated at \$2,020,000. Because long-term obligations for radiological controls on the building are unacceptable to the Grand Junction Projects Office Remedial Action Program (GJPORAP) (DOE 1990), the facility must be released for unrestricted use or demolished while funding is available.

Release criteria were proposed in a data quality objectives (DQO) process in cooperation with the Independent Verification Contractor (IVC), Oak Ridge National Laboratory (ORNL), an independent reviewer of this report. The DQO defines the proposed release criteria, future-use scenarios, survey units, "affected" or "unaffected" assumptions concerning each survey unit, and the statistical tests used. NUREG 1505 defined the required power of the statistical tests (NRC 1995). After the DQO process was completed, it was interpreted into a sampling plan for use by survey personnel (see Volume 2). The DQO states the following:

This document defines the Data Quality Objectives (DQO) and future use assumptions necessary for predicting the public dose associated with future use of Building 2 as part of the DOE Grand Junction Office Remedial Action Program (GJORAP). A formal definition of the "affected areas," which is needed for design of the sampling plan, is also included.

The DQO states that the building may be released for unrestricted use if the predicted dose (excluding radon) to a member of the public occupying the building is less than 15 mrem in a typical year, and less than 30 mrem in the year when demolition occurs. The required confidence level for sampling is set at 95%. In keeping with proposed U.S. Environmental Protection Agency (EPA) guidance (FR No. 246, 59:66415) the dose criteria do not include the contribution from indoor radon, either from naturally occurring radium-bearing soils or fill material situated beneath or near the building. However, the radon concentration in Building 2 must not exceed 4 picocuries per liter (pCi/L), which is the level recommended to the public by the EPA and Centers for Disease Control in "A Citizen's Guide to Radon" (EPA 402-K92-001).

Future use of Building 2 is expected to be the same as its current use, that as an office facility occupied for eight hours per day, five days per week. Some day the building will be demolished. Exposure to potentially radioactive dust on surfaces that are currently inaccessible may occur, creating larger doses compared with normal occupancy.

Demolition is assumed to take 80 hours to complete. No beneficial use of the building debris is expected; all will go to a sanitary landfill.

The "affected area" of Building 2 is the exposed surfaces (including drain lines) that existed during the era of its use as a locker and shower facility for uranium workers. Subsequent construction on the building, which includes interior walls, wood paneling, and floor coverings installed over a leveling slab are designated "unaffected."

This report was composed to comprehensively document an assessment of potential doses and an as low as reasonably achievable (ALARA) process review (Argonne National Laboratory 1994). It was originally published as the *Grand Junction Projects Office Remedial Action Project Building 2 Public Dose Evaluation* (DOE 1996). The original report was submitted to DOE for review and approval. Approval was granted for unrestricted use of Building 2, however, constraints precluding uncontrolled remodeling and disposal of demolition debris were imposed. These constraints were unacceptable to GJPORAP. This subsequent report considers the remodel and disposal scenarios in more detail and provides a basis for consideration for unrestricted release of the building without constraint. An estimate of cost savings has also been completed. This allows performance of a quantitative ALARA analysis. Figure 1 illustrates the sequential process followed in predicting dose and identifies components of each scenario described in this report.

Dose evaluation data were collected to characterize gamma exposure rates, contamination levels, radon concentrations, and contaminants in subsurface drain lines. When direct measurements of the dose component were not possible, RESRAD-Build, Version 1.5, a pathway analysis model developed for DOE, was used to assess the dose potential (Argonne National Laboratory 1994). Dose related to disposal of demolition debris in a sanitary landfill was modeled with the radionuclide transport code RESRAD (Argonne National Laboratory 1993).

2.0 Characterization Data

Qualified personnel followed approved procedures from the *Rust Geotech Environmental Procedures Catalog* (Rust Geotech, Inc.) and the *Rust Geotech Field Assessments Procedures Manual* (Rust Geotech, Inc.) to collect samples and measurements. Characterization data included external gamma exposure rate measurements, radon-222 concentration measurements, contamination measurements, and Pipe Explorer measurements of subsurface drain lines. Comprehensive exposure characterization measurement results are contained in Volume 2 of this report.

