APPENDIX G

Radium Benchmark Dose Calculations And Sensitivity Analyses

Appendix G

RADIUM BENCHMARK DOSE CALCULATIONS and SENSITIVITY ANALYSES

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DETERMINATION OF ANNUAL DOSE
Drainage 005 Scenario

DETERMINATION OF ANNUAL DOSE
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SENSITIVITY ANALYSIS
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DEVELOPMENT OF DERIVED CONCENTRATION GUIDELINE LEVELS

Introduction

Radioactive materials have been processed, used, and/or stored at SFC since 1970. The soils on site are contaminated with radioactive material. The technical criteria for cleanup of contaminated soil are provided in 10 CFR 40[1]. The technical criteria may be summarized as: 1) the concentration of radium in soil does not exceed the background concentration by more than 5 pCi/g; and 2) concentrations of radionuclides other than radium in soil must not result in a total effective dose equivalent (TEDE) exceeding the dose from cleanup of radium contaminated soil to the aforementioned criteria (benchmark dose). The TEDE is applied against an average member of a group of individuals reasonably expected to receive the greatest exposure to residual radioactivity for any applicable set of circumstances.

Exposure pathway modeling was used to calculate the benchmark dose and radionuclide concentrations that could result in a TEDE equal to the benchmark dose. Exposure pathway modeling is an analysis of various exposure pathways of a given exposure scenario used to convert dose into concentration of radioactive material in the source media. Concentrations were developed independently for the radionuclides other than radium present as contaminants in soil at SFC. These concentrations are referred to herein as derived concentration guideline levels (DCGLs).

The exposure pathway modeling completed here to develop the DCGLs was a deterministic analysis of the peak annual dose to the average member of the critical group for a resident farmer exposure scenario. The DCGLs accounted for site-specific information regarding the source term; critical group, scenario, and pathways identification and selection; the conceptual model; and calculations and input parameters. The units of the DCGLs, pCi/g, are the same as for the measurements that will be used to demonstrate compliance with the technical criteria. This allows direct comparison between the DCGLs and results of verification surveys. SFC will show final compliance with the technical criteria by use of radionuclide-specific DCGLs and will ensure that the sum of fractions is met for all radionuclides.

Scope of DCGLs

The DCGLs were developed in particular for the case of license termination. The DCGLs were developed without consideration of any institutional controls and such that there is reasonable assurance that the TEDE from residual radioactivity distinguishable from background to the average member of the critical group is as low as is reasonably achievable.

The development of the DCGLs was completed solely with respect to dose received due to pathways related to residual radioactive material in surface soil. There were several

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[1] 10 CFR 40, Appendix A, Criterion 6, item (6).

pathways not included in the development of the DCGLs. Some pathways were not included because they are not applicable; e.g. drinking water. Other pathways were not included because they cannot be considered directly by the conceptual model applied to develop the DCGLs; e.g. exposure rate from the disposal cell. These and other pathway exceptions are discussed in a following section of this appendix.

If an exposure pathway is later determined applicable, such as drinking water, it may be added into the conceptual model and the DCGLs redeveloped. It is expected that some of the excluded pathways, such as exposure rate from the disposal cell, may be addressed by design; i.e. the disposal cell may be designed to yield an exposure rate comparable to background. In the case of a pathway not considered directly by the conceptual model is discovered significant, the corresponding dose will be independently determined and the DCGLs would be debited accordingly.

Figure G-1 is a schematic of the area to which the DCGLs are applicable.

Source Term

Configuration

The radionuclides that have the potential to contribute the dose against which the dose limit criteria are compared are identified as the constituents of concern (CoC). The CoCs are specifically evaluated for the development of site-specific DCGLs. The CoCs were chosen based on historical information and findings of site investigations[2]. The CoCs were determined to be natural uranium and associated transformation products, thorium-230, and radium-226.

The source term is assumed to be uncovered contaminated soil of cylindrical shape. The contaminated soil is modeled as a 0.3-meter thick zone of unconsolidated soil. The contaminated soil is known underlain by one uncontaminated unsaturated soil zone; this zone is modeled as a 1.4-meter thick zone of unconsolidated soil. The next zone is an uncontaminated saturated zone; this zone is modeled as shale and is independent of thickness. The final zone is an aquitard and is not included in the model; this zone is sandstone. Figure G-2 depicts the soil zones.

The use of nonspecific unconsolidated, shale, and sandstone zones is intentional. The locations inside and outside the ICB that would be available for a farmer to establish residence vary with respect to the particular shale unit that underlies the unconsolidated surface soil. However, shale units 1, 2, 3, and 4 have essentially equivalent physical characteristics. This condition is also true with respect to the sandstone zone beneath the nearest-surface shale zone. Then a single physical description can be used to represent any viable location upon which a farmer might establish residence.

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[2] Sequoyah Fuels Corporation, *Site Characterization Report*, Section 4.2.2. "Summary of Radiological and Chemical Materials Utilization", December 15, 1998.

Residual Radioactivity

The CoCs are assumed homogenously distributed within the contaminated soil at concentrations equivalent to the DCGLs.

Chemical Form

In an effort to quantify the mobility of uranium in soil at the site, a distribution coefficient (K_d) was determined for each of unconsolidated soils, and shale units 1 through 4. These site-specific values were used for development of the DCGLs. Further discussion of the selection and application of the K_d for uranium is provided Attachment 1.

A site-specific K_d was not determined for thorium or radium.

Critical Group, Scenario, and Pathways Identification and Selection

Scenario Identification

The exposure scenario applied here may be described as representing a resident farmer. The resident farmer scenario accounts for exposure involving residual radioactivity that is initially in the surface soil. A farmer moves onto the site and grows some of his diet and uses surface water from the site. The scenario assumes loss no disturbance of the disposal cell (this qualification is discussed later). The scenario is based on prudently conservative assumptions that tend to overestimate potential dose.

Critical Group Determination

The average member of the critical group is the resident farmer. This individual is assumed to be an adult with common habits and characteristics. This individual is reasonably expected to receive the greatest exposure to residual radioactivity for the applicable exposure scenario.

Exposure Pathways

The starting point for exposure of the critical group to the CoCs is the contaminated soil zone. The CoCs are assumed released from the soil by erosion, plant uptake, direct ingestion, infiltration, and leaching. The CoCs may also be transported to or by groundwater to eventually be released from soil. The scenario also considers exposure to direct gamma radiation emitted by the CoCs.

The primary exposure pathways include:

- External exposure from soil;
- Inhalation of suspended soil;
- Ingestion of soil;
- Ingestion of plant products grown in contaminated soil and using potentially contaminated surface water to supply irrigation;
- Ingestion of animal products grown onsite using feed and surface water from potentially contaminated sources; and
- Ingestion of fish from potentially contaminated surface water onsite.

The exposure pathways selected for evaluation are listed in Table G-1. Three exposure pathways not included in the dose assessment are groundwater usage, intrusion of the disposal cell, and radon; each is discussed below.

Groundwater Usage

Groundwater usage includes use of groundwater for irrigation, livestock water supply, and drinking water. Groundwater usage was not considered a pathway applicable to the exposure scenario. There are no existing active water wells near or downgradient from the facility that could be impacted by migrating groundwater. The few active water wells near the plant are either upgradient of the facility or so far removed that future impact due to migration of CoCs is not possible.[3]

A technical evaluation of the Terrace/Shale Unit 1, Shale Unit 2, and Shale Unit 3 revealed they have essentially no ability to yield sufficient quantities of water to satisfy the EPA criteria for consideration as a potential drinking water source.[4] Though Shale Unit 4 may have a very limited potential to yield groundwater slightly greater than the EPA criteria, the background water quality of this formation is of such poor quality that it would not reasonably be used for any domestic purpose. The same reasoning eliminates use of groundwater for irrigation and livestock water. As well, such condition has resulted in the local practice of surface water serving as the supply for irrigation and livestock water.

Limited yield of groundwater wells is typical throughout this part of Oklahoma and has resulted in the construction of extensive potable water distribution systems that

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[3] Letter to Charlotte Abrams, U.S. NRC, from John Ellis, Sequoyah Fuels Corporation, "Response to Request for Additional Information Concerning Environmental Renewal of Decommissioning", No. 14, April 30, 2001.

[4] Technical Memorandum to Sequoyah Fuels Corporation, from Shepherd Miller, Inc., "Sufficient Yield", August 24, 2001.

rely on surface water as their source(s). Also, adjacent to the site is the Illinois River, which is of much higher quality and yield, and more easily accessed than local groundwater. Considering the abundant and more easily accessed alternate water supplies available, drilling through the hard sandstone units is highly improbable.

Localized areas at the Facility producing higher yields of water, have been affected by recharge from existing surface impoundments or man-made subsurface reservoirs such as utility trenches and foundation backfill areas. Once these features are removed during decommissioning, the yield from the higher output wells is expected to decline significantly. In addition, the highest yields occur in the Terrace (surface) unit. It is unlikely that a well would be constructed in this unit due to potential contamination from septic systems or other near surface features.

The Alluvial Groundwater System has been found to have a high water yield. This groundwater system is primarily supplied by in-flow from the R.S. Kerr Reservoir. This water is therefore of relatively low quality (elevated dissolved solids and salinity), is not currently used for drinking water, nor could it be in the future without expensive treatment.

In the context of the previous description, there exists a reasonable assurance that there is no direct groundwater usage pathway, especially drinking water, resulting in exposure to Site-derived constituents at the Facility.