2.1 Gamma Exposure Rate Measurements

Gamma exposure rate measurements were collected with a Reuter-Stokes pressurized ion chamber with a National Institute of Standards and Technology (NIST)-traceable calibration. Building 2 was divided into north and south survey units because the north unit was more likely to be contaminated. The results were pooled because future occupants could use both portions of the building.

Initially, the log cabin portion of Building 12 on the GJO site was selected as the reference survey unit. This portion of Building 12, which has a full basement, was an original structure on the site and has adjacent native soil. Because Building 12 was compared with a conventional frame structure built on a slab, data from Building 12 were expected to underestimate the background gamma exposure rate of a single story, slab-on-grade structure. After data from Building 12 were analyzed, the question was

Figure 1. Use Scenario Flowchart

raised as to whether Building 12 was an appropriate reference survey unit on the basis of its construction. Subsequently, Building 26, which is similar to Building 2, was evaluated as a background reference. Building 26 was not initially selected because contaminated soil around this structure had been replaced with nonnative material.

Section 3.0 of Volume 2 of this report illustrates the exposure rate data for each survey unit. The exposure rate data from Buildings 12 and 26 were pooled and used as the reference unit. Table 1 presents a summary of the mean, maximum, and standard deviation of the data, as well as the number of samples taken for each unit. In addition, the skewness and kurtosis are given for the pooled survey units.

Table 1. Summary of Pressurized Ion Chamber Data^a

Survey Unit	Mean ^b (μ rem/hr)	Maximum (μ rem/hr)	Standard Deviation	Number of Samples in Unit	Skew- ness	Kurtosis
Building 2 North	11.99	12.3	0.19	8		
Building 2 South	11.77	12.3	0.37	10		
Building 2 North/ South Pooled	11.87		1.08		-1.6	4.7
Building 12 Log Cabin	10.94	13.1	0.62	22		
Building 26	12.69	13.6	0.58	9		
Buildings 12 and 26 Pooled	11.45		1.01		0.7	-0.59
Difference Between the Means	0.4					

^asee Section 3.0 of Volume 2 of this report.

^b μ rem/hr = microrem per hour.

These data were tested for statistical differences with the nonparametric Wilcoxon Rank Sum (WRS) and Quantile tests and the parametric 't' test (NRC 1995). The null hypothesis, which was stated as "no statistical difference in the mean exposure rates between the Building 2 survey units and the pooled reference units," was accepted in each test. However, the pooled distributions are not normal and the validity of the 't' test is questionable. The net difference between sample and reference survey units is 0.4 μ rem/hr within a 95% confidence interval of -0.7 to +0.9 μ rem/hr. This difference is not statistically significant.

2.2 Radon Measurements

Landaaur Track Etch radon detectors, type DRN, were used to measure radon-222 concentrations. The north and south survey units of Building 2 and the log cabin portion of Building 12 were monitored from January 3 through February 2, 1996. In the middle latitudes where buildings are heated during the winter, radon sampling in January will provide a conservative estimate of the annualized average concentration.

The radon concentrations measured in these two buildings were less than the detection limit of 1 pCi/L for all measurements. These concentrations are less than the EPA guideline value of 4 pCi/L for households.

Data from a 1989–1990 nationwide study of radon in DOE buildings (UNC Geotech 1990) confirm these measurements. In an exposure from November 13, 1988, to February 13, 1989, the concentrations in Building 2 were 1.4 pCi/L and in Building 12 were 3.0 pCi/L. Since then, significant remedial actions have been conducted on the GJO site and nearby radon sources have been removed.

2.3 Contamination Measurements

No reference unit was used for contamination measurements because it was assumed that the background contamination rate should approach zero. The ambient background count rate for each meter was subtracted from each measurement. Building 2 surfaces were divided into 11 survey units on the basis of location, accessibility, and original or remodeled construction.