Cell Intrusion

Development of the DCGLs did not consider failure of the cell's engineered cover system. Inadvertent intrusion into the cell by construction of a basement is very unlikely since basements are not a common feature of homes in northeast Oklahoma. Because the outer most layer of the cover system will be rip-rap (i.e. not a vegetative cover), it is not reasonable to assume it a surface conducive to placement of a building such as a house. Finally, the cover system is designed such that erosion by surface water, resulting in exposure of a resident to the cell contents either directly or from redistribution by surface water, will not be a threat.[5]

Deliberate intrusion into the cell was not considered during development of the DCGLs. Such an event implies that the intruder knows of the potential hazards but deliberately chooses to ignore them. Deliberate intrusion into the cell cannot reasonably be protected against and so is not considered further.[6]

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[5] NUREG-1727, Appendix C, Section 4.4.3

[6] NUREG-0945, page 4-13

Radon

The radon pathway was not considered because it is specifically excluded from the scope of the technical criteria.[7]

Conceptual Model

The conceptual model used to evaluate the previously described exposure scenario and pathways was the RESRAD[8] computer code version 5.82. RESRAD was developed, in part, to calculate site-specific concentrations for RESidual RADioactive material in soil corresponding to a radiation dose limit to a chronically exposed on-site resident. The RESRAD code considers multiple environmental transport and exposure pathways. A description of the code models, as applied here, is provided below.[9]

RESRAD models external exposure from volume sources when the individual is outside, using volume dose rate factors from Federal Guidance Report No. 12. Correction factors are used to account for soil density, areal extent of contamination, and thickness of contamination. When the individual is indoors, exposure from external radiation is modeled in a similar manner except that additional attenuation is included to account for the building. Exposure through ingestion of contaminated animal and plant products is modeled simply through the use of transfer factors.

The generic source-term conceptual model in RESRAD assumes a time-varying release rate of radionuclides into the water and air pathways. Radionuclides in the contaminant zone are assumed uniformly distributed. No transport is assumed to occur within the source zone, but account is made for radioactive transformation. The radioactive material is not assumed contained. The subject scenario does not include a cover of clean soil over the contaminated area. Release of radionuclides by water is assumed to be a function of a constant infiltration rate, time-varying contaminant zone thickness, constant moisture content, and equilibrium adsorption. The contaminant zone is assumed to decrease over time from a constant erosion rate. Particulates are assumed instantaneously and uniformly released into the air as a function of the concentration of particulates in the air, based on a constant mass loading rate.

The RESRAD conceptual groundwater model includes two horizontal homogenous strata for the unsaturated zone. Transport in the unsaturated zone is assumed to result from steady-state, constant vertical flow, with equilibrium adsorption, and decay, but no dispersion. RESRAD, for the subject case, models radionuclides in the saturated zone by a nondispersion approach. In the nondispersion approach, transport in the saturated zone is assumed to occur

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[7] 10 CFR 40, Appendix A, Criterion 6 (6)

[8] Yu, C., et. al., 1993. *Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD 5.0, Working Draft for Comment,* ANL/EAD/LD-2, Argonne National Laboratory, September 1993.

[9] NUREG-1727, Appendix C, Section 5.3.2.1.2

in a single homogenous stratum, under steady-state, unidirectional flow, with constant velocity, equilibrium adsorption, and radioactive transformation. The nondispersion model is the RESRAD default based on the size of the contaminated area.

The generic conceptual model of the surface water pathway in RESRAD assumes that radionuclides are uniformly distributed in a finite volume of water within a watershed. Radionuclides are assumed to enter the watershed at the same time and concentration as in the groundwater. Accordingly, no additional attenuation is considered as radionuclides are transported to the watershed. Radionuclides are assumed diluted as a function of the size of the contaminated area in relation to the size of the watershed. The model assumes that all radionuclides reaching the surface water are derived from the groundwater pathway. Thus transport of radionuclides overland from runoff is not considered. As well, additional dilution from overland runoff is not considered.

The generic conceptual model of the air pathway in RESRAD uses a constant mass loading factor and area factor to model radionuclide transport. The area factor, which is used to estimate the amount of dilution, relates the concentration of radionuclides from a finite area source to the concentration of radionuclides from an infinite area source. It is calculated as a function of particle diameter, wind speed, and the side length of a square area source. The model assumes a fixed particle density, constant annual rainfall rate, and constant atmospheric stability. No radioactive decay is considered.

Calculations and Input Parameters

Inputs are provided for parameters of the source term configuration and exposure pathways described previously. Site-specific values were used for parameters when available. Otherwise the parameter value was assigned a default value or a value based on professional judgment.

For the source term, the inputs include site-specific values or estimates of contaminated area, thickness, density, porosity, hydraulic conductivity, hydraulic gradient, and distribution coefficient.

Particulars of the input parameters include: the resident farmer spends 25% of the time indoors on site, 50% of the time outdoors on site, and 25% of the time away from the site. Food production is assumed to occur in the contaminated area: 50% of the resident's vegetable, grain, and fruit diet assumed produced from the garden; 50% of the resident's milk and meat diet is assumed produced on site. Dust levels represent tilling, planting, harvesting, and other activities that may increase suspension of soil particles in air.

Vegetables, fruits, and grains are irrigated from overhead with water drawn from a pond at the site boundary, immediately downgradient of the contaminated area. The same water is also used for watering livestock on site. Fifty percent of the resident's aquatic food diet is assumed taken from the pond. The resident's drinking water is assumed from an uncontaminated municipal potable water system or uncontaminated surface water.

The walls, foundation, and floor of the resident's house reduce external exposure by 21%. Indoor dust level in air is assumed to be 56% of the outdoor dust level.

The parameters, associated inputs, and rationale for value, are included in Table G-2.

Attachment 1 provides specific description of the rationale for the value of each parameter. Attachment 2 describes the selection of thicknesses for the contaminated zone and the unsaturated uncontaminated zone.

Compliance with Regulatory Criteria

The exposure scenario and associated inputs and model described above were applied to a soil concentration of 5 pCi/g Ra-226 with 5 pCi/g Pb-210.[10] The resulting dose, i.e. the benchmark dose, to the resident farmer was 54 millirem per year (mrem/y). The radionuclide concentrations in soil for U-natural and Th-230 that result in 54 mrem/y for the same exposure scenario are 540 pCi/g and 64 pCi/g, respectively. The DCGLs are listed in Table G-3.

In areas where thorium and radium are not present, the uranium DCGL will be used. In areas where thorium and radium are present, the DCGLs will be considered in combination to ensure that the applicable dose limit is met; i.e. the sum of ratios of radionuclide concentration to respective DCGL will not exceed one.

The results of the dose assessments determining the DGCLs are provided in this appendix as a copy of the RESRAD output.

Sensitivity Analysis

The results of the sensitivity analysis of the resident farmer scenario are presented in Appendix G and summarized here. The summary is confined to those parameters of the Ra-226 benchmark dose analysis for which a reasonable change in input caused the dose to be less than the benchmark dose of 54 mrem/y by more than 25%; i.e. the dose was less than 43 mrem/y.

The annual dose for radium-226 was found to be significantly sensitive to two parameters: thickness of contaminated zone and depth of roots. Radium-226 is present on site at only a few small areas. The model inputs for area of contaminated zone and thickness of contaminated zone are extremely conservative with respect to actual conditions. In other words, the model grossly overestimates the potential contribution (availability) of Ra-226 to annual dose. Also, the areas where Ra-226 is present will be several feet underground upon completion of reclamation thereby eliminating most or all of the exposure pathways. No adjustment to the scenario is warranted with respect to these parameters.

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[10] NUREG-1620, Appendix H, Section H2.1.3, (2), (b)

DETERMINATION OF ANNUAL DOSE FROM DRAINAGE 005

Introduction

Drainage 005 (the storm water drainage below outfall 005) is contaminated with natural uranium, thorium 230, and radium 226. The concentrations of these radionuclides in the drainage exceed the DCGLs. The contamination is described in the Site Characterization Report.[11]

The Reclamation Plan does not include remediation of Drainage 005. A dose assessment, described below, has been completed demonstrating that the contribution to total annual dose is insignificant. The dose assessment is centered on the resident farmer scenario used to establish the DCGLs.

Source Term

Configuration

The CoCs applicable to Drainage 005 are the same as evaluated for the development of the site-specific DCGLs: natural uranium and associated transformation products, thorium 230, and radium 226.

The source term is assumed to be uncovered contaminated soil of rectangular shape; i.e. length and width of drainage. Specifically, the contaminated zone is modeled as 403 meters long and 1 meter wide. The thickness of the contaminated zone, based on informal empirical information, is modeled as 0.1 meter. Figure G-3 depicts the soil zones.

Residual Radioactivity

The CoCs are assumed homogenously distributed within the contaminated soil at average concentrations derived from the Site Characterization Report. Only the surface sediments are assumed contaminated.

Chemical Form

The discussion of chemical form provided for the development of the site-specific DCGLs is applicable to this scenario.

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[11] Sequoyah Fuels Corporation, *Site Characterization Report*, Table 7, "Unit 34", December 15, 1998.

Critical Group, Scenario, and Pathways Identification and Selection

Scenario Identification

The exposure scenario assumed here is based on the resident farmer scenario used to derive the site-specific DCGLs. However, it accounts only for the resident farmer's interaction with Drainage 005. The scenario is based on prudently conservative assumptions that tend to overestimate potential dose.

Critical Group Determination

The average member of the critical group is the resident farmer. This individual is assumed to be an adult with common habits and characteristics. This individual is reasonably expected to receive the greatest exposure to residual radioactivity for the applicable exposure scenario.

Exposure Pathways

The Drainage 005 scenario accounts for exposure involving residual radioactivity that is in the surface sediments of the drainage. The resident farmer enters the drainage and performs light-duty activities. The primary exposure pathways include:

- External exposure from soil;
- Inhalation of suspended soil; and
- Ingestion of soil.

The radon pathway is not considered because it is not within the scope of the technical criteria.[12]

The exposure pathways selected are listed in Table G-4.

Conceptual Model

The conceptual model used to evaluate the subject exposure scenario and pathways was the RESRAD[13] computer code version 5.82. RESRAD was developed, in part, to calculate annual dose to a chronically exposed on-site individual for site-specific concentrations of

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[12] 10 CFR 40, Appendix A, Criterion 6 (6).

[13] Yu, C., et. al., 1993. *Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD 5.0, Working Draft for Comment,* ANL/EAD/LD-2, Argonne National Laboratory, September 1993.

RESidual RADioactive material in soil. The RESRAD code considers multiple environmental transport and exposure pathways.

Calculations and Input Parameters

Site-specific values were used for parameters when available. Otherwise the parameter value was assigned a default value or a value based on professional judgment.

In particular, the total exposure time is outdoors; the resident farmer is assumed to spend 1 hour per day each day of the year in the drainage. Other differences from the resident farmer scenario include no irrigation, no runoff, and a shallower depth of soil mixing layer. The other parameters are the same as for the resident farmer scenario.

The parameters (i.e. inputs to the conceptual model) describing the aforementioned source term and exposure pathways are listed in Table G-5. The table also describes each parameter's value and a rationale for the value.

Compliance with Regulatory Criteria

This dose assessment was performed to evaluate the specific contribution of the residual radioactivity in Drainage 005 to the total dose estimated for the resident farmer (i.e. the benchmark dose limit of 54 mrem per year). The result of the dose assessment for Drainage 005 to the resident farmer was 0.2 mrem per year. This value is an insignificant contribution to the total dose estimated for the resident farmer scenario; i.e. from application of the site specific DCGLs.

The results of the dose assessment are provided in this appendix as a copy of the RESRAD output.

Sensitivity Analysis

A sensitivity analysis was completed of the parameters used in the subject dose assessment. The sensitivity analysis was completed for the three COCs together. The results of the sensitivity analysis are summarized in Attachment Drainage-1.

The sensitivity analysis revealed the dose not sensitive to any parameter with respect to the difference between the annual dose (0.2 mrem/y) and the benchmark dose (54 mrem/y).

DETERMINATION OF ANNUAL DOSE TO THE INDUSTRIAL WORKER

Introduction

The decommissioning of the Facility includes provision for long-term control of the site. The control includes periodic groundwater monitoring, inspection, mowing, and general physical maintenance. These tasks will be performed by an individual (i.e. Industrial Worker) employed or contracted by the long-term custodian.

The applicable regulatory dose limit will be assumed that for a member of the general public, currently 100 mrem per year.[14] The dose assessment described in the following sections demonstrates that the annual dose to the industrial worker is substantially below this limit.

Source Term

Configuration

The configuration applicable to the industrial worker scenario is the same as evaluated for development of the site-specific DCGLs.

Residual Radioactivity

The source term is assumed to be uncovered contaminated soil of cylindrical shape. The CoCs are assumed homogenously distributed within the contaminated soil at concentrations equivalent to the DCGLs. As an element of conservatism, and for ease of assessment, the CoCs are assumed to all be present together at the respective DCGL. Figure G-4 depicts the soil zones.

Chemical Form

The chemical form applicable to the industrial worker scenario is the same as evaluated for development of the site-specific DCGLs.

Critical Group, Scenario, and Pathways Identification and Selection

Scenario Identification

The exposure scenario applied here may be described as representing an industrial worker. The industrial worker moves across the site performing the tasks described previously. The scenario is applicable only to the time the worker spends on site. The scenario is based on prudently conservative assumptions that tend to overestimate potential dose.

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[14] 10 CFR 20.1301(a)(1) and (b).

Critical Group Determination

The average member of the critical group is the industrial worker. This individual is assumed to be an adult male with common habits and characteristics. This individual is reasonably expected to receive the greatest exposure to residual radioactivity for the applicable scenario.

Exposure Pathways

The industrial worker scenario accounts for exposure involving residual radioactivity that is in the surface soil. The worker enters the area and performs light-duty activities. The primary exposure pathways include:

- External exposure from soil;
- Inhalation of suspended soil; and
- Ingestion of suspended soil.

The radon pathway is not considered because it is not within the scope of the technical criteria.[15]

The exposure pathways selected are listed in Table G-6.

Conceptual Model

The conceptual model used to evaluate the subject exposure scenario and pathways was the RESRAD[16] computer code version 5.82. RESRAD was developed, in part, to calculate annual dose to a chronically exposed on-site individual for site-specific concentrations of RESidual RADioactive material in soil. The RESRAD code considers multiple environmental transport and exposure pathways.

Calculations and Input Parameters

Site-specific values were used for parameters when available. Otherwise the parameter value was assigned a default value or a value based on professional judgment.

In particular, the contaminated zone physical and hydrological parameters are the same as for determination of the site-specific DCGLs. The inhalation rate and mass loading for inhalation are also the same as for the resident farmer. The total exposure time is 130 hours per year outdoors (32 hours well sampling and 96 hours mowing).

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[15] 10 CFR 40 Appendix A, Criterion 6 (6).

[16] Yu, C., et. al., 1993. *Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD 5.0, Working Draft for Comment*, ANL/EAD/LD-2, Argonne National Laboratory, September 1993.

The parameters (i.e. inputs to the conceptual model) describing the aforementioned source term and exposure pathways are listed in Table G-7. The table also describes each parameter's value and a rationale for the value.

Compliance with Regulatory Criteria

This dose assessment was performed to evaluate compliance with the dose limit for individual members of the public of 100 mrem in a year. The result of the dose assessment was about 2 mrem per year to the industrial worker. This value is far below the applicable regulatory dose limit.

The results of the dose assessment are provided in this appendix as a copy of the RESRAD output.

Sensitivity Analysis

A sensitivity analysis was completed of the parameters used in the subject dose assessment. The sensitivity analysis was completed for the three CoCs together. The results of the sensitivity analysis are summarized in Attachment Worker-1.

The sensitivity analysis revealed the dose not sensitive to any parameter with respect to the difference between the annual dose (2 mrem/y) and the annual dose limit (100 mrem/y).

TABLE G-1: RESIDENT FARMER SCENARIO EXPOSURE PATHWAY SELECTIONS

PATHWAY[1]	USER SELECTION
External Gamma	Active
Inhalation (w/o radon)	Active
Plant Ingestion	Active
Meat Ingestion	Active
Milk Ingestion	Active
Aquatic Foods	Active
Drinking Water	Suppressed
Soil Ingestion	Active
Radon	Suppressed

[1] These pathways match those available from the conceptual model used in the dose assessment; i.e. RESRAD version 5.82.

TABLE G-2: RESIDENT FARMER SCENARIO MODEL SFC SELECTED VALUES		
Parameter	**SFC Input**	**Background Information**
Source		
Nuclide concentration for U-238 (pCi/g)		To be determined for the "Basic radiation dose limit (mrem/yr)"; i.e. the Ra-226 benchmark dose.
Transport Distribution coefficients for U-238		
Contaminated zone (cm**3/g)	500	
Unsaturated zone 1 (cm**3/g)	500	
Saturated zone (cm**3/g)	33.575	
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[1]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for U-235 (pCi/g)		To be determined for the "Basic radiation dose limit (mrem/yr)"; i.e. the Ra-226 benchmark dose.
Transport Distribution coefficients for U-235		
Contaminated zone (cm**3/g)	500	
Unsaturated zone 1 (cm**3/g)	500	
Saturated zone (cm**3/g)	33.575	
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[1]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for Pa-231 (pCi/g)		To be determined for the "Basic radiation dose limit (mrem/yr)"; i.e. the Ra-226 benchmark dose.
Transport Distribution coefficients for daughter Pa-231		
Contaminated zone (cm**3/g)	380	Assigned by RESRAD guidance.[2]
Unsaturated zone 1 (cm**3/g)	380	Assigned by RESRAD guidance.[2]
Saturated zone (cm**3/g)	380	Assigned by RESRAD guidance.[2]
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[1]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for Ac-227 (pCi/g)		To be determined for the "Basic radiation dose limit (mrem/yr)"; i.e. the Ra-226 benchmark dose.

TABLE G-2: RESIDENT FARMER SCENARIO MODEL SFC SELECTED VALUES		
Parameter	**SFC Input**	**Background Information**
Transport Distribution coefficients for daughter Ac-227		
Contaminated zone (cm**3/g)	825	Assigned by RESRAD guidance.[2]
Unsaturated zone 1 (cm**3/g)	825	Assigned by RESRAD guidance.[2]
Saturated zone (cm**3/g)	825	Assigned by RESRAD guidance.[2]
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[1]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for U-234 (pCi/g)		To be determined for the "Basic radiation dose limit (mrem/yr)"; i.e. the Ra-226 benchmark dose.
Transport Distribution coefficients for U-234		
Contaminated zone (cm**3/g)	500	
Unsaturated zone 1 (cm**3/g)	500	
Saturated zone (cm**3/g)	33.575	
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[1]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for Th-230 (pCi/g)		To be determined for the "Basic radiation dose limit (mrem/yr)"; i.e. the Ra-226 benchmark dose.
Transport Distribution coefficients for Th-230		
Contaminated zone (cm**3/g)	5884	Assigned by RESRAD guidance.[2]
Unsaturated zone 1 (cm**3/g)	5884	Assigned by RESRAD guidance.[2]
Saturated zone (cm**3/g)	5884	Assigned by RESRAD guidance.[2]
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[1]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for Ra-226 (pCi/g)	5	10 CFR 40, Appendix A, Criterion 6 (6)
Transport Distribution coefficients for Ra-226		
Contaminated zone (cm**3/g)	3533	Assigned by RESRAD guidance.[2]
Unsaturated zone 1 (cm**3/g)	3533	Assigned by RESRAD guidance.[2]
Saturated zone (cm**3/g)	3533	Assigned by RESRAD guidance.[2]
Time since material placement (yr)	0	RESRAD default