Using combination rate meter and scaler survey meters calibrated with NIST-traceable chlorine-36 sources, measurements of total and removable contamination were collected in accessible areas and from core samples of inaccessible areas. Uranium and its by-products emit alpha and beta radiation in approximately equal proportions. Only beta measurements were collected for this characterization because beta radiation is reliably detected under field conditions and the contamination guidelines for alpha and beta contamination apply separately. Contamination data are used for comparison to generic surface contamination guidelines, which are 5,000 dpm/100 cm² total average and 1,000 dpm/100 cm² removable (DOE Order 5400.5), and to model the dose during future use of the building.

Scanning measurements were used to estimate average contamination levels and to locate elevated areas of contamination. Areas of elevated contamination were measured using the mode function. Besides measurements at points with elevated scan readings, other areas were also evaluated. This method results in a conservatively biased estimate of the average activity per unit area. When scanning in a survey unit was not feasible because of surface coverings, core samples were obtained at random locations selected according to the method in the sampling plan. Core sampling should produce an unbiased estimate of the contamination levels on inaccessible surfaces. Table 2 presents a summary of data presented in Section 5.0 of Volume 2 of this report for all contamination survey units.

On average, no survey unit exceeded the contamination standard defined in the DQO criteria, however localized areas within some survey units exceeded this criteria. The data was validated by comparing each sample unit standard deviation with parameters identified in Table 1–3 presented in the DQO.

Table 2. Summary of Average and Maximum Contamination Levels for Each Survey Unit^a

Survey Unit	Accessible	Total Average Contamination (dpm/100 cm ²)	Maximum Contamination (dpm/100 cm ²)	Standard Deviation	Number of Samples in Unit
North Old Wall ^b	Yes	1,225	3,449	2,010	26
North New Wall	Yes	-117	209	203	26
South Old Wall	Yes	3,026	9,010	3,996	4
South New Wall	Yes	-105	129	131	30
North Floor ^c	Yes	352	796	375	6
South Floor ^c	Yes	425	5,427	1,025	31
North Floor (cores) ^d	No	1,023	3,623	1,129	16
North North Wall (cores)	No	4,868	34,362	9,913	35
North East Wall (cores)	No	1,659	33,283	6,706	45
North West Wall (cores)	No	1,897	30,046	5,254	47
South Floor (cores) ^e	No	679	2,655	743	18
South East Wall (cores)	No	786	26,892	5,526	45
South West Wall (cores)	No	2,499	22,825	5,962	45

^aFor comparison to generic surface contamination guidelines, which are 5,000 dpm/100 cm² total average and 1,000 dpm/100 cm² removable (DOE Order 5400.5), no removable contamination greater than guideline values was located in any sampling unit. Using field screening techniques, the highest 34 smears with the highest values were reevaluated with a desktop scaler counter. The mean of these measurements was -4.7 dpm/100 cm² with a standard deviation of 43. For dose modeling purposes, the 1 σ upper limit, 39 dpm/100 cm², from this conservatively biased sample of smears will be used as the removable contamination level for each sampling unit when such a value is required.

^bLocation D90, the contaminated radiator that was removed from consideration, has a mean of 1,150 dpm/100 cm² and a standard deviation of 1,643. Before removal of the radiator, the mean was 1,484 dpm/100 cm² and the standard deviation was 2,313.

^cThese sampling units are in addition to the DQO required units.

^dData in the table represent the average over all concrete surfaces, including the new slab. When only the surface of the original slab is considered, the mean is 2,352 dpm/100 cm² and the standard deviation is 1,198.

^eData in the table represent the average over all concrete surfaces, including the new slab. When only the surface of the original slab is considered, the mean is 1,460 dpm/100 cm² and the standard deviation is 681.

2.3.1 Scanning Measurements

A summary of the scanning measurements compiled with hand-held contamination survey meters is included in Volume 2. Scanning measurements detected only three areas where contamination exceeded

generic surface contamination guidelines. No hot spot greater than 3 times the average guideline limit in any 100 cm² area was located.