TABLE G-2: RESIDENT FARMER SCENARIO MODEL SFC SELECTED VALUES		
Parameter	**SFC Input**	**Background Information**
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[1]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for Pb-210 (pCi/g)	5	NUREG-1620, Appendix H, Section H2.1.3, (2), (b)
Transport Distribution coefficients for Pb-210		
Contaminated zone (cm**3/g)	2392	Assigned by RESRAD guidance.[2]
Unsaturated zone 1 (cm**3/g)	2392	Assigned by RESRAD guidance.[2]
Saturated zone (cm**3/g)	2392	Assigned by RESRAD guidance.[2]
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[1]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Calculation Parameters		
Basic radiation dose limit (mrem/yr)	76	The Ra-226 benchmark dose.
Times for Calculations (years)	1	RESRAD default
Times for Calculations (years)	3	RESRAD default
Times for Calculations (years)	10	RESRAD default
Times for Calculations (years)	30	RESRAD default
Times for Calculations (years)	100	RESRAD default
Times for Calculations (years)	300	RESRAD default
Times for Calculations (years)	1000	RESRAD default
Contaminated Zone Parameters		
Area of contaminated zone (m**2)	263120	Site-specific estimate: see Attachment 2.
Thickness of contaminated zone (m)	0.3	Site-specific estimate: unconsolidated soils over shale; see Attachment 2.
Length parallel to aquifer flow (m)	662	Diameter of circle of 85 acre area
Cover and Contaminated Zone Hydrological Data		
Cover depth (m)	0	Planned actual conditions
Density of cover material (g/cm**3)	-	Not available; reflects absence of cover.[1]
Cover erosion rate (m/yr)	-	Not available; reflects absence of cover.[1]
Density of contaminated zone (g/cm**3)	1.76	
Contaminated zone erosion rate (m/yr)	0.0006	Recommendation from RESRAD guidance.[2]
Contaminated zone total porosity	0.40	Estimate from RESRAD guidance.[3]
Contaminated zone effective porosity	0.24	Estimate from RESRAD guidance.[3]
Contaminated zone hydraulic conductivity (m/yr)	8.9	

TABLE G-2: RESIDENT FARMER SCENARIO MODEL SFC SELECTED VALUES		
Parameter	**SFC Input**	**Background Information**
Contaminated zone b parameter	3	Recommendation from RESRAD guidance.[3]
Humidity in air (g/cm**3)		Not available; reflects absence of radon pathway.[1]
Evapotranspiration coefficient	0.5	Suggestion from RESRAD guidance.[2]
Wind Speed (m/sec)	4	Site-specific estimate.
Precipitation (m/yr)	1.1	Site-specific estimate.
Irrigation (m/yr)	0.6	Estimate from RESRAD guidance.[3]
Irrigation mode	overhead	Site specific observation (local practice).
Runoff coefficient	0.4	Estimate from RESRAD guidance.[2]
Watershed area for nearby stream or pond (m**2)	575000	Site-specific estimate.
Accuracy for water/soil computations	1.00E-03	RESRAD default
Saturated Zone Hydrological Data		
Density of saturated zone (g/cm**3)	2.69	
Saturated zone total porosity	0.1	Estimate from RESRAD guidance.[3]
Saturated zone effective porosity	0.1	
Saturated zone hydraulic conductivity (m/yr)	89	
Saturated zone hydraulic gradient	0.08	
Saturated zone b parameter	-	Not available; reflects *water table drop rate* equal zero[1]
Water table drop rate (m/yr)	0	Assume unconfined groundwater system
Well pump intake depth (m below water table)	0.00001	Lowest value allowed by RESRAD[1]; reflects absence of a well
(continued, 5 of 7)		
Model for Water Transport Parameters		
Nondispersion (ND) or Mass-Balance (MB)	ND	RESRAD default based on size of contaminated area.[1]
Well pumping rate (m**3/yr)	0	Reflects absence of a well (no groundwater usage).
Uncontaminated Unsaturated Zone Parameters		
Unsaturated Zones	1	Unconsolidated soils over shale.
Unsaturated Zone 1, Thickness (m)	1.4	Site-specific estimate: see Attachment 2.
Unsaturated Zone 1, Density (g/cm**3)	1.76	
Unsaturated Zone 1, Total Porosity	0.4	Estimate from RESRAD guidance[3].
Unsaturated Zone 1, Effective Porosity	0.24	
Unsaturated Zone 1, Hydraulic Conductivity (m/yr)	8.9	
Unsaturated Zone 1, b Parameter	3	Recommendation from RESRAD guidance.[3]

TABLE G-2: RESIDENT FARMER SCENARIO MODEL SFC SELECTED VALUES		
Parameter	**SFC Input**	**Background Information**
Occupancy, Inhalation, and External Gamma Data		
Inhalation rate (m**3/yr)	8400	Recommendation from RESRAD guidance.[2]
Mass loading for inhalation (g/m**3)	2.00E-04	Suggestion from RESRAD guidance.[3]
Exposure duration	1	Reflects applicable regulatory evaluation period.
Indoor dust filtration factor	0.56	Estimate from RESRAD guidance.[2]
External gamma shielding factor	0.21	Suggestion from RESRAD guidance.[2]
Indoor time fraction	0.25	Recommendation from NRC guidance.[4]
Outdoor time fraction	0.50	Recommendation from NRC guidance.[4]
Shape of the contaminated zone	circular	Assumed shape of *area of contaminated zone*.
Ingestion Pathway, Dietary Data		
Fruits, vegetables and grain consumption (kg/yr)	178	Suggestion from RESRAD guidance.[2]
Leafy vegetable consumption (kg/yr)	25	Estimate from RESRAD guidance.[2]
Milk consumption (L/yr)	101	Suggestion from RESRAD guidance.[2]
Meat and poultry consumption (kg/yr)	63	RESRAD default.
Fish consumption (kg/yr)	21	Suggestion from RESRAD guidance.[3]
Other seafood consumption	0	Not applicable
Soil ingestion (g/yr)	18.3	Suggestion from RESRAD guidance.[2]
Drinking water intake (L/yr)		Not available; reflects absence of drinking water pathway.[1]
Contaminated fraction Drinking water	-	Not available; reflects absence of drinking water pathway.[1]
Contaminated fraction Household water		Not available; reflects absence of radon pathway.[1]
Contaminated fraction Livestock water	1	Assume all from onsite pond
Contaminated fraction Irrigation water	1	Assume all from onsite pond
Contaminated fraction Aquatic food	0.5	Assume half from uncontaminated surface water system
Contaminated fraction Plant food	0.5	Assume half from uncontaminated source.
Contaminated fraction Meat	0.5	Assume half from uncontaminated source.
Contaminated fraction Milk	0.5	Assume half from uncontaminated source.
Ingestion Pathway, Nondietary Data		
Livestock fodder intake for meat (kg/day)	68	RESRAD default
Livestock fodder intake for milk (kg/day)	55	RESRAD default
Livestock water intake for meat (L/day)	50	RESRAD default

TABLE G-2: RESIDENT FARMER SCENARIO MODEL SFC SELECTED VALUES		
Parameter	**SFC Input**	**Background Information**
Livestock water intake for milk (L/day)	160	RESRAD default
Livestock soil intake (kg/day)	0.5	RESRAD default
Mass loading for foliar deposition (g/m**3)	1.00E-04	RESRAD default
Depth of soil mixing layer (m)	0.15	RESRAD default
Depth of roots (m)	0.9	RESRAD default
Groundwater Fractional Usage Drinking water	-	Not available; reflects absence of drinking water pathway.[1]
Groundwater fractional Usage Household water	-	Not available; reflects absence of radon pathway.[1]
Groundwater Fractional Usage Livestock water	0	Reflects the absence of groundwater usage; e.g. *well pumping rate* equal zero.
Groundwater Fractional Usage Irrigation water	0	Reflects the absence of groundwater usage; e.g. *well pumping rate* equal zero.
Plant Factors		
Wet weight crop yield for Non-Leafy (kg/m**2)	0.6	A State-specific value from RESRAD guidance.[2]
Wet weight crop yield for Leafy (kg/m**2)	1.5	RESRAD default
Wet weight crop yield for Fodder (kg/m**2)	1.1	RESRAD default
Length of growing season for Non-Leafy (years)	0.17	RESRAD default
Length of growing season for Leafy (years)	0.25	RESRAD default
Length of growing season for Fodder (years)	0.08	RESRAD default
Translocation factor for Non-Leafy	0.1	RESRAD default
Translocation factor for Leafy	1	RESRAD default
Translocation factor for Fodder	1	RESRAD default
Weathering removal constant for vegetation	18	Suggestion from RESRAD guidance.[2]
Wet foliar interception fraction for Non-Leafy	0.25	RESRAD default
Wet foliar interception fraction for leafy	0.67	Suggestion from RESRAD guidance.[2]
Wet foliar interception fraction for fodder	0.25	RESRAD default
Dry foliar interception fraction for Non-Leafy	0.25	RESRAD default
Dry foliar interception fraction for Leafy	0.25	RESRAD default

TABLE G-2: RESIDENT FARMER SCENARIO MODEL SFC SELECTED VALUES		
Parameter	**SFC Input**	**Background Information**
Dry foliar interception fraction for Fodder	0.25	RESRAD default

[1] Yu, C., et. al. "Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5.0: Working Draft for Comment." Argonne, IL: Argonne National Laboratory. ANL/EAD/LD-2. September 1993.

[2] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000.

[3] Yu, C., et.al. "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil." Argonne, IL: Argonne National Laboratory. ANL/EAIS-8. April 1993.

[4] U.S. Nuclear Regulatory Commission. Draft Standard Review Plan for the Review of a Reclamation Plan for Mill Tailings Sites Under Title II of the Uranium Mill Tailings Radiation Control Act (Draft Revision 1). Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG-1620. January 2000.

TABLE G-3: DERIVED CONCENTRATION GUIDELINE LEVELS (DCGLs)

Condition	U-natural (pCi/g)	Th-230 (pCi/g)	Ra-226 (pCi/g)
DCGL	540	64	5

TABLE G-4: DRAINAGE 005 SCENARIO EXPOSURE PATHWAY SELECTIONS

PATHWAY[1]	USER SELECTION
External Gamma	Active
Inhalation (w/o radon)	Active
Plant Ingestion	Suppressed
Meat Ingestion	Suppressed
Milk Ingestion	Suppressed
Aquatic Foods	Suppressed
Drinking Water	Suppressed
Soil Ingestion	Active
Radon	Suppressed

[1] These pathways match those available from the conceptual model used in the dose assessment; i.e. RESRAD version 5.82.

TABLE G-5: DRAINAGE 005 SCENARIO SFC SELECTED VALUES		
Parameter	**SFC Input**	**Background Information**
Source		
Nuclide concentration for U-238 (pCi/g)	45	Average from Table 7 of SCR.[1]
Transport Distribution coefficients for U-238		
Contaminated zone (cm**3/g)	500	
Unsaturated zone 1 (cm**3/g)	-	Not applicable
Saturated zone (cm**3/g)	33.575	
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[2]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for U-235 (pCi/g)	2	Average from Table7 of SCR.[1]
Transport Distribution coefficients for U-235		
Contaminated zone (cm**3/g)	500	
Unsaturated zone 1 (cm**3/g)	-	Not applicable
Saturated zone (cm**3/g)	33.575	
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[2]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for Pa-231 (pCi/g)		Determined by RESRAD
Transport Distribution coefficients for daughter Pa-231		
Contaminated zone (cm**3/g)	380	Assigned by RESRAD guidance.[3]
Unsaturated zone 1 (cm**3/g)	-	Not applicable
Saturated zone (cm**3/g)	380	Assigned by RESRAD guidance.[3]
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[2]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for Ac-227 (pCi/g)		Determined by RESRAD
Transport Distribution coefficients for daughter Ac-227		
Contaminated zone (cm**3/g)	825	Assigned by RESRAD guidance.[3]

TABLE G-5: DRAINAGE 005 SCENARIO SFC SELECTED VALUES		
Parameter	**SFC Input**	**Background Information**
Unsaturated zone 1 (cm**3/g)	-	Not applicable
Saturated zone (cm**3/g)	825	Assigned by RESRAD guidance.[3]
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[2]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for U-234 (pCi/g)	47	Average from Table 7 of SCR.[1]
Transport Distribution coefficients for U-234		
Contaminated zone (cm**3/g)	500	
Unsaturated zone 1 (cm**3/g)		Not applicable
Saturated zone (cm**3/g)	33.575	
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[2]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for Th-230 (pCi/g)	44	Average from Table 7 of SCR.[1]
Transport Distribution coefficients for Th-230	-	
Contaminated zone (cm**3/g)	5884	Assigned by RESRAD guidance.[3]
Unsaturated zone 1 (cm**3/g)	-	Not applicable
Saturated zone (cm**3/g)	5884	Assigned by RESRAD guidance.[3]
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[2]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for Ra-226 (pCi/g)	1.4	Average from Table 7 of SCR.[1]
Transport Distribution coefficients for Ra-226		
Contaminated zone (cm**3/g)	3533	Assigned by RESRAD guidance.[3]
Unsaturated zone 1 (cm**3/g)	-	Not applicable
Saturated zone (cm**3/g)	3533	Assigned by RESRAD guidance.[3]
Time since material placement (yr)	0	RESRAD default

TABLE G-5: DRAINAGE 005 SCENARIO SFC SELECTED VALUES		
Parameter	**SFC Input**	**Background Information**
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[2]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for Pb-210 (pCi/g)		Determined by RESRAD
Transport Distribution coefficients for Pb-210		
Contaminated zone (cm**3/g)	2392	Assigned by RESRAD guidance.[3]
Unsaturated zone 1 (cm**3/g)	-	Not applicable
Saturated zone (cm**3/g)	2392	Assigned by RESRAD guidance.[3]
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[2]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Calculation Parameters		
Basic radiation dose limit (mrem/yr)	100	10 CFR 20.1403(e)
Times for Calculations (years)	1	RESRAD default
Times for Calculations (years)	3	RESRAD default
Times for Calculations (years)	10	RESRAD default
Times for Calculations (years)	30	RESRAD default
Times for Calculations (years)	100	RESRAD default
Times for Calculations (years)	300	RESRAD default
Times for Calculations (years)	1000	RESRAD default
Contaminated Zone Parameters		
Area of contaminated zone (m**2)	540	L x W x r = 403m x 1m x RESRAD radii factor
Thickness of contaminated zone (m)	0.1	Typical depth of sediment
Length parallel to aquifer flow (m)	-	Not available
Cover and Contaminated Zone Hydrological Data		
Cover depth (m)	0	Planned actual conditions
Density of cover material (g/cm**3)	-	Not available; reflects absence of cover.[2]
Cover erosion rate (m/yr)	-	Not available; reflects absence of cover.[2]
Density of contaminated zone (g/cm**3)	1.76	
Contaminated zone erosion rate (m/yr)	0.001	RESRAD default
Contaminated zone total porosity	0.40	Estimate from RESRAD guidance.[4]
Contaminated zone effective porosity	0.24	Estimate from RESRAD guidance.[4]

TABLE G-5: DRAINAGE 005 SCENARIO SFC SELECTED VALUES		
Parameter	**SFC Input**	**Background Information**
Contaminated zone hydraulic conductivity (m/yr)	8.9	
Contaminated zone b parameter	-	Recommendation from RESRAD guidance.[4]
Humidity in air (g/cm**3)		Not available; reflects absence of radon pathway.[1]
Evapotranspiration coefficient	0.5	Suggestion from RESRAD guidance.[2]
Wind Speed (m/sec)	4	Site-specific estimate.
Precipitation (m/yr)	1.1	Site-specific estimate.
Irrigation (m/yr)	0	Not applicable
Irrigation mode	-	Not applicable
Runoff coefficient	0	Conservative assumption.
Watershed area for nearby stream or pond (m**2)	-	Not available
Accuracy for water/soil computations	-	Not available
Saturated Zone Hydrological Data		
Density of saturated zone (g/cm**3)	2.69	
Saturated zone total porosity	0.1	Estimate from RESRAD guidance.[4]
Saturated zone effective porosity	0.1	
Saturated zone hydraulic conductivity (m/yr)	89	
Saturated zone hydraulic gradient	0.08	
Saturated zone b parameter		Not available; reflects *water table drop rate* equal zero[1]
Water table drop rate (m/yr)	0	Assume unconfined groundwater system.
Well pump intake depth (m below water table)	0.00001	Lowest value allowed by RESRAD[1]; reflects absence of a well.
Model for Water Transport Parameters		
Nondispersion (ND) or Mass-Balance (MB)	ND	RESRAD default based on size of contaminated area.[1]
Well pumping rate (m**3/yr)	0	Reflects absence of a well (no groundwater usage).
Uncontaminated Unsaturated Zone Parameters		
Unsaturated Zones	0	Assume contaminated sediments on saturated shale.
Unsaturated Zone Thickness (m)	-	Not available
Unsaturated Zone Density (g/cm**3)	-	Not available
Unsaturated Zone Total Porosity	-	Not available
Unsaturated Zone Effective Porosity	-	Not available
Unsaturated Zone Hydraulic Conductivity (m/yr)	-	Not available
Unsaturated Zone b Parameter	-	Not available

TABLE G-5: DRAINAGE 005 SCENARIO SFC SELECTED VALUES		
Parameter	**SFC Input**	**Background Information**
Occupancy, Inhalation, and External Gamma Data		
Inhalation rate (m**3/yr)	8400	Recommendation from RESRAD guidance.[3]
Mass loading for inhalation (g/m**3)	2.00E-04	Suggestion from RESRAD guidance.[4]
Exposure duration	1	Reflects applicable regulatory evaluation period.
Indoor dust filtration factor	0	Not applicable
External gamma shielding factor	0	Not applicable
Indoor time fraction	0	Not applicable
Outdoor time fraction	0.042	1 h/d x 365 d/y x y/8760 h = 0.042
Shape of the contaminated zone	non-circular	Assume straight line 403 m x 1 m
Ingestion Pathway, Dietary Data		
Fruits, vegetables and grain consumption (kg/yr)	-	Not available due to suppressed pathways.[2]
Leafy vegetable consumption (kg/yr)	-	Not available due to suppressed pathways.[2]
Milk consumption (L/yr)	-	Not available due to suppressed pathways.[2]
Meat and poultry consumption (kg/yr)	-	Not available due to suppressed pathways.[2]
Fish consumption (kg/yr)	-	Not available due to suppressed pathways.[2]
Other seafood consumption	-	Not available due to suppressed pathways.[2]
Soil ingestion (g/yr)	18.3	Suggestion from RESRAD guidance.[3]
Drinking water intake (L/yr)	-	Not available due to suppressed pathways.[2]
Contaminated fraction Drinking water	-	Not available due to suppressed pathways.[2]
Contaminated fraction Household water	-	Not available due to suppressed pathways.[2]
Contaminated fraction Livestock water	-	Not available due to suppressed pathways.[2]
Contaminated fraction Irrigation water	-	Not available due to suppressed pathways.[2]
Contaminated fraction Aquatic food	-	Not available due to suppressed pathways.[2]
Contaminated fraction Plant food	-	Not available due to suppressed pathways.[2]
Contaminated fraction Meat	-	Not available due to suppressed pathways.[2]
Contaminated fraction Milk	-	Not available due to suppressed pathways.[2]
Ingestion Pathway, Nondietary Data		
Livestock fodder intake for meat (kg/day)	-	Not available due to suppressed pathways.[2]
Livestock fodder intake for milk (kg/day)	-	Not available due to suppressed pathways.[2]
Livestock water intake for meat (L/day)	-	Not available due to suppressed pathways.[2]
Livestock water intake for milk (L/day)	-	Not available due to suppressed pathways.[2]
Livestock soil intake (kg/day)	-	Not available due to suppressed pathways.[2]
Mass loading for foliar deposition (g/m**3)	-	Not available due to suppressed pathways.[2]