2.3.2 Direct Contamination Measurements of Accessible Areas

Only three locations were contaminated more than the average guideline limit. No location exceeded the excursion limit of 3 times the average guideline limit. These three areas correlate with the elevated areas, which are identified in the scanning surveys. One location, D90, an old room radiator, that was removed in 1996, is contaminated to the level of 10,330 dpm/100 cm². Measurement locations are presented in Volume 2 of this report.

2.3.3 Smear Contamination Measurements of Accessible Areas

Removable contamination smears were obtained at the same location where direct contamination measurements were collected. The smears were semi-quantitatively evaluated in the field with the hand probe in the scaler mode to determine if a more quantitative measurement was required. The results of these field measurements are presented in Volume 2.

Thirty-four wipes were identified for quantitative analysis. The highest value measured was 75 dpm/100 cm². To avoid introducing more variance than necessary, field estimates of removable contamination were discarded and replaced with the 1 σ upper confidence interval value from the quantitative measurements of the 34 highest wipe counts. This action provides a conservative estimate of the removable contamination for use in dose modeling. The mean and the standard deviation of the potentially elevated wipes was -4.7 ± 43 dpm/100 cm². The value of the 1 σ upper confidence interval was 39 dpm/100 cm². This value was also assigned to wipes taken on cores from inaccessible survey units.

2.3.4 Direct Contamination Measurements of Inaccessible Areas Using Core Samples

Core samples were obtained to determine the average contamination level on originally exposed surfaces that are now covered. Core-sample locations and data are provided in Volume 2. These data suggest that the contamination levels do not vary as much with spatial location as they do with material type. Table 3 presents a summary of the mean and standard deviation of the measured activity per 100 cm² for each material type having elevated contamination levels.

The concrete material type forms the lower half of the north and east walls of the telecommunications room. The interior face of this concrete appears to be contaminated. It is possible that the concrete aggregate is naturally radioactive, but it is more likely that this is residual activity from the facility's original use as a shower room for uranium-processing mill workers.

The insulation material type was substantially elevated inside external walls on the south portion of the building. The mean for the southwest survey unit was 19,643 dpm/100 cm² with a standard deviation of 2,825.

The wood material type had elevated contamination in five different survey units. This contamination was associated with the structural wood and was distributed throughout the exterior walls. The contaminant level for wood averaged over all affected survey units was approximately 8,000 dpm/100 cm² with a standard deviation of approximately 8,500.

Table 3. Summary of Average Total Contamination Levels for Each Material Type

Material Type*	Survey Unit	Mean (dpm/100 cm ²)	Standard Deviation
Concrete	North-N	26,676	5,036
Concrete	North-E	13,114	14,828
Insulation	South-W	19,643	2,825
Insulation	South-E	9,586	9,618
Wood	North-N	12,146	5,828
Wood	North-E	4,050	12,951
Wood	North-W	9,075	9,309
Wood	South-W	10,641	4,005
Wood	South-E	1,735	3,172

*For material types not shown, the average total contamination level in each survey unit was less than 500 dpm/100 cm².

The core samples from the concrete floor slabs revealed relatively uniform contamination levels over the two survey units. The mean value of the pooled data was 1,906 dpm/100 cm² with a standard deviation of 1,039.

2.3.5 Smear Contamination Measurements of Inaccessible Areas Using Core Samples

No removable contamination exceeding guideline limits was detected in any core sample. The smears exhibiting the largest values were reevaluated using a tabletop smear counter. These reevaluated results are discussed in Section 2.3.3. For dose modeling purposes, the value of 39 dpm/100 cm² was used.

2.4 Pipe Explorer Measurements

Science and Engineering Associates, Inc. (SEA) conducted radiological and video characterization surveys of the two drain pipes running below Building 2. A report of SEA operations provides information on work performed (SEA 1996). SEA used a Pipe Explorer to tow a small video camera and a beta detector through the pipes to collect information. The Pipe Explorer process involves inverting (turning inside out) a tubular impermeable membrane under air pressure. The membrane can tow a sensor through constricted pipes, 90° bends, and vertical pipes. Because the sensor is transported inside the disposable membrane, it is protected from contamination.

Calibration of the beta detector was established using a NIST-traceable strontium-90 source in a geometry matched to the 10-centimeter (4-inch) iron drain pipe. This calibration results in an overestimate of the activity compared with the result that would be calculated using lower energy chlorine-36 as the calibration standard.

Two abandoned drain pipes were imaged and measured for beta contamination. Line #1 drained the bathrooms on the northwest side of Building 2. Line #2 drained water from sinks and showers. Figure 2 illustrates the data collected from Line #1. The contamination level in this pipe is below guideline limits and below the minimum detectable activity for this system is 2,700 dpm/100 cm². The Pipe Explorer

could not be used in Line #2 because it was blocked by sediments. The most important effect of the contamination in Line #2 was external exposure, which was measured as part of the overall exposure rate in the north gamma survey unit.

Figure 2. Pipe Explorer Data From the Sanitary Sewer Drain Line

3.0 Dose Assessment

Prospective dose assessment requires measured data and assumptions concerning future interaction with residual radioactive material. To avoid underestimating the true risk, it is common practice to make realistic but conservative assumptions. This practice implies that the assumptions are plausible, but errors may overestimate a person's exposure to hazardous material. Conservative assumptions are not "worst-case" assumptions, which can be unrealistic but useful in simplifying a problem. Complete

descriptions of the exposure scenarios, assumptions, and pathway-modeling software input and output data are contained in Volume 2 of this report.

The following dose assessments were generated for Building 2:

- Realistic dose during normal occupancy as an office.
- Worst-case dose during normal occupancy as an office.
- Dose to a construction worker during demolition.
- Dose to a park visitor playing on the reclaimed sanitary landfill where debris was disposed.
- Worst-case dose to a residential farmer living on the reclaimed sanitary landfill where debris was disposed.

For occupancy and demolition scenarios, RESRAD-Build was used to model inhalation and ingestion dose components that were not directly measured. Although external gamma exposure and radon concentrations are predicted in this code, the model results were discarded and measured quantities were used. Table 4 presents summaries of the doses for each scenario.

Table 4. Summary of Doses for the Scenarios

Scenario	Realistic (R) or Worst Case (W)	Gamma (mrem/yr)	Inhalation (mrem/yr)	Ingestion (mrem/yr)	Radon (pCi/L)	TEDE*
Occupancy	R	0.8	0.1	0.0005	< 1	0.9 mrem/yr
Occupancy	W	0.8	0.3	0.002	< 1	1.1 mrem/yr
Demolition	R	0.03	0.69	0.002	< 1	0.7 mrem
Landfill to Park	R	See Table 5				0.05 mrem/yr
Landfill to Farm	W	See Table 5				0.2 mrem/yr

*TEDE = Total Effective Dose Equivalent.

3.1 Realistic Dose During Normal Occupancy

TEDE was calculated assuming 2,000 hours per year occupancy. Measured gamma exposure rates were converted to dose using the convention 1 roentgen (R) is equal to 1 rem. Gamma exposure rates (see Table 1) result in an annual dose of 0.8 mrem/yr within a 95% confidence interval of -0.14 to 1.8 mrem/yr. Although this value is not statistically different from zero, the value was used because of the preference for conservative assumptions.

The measured radon concentrations were less than the detection limit and EPA guidelines.

Contamination in buried pipes is not a significant concern. The measured pipe had contamination levels less than the release limits. The unmeasured pipe is not routinely accessible and any contribution to dose is accounted for in the external exposure measurements.

Modeled doses, which are highest in the first year of occupancy because of the removable fraction caused by erosion and radioactive ingrowth factors, are dominated by the inhalation and ingestion pathways. Inhalation dose was 0.1 mrem/yr; ingestion dose was 0.0005 mrem/yr.