TABLE G-5: DRAINAGE 005 SCENARIO SFC SELECTED VALUES		
Parameter	**SFC Input**	**Background Information**
Depth of soil mixing layer (m)	0.1	Informal empirical determination of sediment depth.
Depth of roots (m)	-	Not available due to suppressed pathways.[2]
Groundwater Fractional Usage Drinking water	-	Not available due to suppressed pathways.[2]
Groundwater fractional Usage Household water	-	Not available due to suppressed pathways.[2]
Groundwater Fractional Usage Livestock water	-	Not available due to suppressed pathways.[2]
Groundwater Fractional Usage Irrigation water	-	Not available due to suppressed pathways.[2]
Plant Factors		
Wet weight crop yield for Non-Leafy (kg/m**2)	-	Not available due to suppressed pathways.[2]
Wet weight crop yield for Leafy (kg/m**2)	-	Not available due to suppressed pathways.[2]
Wet weight crop yield for Fodder (kg/m**2)	-	Not available due to suppressed pathways.[2]
Length of growing season for Non-Leafy (years)	-	Not available due to suppressed pathways.[2]
Length of growing season for Leafy (years)	-	Not available due to suppressed pathways.[2]
Length of growing season for Fodder (years)	-	Not available due to suppressed pathways.[2]
Translocation factor for Non-Leafy	-	Not available due to suppressed pathways.[2]
Translocation factor for Leafy	-	Not available due to suppressed pathways.[2]
Translocation factor for Fodder	-	Not available due to suppressed pathways.[2]
Weathering removal constant for vegetation	-	Not available due to suppressed pathways.[2]
Wet foliar interception fraction for Non-Leafy	-	Not available due to suppressed pathways.[2]
Wet foliar interception fraction for leafy	-	Not available due to suppressed pathways.[2]
Wet foliar interception fraction for fodder	-	Not available due to suppressed pathways.[2]
Dry foliar interception fraction for Non-Leafy	-	Not available due to suppressed pathways.[2]
Dry foliar interception fraction for Leafy	-	Not available due to suppressed pathways.[2]
Dry foliar interception fraction for Fodder	-	Not available due to suppressed pathways.[2]

[1] Sequoyah Fuels Corporation, "Site Characterization Report", December 15, 1998.

[2] Yu, C., et. al. "Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5.0: Working Draft for Comment." Argonne, IL: Argonne National Laboratory. ANL/EAD/LD-2. September 1993.

[3] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000.

[4] Yu, C., et.al. "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil." Argonne, IL: Argonne National Laboratory. ANL/EAIS-8. April 1993.

Table G-6: Industrial Worker Scenario Exposure Pathway Selections

PATHWAY[1]	USER SELECTION
External Gamma	Active
Inhalation (w/o radon)	Active
Plant Ingestion	Suppressed
Meat Ingestion	Suppressed
Milk Ingestion	Suppressed
Aquatic Foods	Suppressed
Drinking Water	Suppressed
Soil Ingestion	Active
Radon	Suppressed

[1] These pathways match those available from the conceptual model used in the dose assessment; i.e. RESRAD version 5.82.

Table G-7: Industrial Worker Scenario SFC Selected Values		
Parameter	**SFC Input**	**Background Information**
Source		
Nuclide concentration for U-238 (pCi/g)	264	DCGL for U-natural times 0.489.
Transport Distribution coefficients for U-238		
Contaminated zone (cm**3/g)	500	
Unsaturated zone 1 (cm**3/g)	500	
Saturated zone (cm**3/g)	33.575	
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[1]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for U-235 (pCi/g)	11.8	DCGL for U-natural times 0.022.
Transport Distribution coefficients for U-235		
Contaminated zone (cm**3/g)	500	
Unsaturated zone 1 (cm**3/g)	500	
Saturated zone (cm**3/g)	33.575	
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[1]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for Pa-231 (pCi/g)		Determined by RESRAD
Transport Distribution coefficients for daughter Pa-231		
Contaminated zone (cm**3/g)	380	Assigned by RESRAD guidance.[2]
Unsaturated zone 1 (cm**3/g)	380	Assigned by RESRAD guidance.[2]
Saturated zone (cm**3/g)	380	Assigned by RESRAD guidance.[2]
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[1]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for Ac-227 (pCi/g)		Determined by RESRAD
Transport Distribution coefficients for daughter Ac-227		
Contaminated zone (cm**3/g)	825	Assigned by RESRAD guidance.[2]

Table G-7: Industrial Worker Scenario SFC Selected Values		
Parameter	**SFC Input**	**Background Information**
Unsaturated zone 1 (cm**3/g)	825	Assigned by RESRAD guidance.[2]
Saturated zone (cm**3/g)	825	Assigned by RESRAD guidance.[2]
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[1]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for U-234 (pCi/g)	264	DCGL for U-natural times 0.489.
Transport Distribution coefficients for U-234		
Contaminated zone (cm**3/g)	500	
Unsaturated zone 1 (cm**3/g)	500	
Saturated zone (cm**3/g)	33.575	
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[1]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for Th-230 (pCi/g)	64	DCGL
Transport Distribution coefficients for Th-230		
Contaminated zone (cm**3/g)	5884	Assigned by RESRAD guidance.[2]
Unsaturated zone 1 (cm**3/g)	5884	Assigned by RESRAD guidance.[2]
Saturated zone (cm**3/g)	5884	Assigned by RESRAD guidance.[2]
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[1]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for Ra-226 (pCi/g)	5	DCGL
Transport Distribution coefficients for Ra-226		
Contaminated zone (cm**3/g)	3533	Assigned by RESRAD guidance.[2]
Unsaturated zone 1 (cm**3/g)	3533	Assigned by RESRAD guidance.[2]
Saturated zone (cm**3/g)	3533	Assigned by RESRAD guidance.[2]
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[1]

Table G-7: Industrial Worker Scenario SFC Selected Values		
Parameter	**SFC Input**	**Background Information**
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Nuclide concentration for Pb-210 (pCi/g)	5	DCGL
Transport Distribution coefficients for Pb-210		
Contaminated zone (cm**3/g)	2392	Assigned by RESRAD guidance.[2]
Unsaturated zone 1 (cm**3/g)	2392	Assigned by RESRAD guidance.[2]
Saturated zone (cm**3/g)	2392	Assigned by RESRAD guidance.[2]
Time since material placement (yr)	0	RESRAD default
Groundwater concentration (pCi/L)	-	Not available; reflects availability of distribution coeff.[1]
Solubility Limit (mol/L)	0	RESRAD default
Leach Rate (/yr)	0	RESRAD default
Calculation Parameters		
Basic radiation dose limit (mrem/yr)	100	10 CFR20.1301
Times for Calculations (years)	1	RESRAD default
Times for Calculations (years)	3	RESRAD default
Times for Calculations (years)	10	RESRAD default
Times for Calculations (years)	30	RESRAD default
Times for Calculations (years)	100	RESRAD default
Times for Calculations (years)	300	RESRAD default
Times for Calculations (years)	1000	RESRAD default
Contaminated Zone Parameters		
Area of contaminated zone (m**2)	263120	RESRAD default
Thickness of contaminated zone (m)	0.3	Site-specific estimate: unconsolidated soils over shale
Length parallel to aquifer flow (m)	-	Not available due to suppressed pathways.[1]
Cover and Contaminated Zone Hydrological Data		
Cover depth (m)	0	Planned actual conditions
Density of cover material (g/cm**3)	-	Not available; reflects absence of cover.[1]
Cover erosion rate (m/yr)	-	Not available; reflects absence of cover.[1]
Density of contaminated zone (g/cm**3)	1.76	

Table G-7: Industrial Worker Scenario SFC Selected Values

Parameter	SFC Input	Background Information
Contaminated zone erosion rate (m/yr)	0.0006	Recommendation from RESRAD guidance.[2]
Contaminated zone total porosity	0.40	Estimate from RESRAD guidance.[3]
Contaminated zone effective porosity	0.24	Estimate from RESRAD guidance.[3]
Contaminated zone hydraulic conductivity (m/yr)	8.9	
Contaminated zone b parameter	3	Recommendation from RESRAD guidance.[3]
Humidity in air (g/cm**3)		Not available; reflects absence of radon pathway.[1]
Evapotranspiration coefficient	0.5	Suggestion from RESRAD guidance.[2]
Wind Speed (m/sec)	4	Site-specific measurement (5.7 mph).
Precipitation (m/yr)	1.1	Site-specific measurement (49 inch/y).
Irrigation (m/yr)	0	Not applicable
Irrigation mode	-	Not applicable
Runoff coefficient	0.4	Estimate from RESRAD guidance.[2]
Watershed area for nearby stream or pond (m**2)	-	Not available due to suppressed pathways.[1]
Accuracy for water/soil computations	-	Not available due to suppressed pathways.[1]
Saturated Zone Hydrological Data		
Density of saturated zone (g/cm**3)	2.69	
Saturated zone total porosity	0.1	Estimate from RESRAD guidance.[3]
Saturated zone effective porosity	0.1	
Saturated zone hydraulic conductivity (m/yr)	89	
Saturated zone hydraulic gradient	0.08	
Saturated zone b parameter	-	Not available; reflects *water table drop rate* equal zero[1]
Water table drop rate (m/yr)	0	Assume unconfined groundwater system
Well pump intake depth (m below water table)	0.00001	Lowest value allowed by RESRAD[1]; reflects absence of a well
Model for Water Transport Parameters		
Nondispersion (ND) or Mass-Balance (MB)	ND	RESRAD default based on size of contaminated area.[1]
Well pumping rate (m**3/yr)	0	Reflects absence of a well (no groundwater usage).
Uncontaminated Unsaturated Zone Parameters		
Unsaturated Zones	-	Not available due to suppressed pathways.[1]
Unsaturated Zone 1 Thickness (m)	-	Not available due to suppressed pathways.[1]
Unsaturated Zone 1 Density (g/cm**3)	-	Not available due to suppressed pathways.[1]
Unsaturated Zone 1 Total Porosity	-	Not available due to suppressed pathways.[1]
Unsaturated Zone 1 Effective Porosity	-	Not available due to suppressed pathways.[1]