Summing all sources, the predicted dose from normal occupancy of Building 2 was 0.9 mrem/yr TEDE. Measured radon concentrations are substantially less than the EPA guidance value of 4 pCi/L for households.

3.2 Worst-Case Dose During Normal Occupancy

Worst-case dose during normal occupancy scenario describes a situation where remodeling occurs while the building is occupied. Exposure conditions are the same except wall and floor coverings are removed and the release fractions are increased. All contamination, except in the subsurface drain lines, is accessible and removable. This scenario could not be repeated annually because the contaminants would be removed or covered. Therefore, it should be interpreted as a single-year exposure scenario.

Modeled doses are dominated by the inhalation and ingestion pathways. Inhalation dose was 0.3 mrem/yr; ingestion dose was 0.002 mrem/yr.

Summing all sources, the worst-case predicted dose from occupancy of Building 2 was 1.1 mrem TEDE and the measured radon concentrations are substantially less than the EPA guideline value of 4 pCi/L for households.

3.3 Dose to a Construction Worker During Demolition

Dose to a construction worker during demolition includes all the same pathways. However, important differences include the fraction of removable contamination, dust resuspension rate, workers' breathing rate, dust ingestion rate, and duration of exposure. The assumptions and input parameters used are detailed in Volume 2.

Demolition could take 2 weeks to complete. The effect of shielding configuration changes on the external gamma exposure dose rate was determined to be unimportant. Therefore, the measured exposure rate of 0.4 μ R/hr was assumed. The predicted external gamma dose during demolition was 0.03 mrem within a 95% confidence interval of -0.005 to 0.07 mrem. Inhalation dose was 0.69 mrem; ingestion dose was 0.002 mrem. The radon concentrations will reduce to ambient outdoor levels and are of no concern.

Contamination that may be in buried drainage pipes will be mostly contained by those pipes during demolition and disposal. Because extensive size reduction is not necessary for landfill disposal, it is unlikely this source term will contribute substantially to the inhalation dose.

Summing all sources, the predicted dose during demolition of Building 2 was 0.7 mrem TEDE, which occurs during the year when the demolition occurs. The measured radon concentrations are substantially less than the EPA guidance value of 4 pCi/L for households.

3.4 Dose Related to Disposal of Demolition Debris

No beneficial use of Building 2 disposal debris is expected and it is likely that all will be incorporated into the subsurface structure of the nearby Orchard Mesa Landfill in Mesa County. Demolition will cause radioactive contaminants to be averaged into the mass of debris, resulting in lower concentrations than those measured during characterization. For comparison, consider the EPA disposal criteria for uranium mill tailings. This criteria, specified in Title 40, Part 192 of the *U.S. Code of Federal Regulations* (40 CFR 192), is that the concentration of radioactivity should not exceed 15 picocuries per gram (pCi/g) above background in soil structures that are 15 cm or more below the surface. The concentration of radioactivity in all Building 2 debris will be less than this value.

Because no radioactive material waste management acceptance criteria for the Orchard Mesa Landfill exists, RESRAD was used to predict dose to the general public from two use scenarios. The realistic scenario is a visit to a public park and the worst-case scenario is living on a family farm.

The Orchard Mesa Landfill storage capacity was estimated at 16 years. Mesa County intends to extend the landfill life to approximately 50 years through horizontal expansion. The landfill accepts municipal solid waste and limited amounts of petroleum-contaminated soils, asbestos, and wastewater treatment plant sludges.

The dose assessment assumes that the debris is disposed of in a 1-foot thick layer below the surface of the landfill cover. Assuming the landfill will not be released to the public until 50 years after closure of the facility, the time from Building 2 debris disposal to occupancy by the public is assumed to be 100 years.

The maximum dose in each scenario occurs 600 years after disposal because the cover material erodes, exposing the contaminants. The groundwater pathway is of no significance because of the thick unsaturated zone of shale, that has a low permeability, located below the landfill.

The maximum annual dose for the park scenario was 0.05 mrem/yr TEDE. For the family farm, the maximum annual dose was 0.2 mrem/yr TEDE. Table 5 presents dose pathways for both scenarios.

Table 5. Dose Pathways From Two Scenarios for Disposal of Debris in the Sanitary Landfill

Pathway	Park Scenario (μ rem/yr)	Farm Scenario (μ rem/yr)
Surface gamma	16	43
Inhalation	30	66
Radon	5.6	60
Soil ingestion	2.2	0.72
Plant ingestion	—	4.0
Meat ingestion	—	0.02
Milk ingestion	—	0.04
Other	0.0	0.0
Total	54	174

4.0 Remedial Actions

The following remedial actions have been completed since contamination measurements were performed:

- Removal of a contaminated radiator from the northwest wall of Building 2
- Removal of a lens of contaminated soil from Building 2 beneath the west foundation, that extended southwest from a direction north of the south wall

All other residual radioactive material dose effects are incorporated into gamma dose measurements and source terms used to perform the dose modeling described in Section 3.0. These materials include celotex, concrete, insulation, masonite, paneling, plywood, sheetrock, and wood.

5.0 As Low As Reasonably Achievable Analysis

The DOE Order 5400.5 supplemental standards application process requires an analysis to determine if the proposed action is within regulatory limits and is as low as reasonably achievable (ALARA). In other words, is further reduction in dose worth the incremental cost? This cost/benefit analysis is normally reduced to units of dollars per person-rem (derived from lifetime cancer fatality risk estimates), then compared with a reference value as the basis for a decision. Often the reference value is set in the range of \$1,000 to \$10,000 per person-rem, and may vary as much as a factor of 10 above or below this range (Argonne National Laboratory 1993).

5.1 Discussion

The GJORAP staff developed Building 2 remediation options and cost estimates with respect to DOE's generic guideline limits. Given the funding period available for GJORAP and the requirement to maintain a telecommunications system, the staff concluded that the only feasible option was telecommunications equipment and personnel relocation followed by demolition. An associated ALARA cost/benefit analysis was performed by relating these cost estimate assumptions and figures to the predicted dose assessments reported in Section 3.0. Figure 3 presents the ALARA cost/benefit analysis.

Calculation of Cost Savings For Unrestricted Release As Is		
Estimated Cost to Demolish Building 2		\$ 2, 020,000
Cost to Perform RESRAD—Build Risk Modeling	\$84,000	
Cost to Perform Soil (Yellowcake) Removal	36,000	
<u>Total Cost for Supplemental Standard Release</u>		<u>\$ 120,000</u>
Potential Cost Savings		\$ 1,900,000
Calculation of Person-Rem Avoided		
Predicted TEDE dose per person for normal occupancy		0.0009 rem/yr
Predicted TEDE dose per person for remodeling		0.001 rem
Predicted term of available building use		30 years
Predicted number of regular occupants		5 persons
[(0.0009 rem/yr x 30 years) + 0.001 rem] x 5 persons		= 0.14 person-rem avoided
Calculation of Cost per Person-Rem Avoided		
\$1,900,000 ÷ 0.14 person-rem avoided		= \$14,000,000/person-rem avoided

Figure 3. Cost per Person-Rem Avoided

6.0 Conclusion

A well-planned data collection and analysis was performed with the intent of predicting the dose to members of the public who might be exposed to residual radioactive material in Building 2 or the construction debris from future demolition of Building 2. The process was designed to generate the information needed in an application for supplemental standards under the requirements of DOE Order 5400.5, *Radiation Protection of the Public and the Environment*.

Dose assessments using both measured and modeled information indicate that the dose above background levels to members of the public resulting from Building 2 occupancy, demolition, and debris disposal would be below the DQO criteria established as a constraint on the source and far below the public dose limit of 100 mrem per year (DOE Order 5400.5). The dose to the public poses no significant risk. An ALARA analysis, that compares the cost and benefit of a proposed action, indicates that a cost avoidance of approximately \$14,000,000 per person-rem saved would be realized by releasing Building 2 for unrestricted use without constraint.