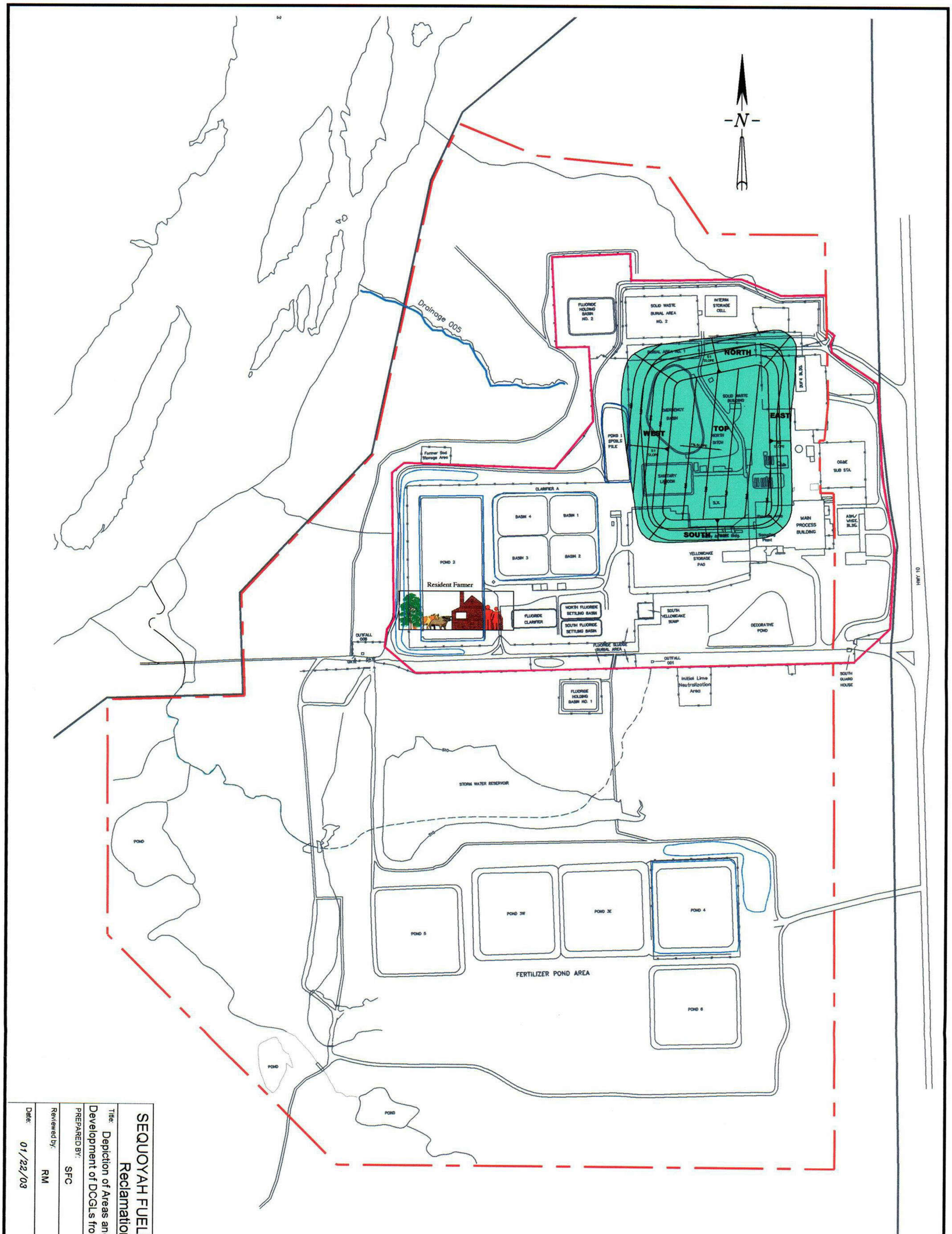
Table G-7: Industrial Worker Scenario SFC Selected Values		
Parameter	**SFC Input**	**Background Information**
Unsaturated Zone 1 Hydraulic Conductivity (m/yr)	-	Not available due to suppressed pathways.[1]
Unsaturated Zone 1 b Parameter	-	Not available due to suppressed pathways.[1]
Occupancy, Inhalation, and External Gamma Data		
Inhalation rate (m**3/yr)	8400	Recommendation from RESRAD guidance.[2]
Mass loading for inhalation (g/m**3)	2.00E-04	Suggestion from RESRAD guidance.[3]
Exposure duration	1	Reflects applicable regulatory evaluation period.
Indoor dust filtration factor	0	Not applicable; all maintenance work outdoors
External gamma shielding factor	0	Not applicable; all maintenance work outdoors
Indoor time fraction	0	Not applicable; all maintenance work outdoors
Outdoor time fraction	0.015	130 hours worked/y x y/8760 hours = 0.015
Shape of the contaminated zone	circular	Assumed shape of *area of contaminated zone*.
Ingestion Pathway, Dietary Data		
Fruits, vegetables and grain consumption (kg/yr)	-	Not available due to suppressed pathways.[1]
Leafy vegetable consumption (kg/yr)	-	Not available due to suppressed pathways.[1]
Milk consumption (L/yr)	-	Not available due to suppressed pathways.[1]
Meat and poultry consumption (kg/yr)	-	Not available due to suppressed pathways.[1]
Fish consumption (kg/yr)	-	Not available due to suppressed pathways.[1]
Other seafood consumption	-	Not available due to suppressed pathways.[1]
Soil ingestion (g/yr)	18.3	Suggestion from RESRAD guidance.[2]
Drinking water intake (L/yr)	-	Not available due to suppressed pathways.[1]
Contaminated fraction Drinking water	-	Not available due to suppressed pathways.[1]
Contaminated fraction Household water	-	Not available due to suppressed pathways.[1]
Contaminated fraction Livestock water	-	Not available due to suppressed pathways.[1]
Contaminated fraction Irrigation water	-	Not available due to suppressed pathways.[1]
Contaminated fraction Aquatic food	-	Not available due to suppressed pathways.[1]
Contaminated fraction Plant food	-	Not available due to suppressed pathways.[1]
Contaminated fraction Meat	-	Not available due to suppressed pathways.[1]
Contaminated fraction Milk	-	Not available due to suppressed pathways.[1]
Ingestion Pathway, Nondietary Data		
Livestock fodder intake for meat (kg/day)	-	Not available due to suppressed pathways.[1]
Livestock fodder intake for milk (kg/day)	-	Not available due to suppressed pathways.[1]
Livestock water intake for meat (L/day)	-	Not available due to suppressed pathways.[1]
Livestock water intake for milk (L/day)	-	Not available due to suppressed pathways.[1]
Livestock soil intake (kg/day)	-	Not available due to suppressed pathways.[1]

Table G-7: Industrial Worker Scenario SFC Selected Values		
Parameter	**SFC Input**	**Background Information**
Mass loading for foliar deposition (g/m**3)	-	Not available due to suppressed pathways.[1]
Depth of soil mixing layer (m)	0.15	RESRAD default
Depth of roots (m)	-	Not available due to suppressed pathways.[1]
Groundwater Fractional Usage Drinking water	-	Not available due to suppressed pathways.[1]
Groundwater fractional Usage Household water	-	Not available due to suppressed pathways.[1]
Groundwater Fractional Usage Livestock water	-	Not available due to suppressed pathways.[1]
Groundwater Fractional Usage Irrigation water	-	Not available due to suppressed pathways.[1]
Plant Factors	-	Not available due to suppressed pathways.[1]
Wet weight crop yield for Non-Leafy (kg/m**2)	-	Not available due to suppressed pathways.[1]
Wet weight crop yield for Leafy (kg/m**2)	-	Not available due to suppressed pathways.[1]
Wet weight crop yield for Fodder (kg/m**2)	-	Not available due to suppressed pathways.[1]
Length of growing season for Non-Leafy (years)	-	Not available due to suppressed pathways.[1]
Length of growing season for Leafy (years)	-	Not available due to suppressed pathways.[1]
Length of growing season for Fodder (years)	-	Not available due to suppressed pathways.[1]
Translocation factor for Non-Leafy	-	Not available due to suppressed pathways.[1]
Translocation factor for Leafy	-	Not available due to suppressed pathways.[1]
Translocation factor for Fodder	-	Not available due to suppressed pathways.[1]
Weathering removal constant for vegetation	-	Not available due to suppressed pathways.[1]
Wet foliar interception fraction for Non-Leafy	-	Not available due to suppressed pathways.[1]
Wet foliar interception fraction for leafy	-	Not available due to suppressed pathways.[1]
Wet foliar interception fraction for fodder	-	Not available due to suppressed pathways.[1]
Dry foliar interception fraction for Non-Leafy	-	Not available due to suppressed pathways.[1]
Dry foliar interception fraction for Leafy	-	Not available due to suppressed pathways.[1]
Dry foliar interception fraction for Fodder	-	Not available due to suppressed pathways.[1]

[1] Yu, C., et. al. "Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5.0: Working Draft for Comment." Argonne, IL: Argonne National Laboratory. ANL/EAD/LD-2. September 1993.

[2] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000.

[3] Yu, C., et.al. "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil." Argonne, IL: Argonne National Laboratory. ANL/EAIS-8. April 1993.