The following facts support release of Building 2 under the supplemental standards process defined in DOE Order 5400.5:

- The predicted maximum annual dose during normal occupancy was 0.9 mrem TEDE.
- Measured radon concentrations are less than the EPA guideline of 4 pCi/L for homeowners.
- The predicted maximum dose during demolition was 0.7 mrem TEDE.
- The predicted maximum annual dose from disposal in the Orchard Mesa Sanitary Landfill under future use scenarios was predicted to be 0.2 mrem/yr TEDE.
- Building 2 will not cause a maximum individual dose to a member of the public in excess of 1 mrem in a year or a collective dose of more than 10 person-rem in a year (DOE 1995).
- The ALARA process review requirements have been met (DOE Order 5400.5).
- Average external gamma exposure readings do not exceed 20 μ R/hr above background (DOE Order 5400.5).
- The cost of remediation is unreasonably high relative to long-term benefits and the residual radioactive material does not pose a clear present or future risk (DOE Order 5400.5).
- Concerns regarding unanalyzed scenarios raised in a DOE Albuquerque Operations Office Environmental Protection Division review of a prior submittal for release of Building 2 have been addressed and show no significant impact on public dose.

The results of this collection and analysis indicate that the dose above background levels to a member of the public in all considered scenarios was less than 1 mrem/yr. The cost to replace the building and the telecommunications facilities housed there is estimated at \$2,020,000. Comparing the cost of demolition and replacement to the public, dose avoided results in an estimate of \$14,000,000 per person-rem. This is a high cost/benefit ratio and illustrates that it is not reasonable to demolish and replace the building and equipment. Therefore, the remedial action is judged not to be ALARA and is not recommended.

7.0 References

Argonne National Laboratory, 1994. *RESRAD-Build [Version 1.5]: A Computer Model for Analyzing the Radiological Doses Resulting from the Remediation and Occupancy of Buildings Contaminated with Radioactive Material*, ANL/EAD/LD-3, Argonne, Illinois.

———, 1993. *Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5.0*, ANL/EAD/LD-2, Argonne, Illinois.

Manugraphics, Inc., 1991. *STATGRAPHICS, Version 5*.

Rust Geotech, Inc., 1996. *Rust Geotech Environmental Procedures Catalog*.

———, 1996. *Rust Geotech Field Assessments Procedures Manual*.

Science & Engineering Associates, Inc. (SEA), 1996. *Results of the Radiological and Video Surveys of Drain Lines at the DOE Grand Junction Projects Office with the Pipe Explorer™ System*, Albuquerque, New Mexico, March.

UNC Geotech, 1990. *Results of the U.S. Department of Energy Indoor Radon Study, Volume 2*, CNG/GJ-TP-1, U.S. Department of Energy Grand Junction Projects Office, Grand Junction, Colorado.

U.S. Department of Energy (DOE), 1996. *GJPORAP Building 2 Public Dose Evaluation*, DOE/ID/12584-265, prepared by Rust Geotech for the U.S. Department of Energy Grand Junction Projects Office, Grand Junction, Colorado, May.

———, 1995. *Response to Questions and Clarification of Requirements and Processes: DOE 5400.5, Section II.5 and Chapter IV Implementation (Requirements Relating to Residual Radioactive Material)*, Office of the Assistant Secretary for Environment, Safety and Health, Office of Environment, November.

———Order 5400.5, 1990. *Radiation Protection of the Public and the Environment*, Figure IV-1, Surface Contamination Guidelines, February 8.

———, 1990. *Grand Junction Projects Office Remedial Action Project Plan*, P-GJPO-142, prepared by UNC Geotech, Inc. for the U.S. Department of Energy Grand Junction Projects Office, Grand Junction, Colorado, December.

U.S. Nuclear Regulatory Commission (NRC), 1995. *A Nonparametric Statistical Methodology for the Design and Analysis of Final Status Decommissioning Surveys*, Draft Report for Comment, NUREG 1505.