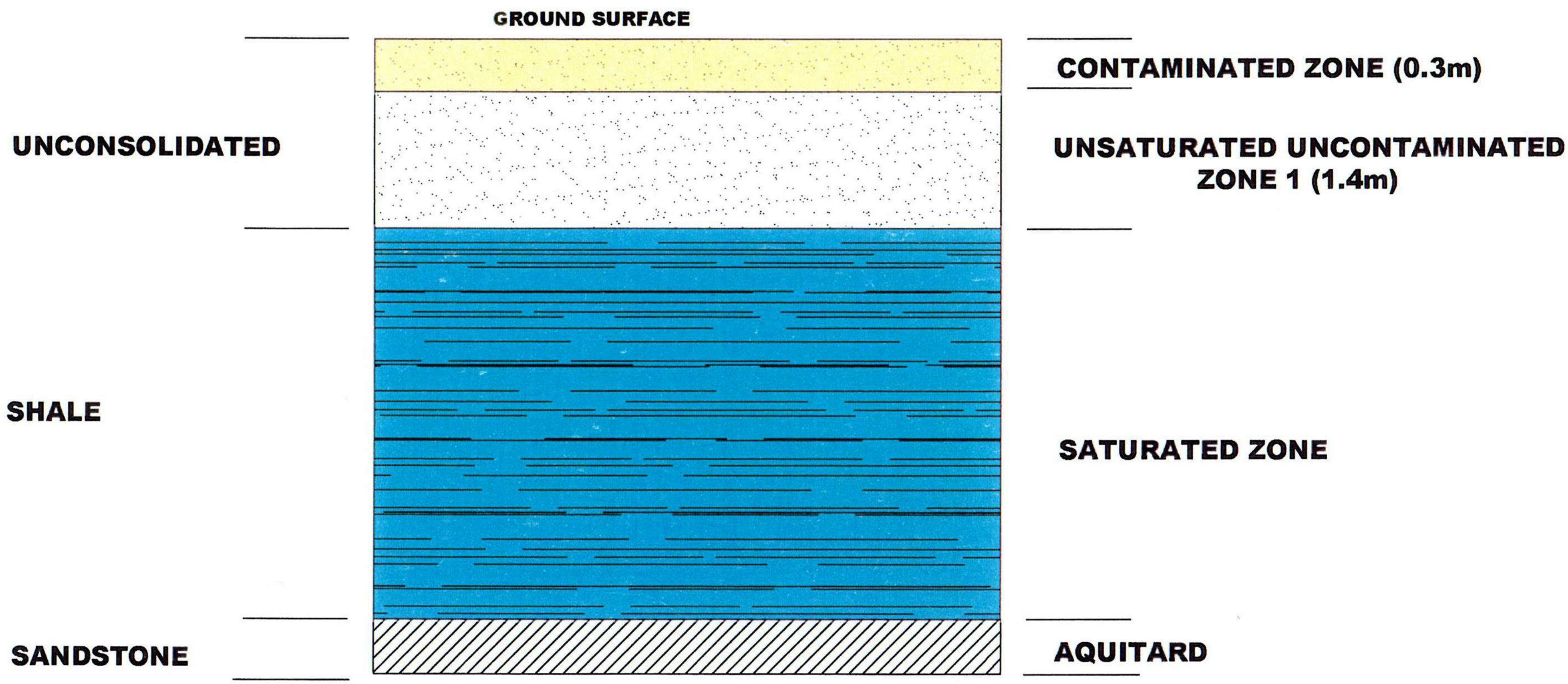
SEQUOYAH FUELS CORPORATION
Reclamation Plan

Title: Depiction of Areas and Boundaries Used for Development of DGLs from Resident Farmer Scenario

PREPARED BY:	SFC	Filename: SFC0084C
Reviewed by:	RM	Figure No. G-1
Date:	01/22/03	

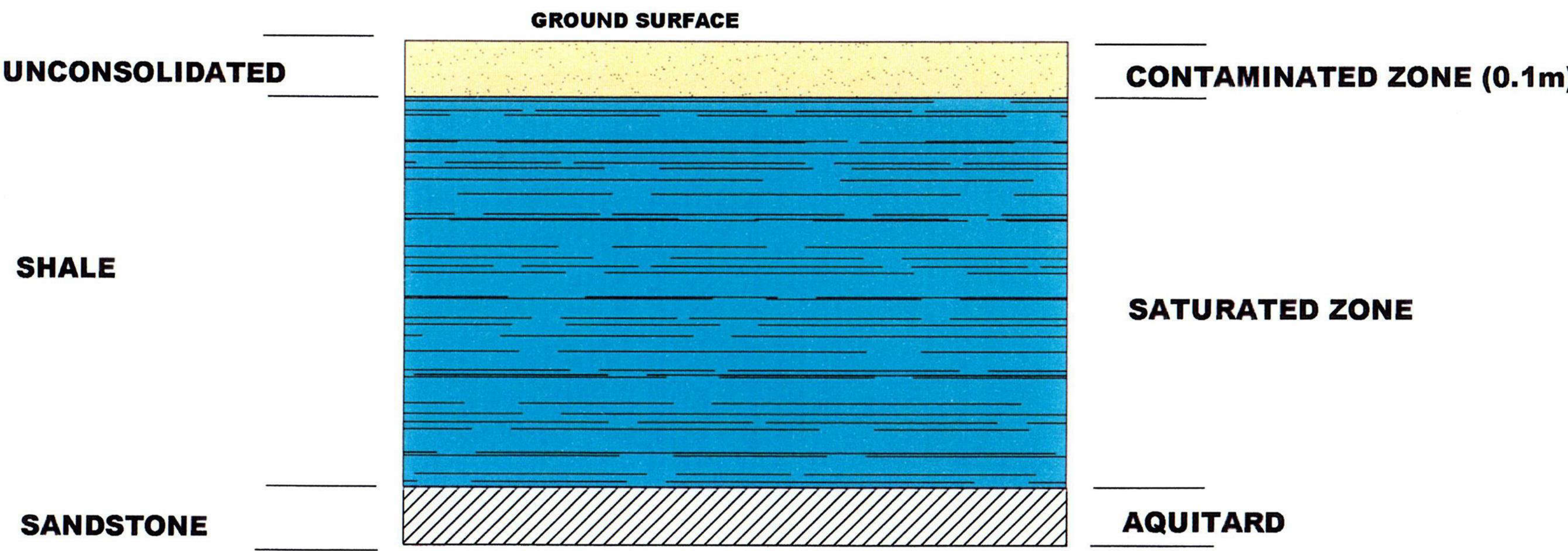
Institutional Control Boundary
Process Area Boundary
Th/Ra Area

C01



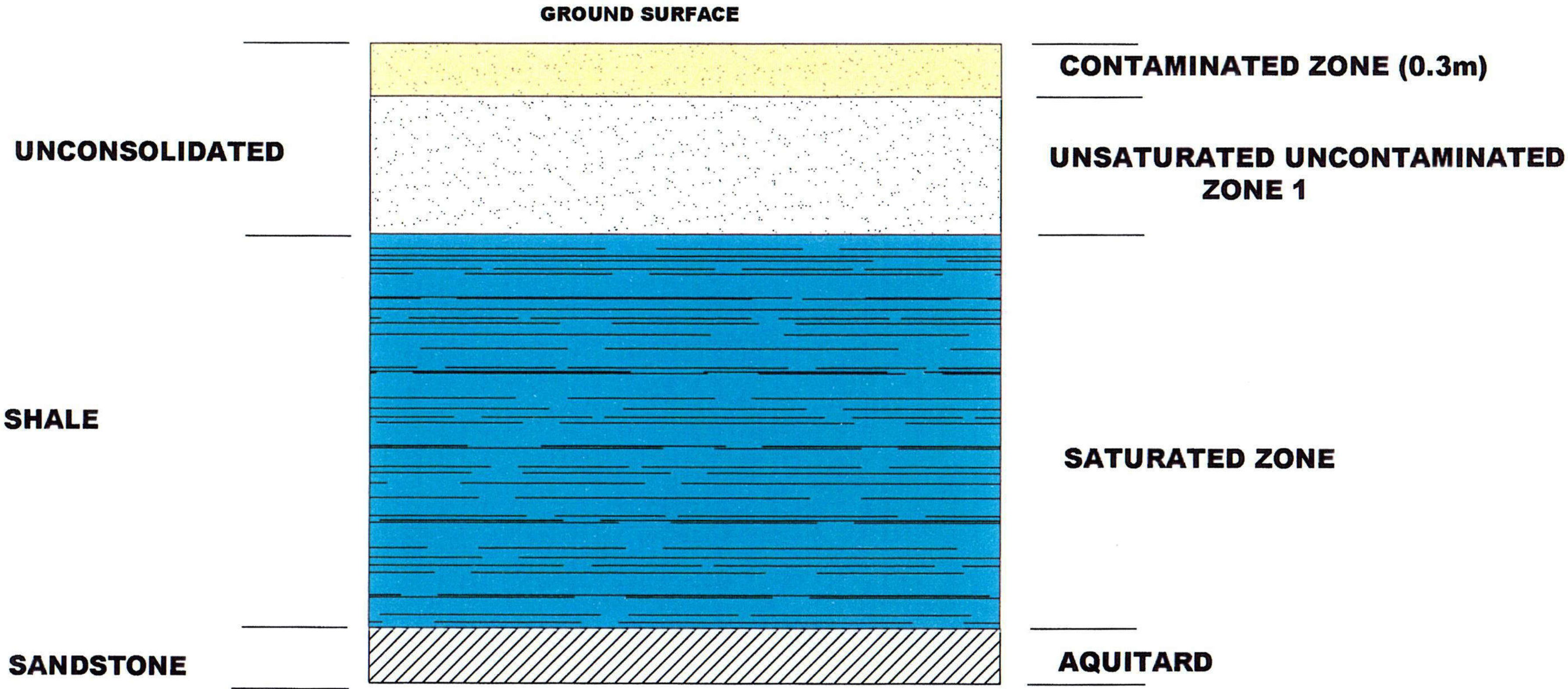
SEQUOYAH FUELS CORPORATION Reclamation Plan	
Title: Depiction of Soil Zones Used for Development of DCGLs from the Resident Farmer Scenario	
PREPARED BY: SFC	Filename: SFC0068B1
Reviewed by: RM	Figure No. G-2
Date: 01/22/03	

C01A



SEQUOYAH FUELS CORPORATION Reclamation Plan	
Title: Depiction of Soil Zones Used for Determination of Annual Dose from the Drainage 005 Senario	
PREPARED BY: SFC	Filename: SFC0068C1
Reviewed by: RM	Figure No. G-3
Date: 01/22/03	

202



SEQUOYAH FUELS CORPORATION Reclamation Plan	
Title: Depiction of Soil Zones Used for Determination of Annual Dose from the Industrial Worker Senario	
PREPARED BY: SFC	Filename: SFC0068D1
Reviewed by: RM	Figure No. G-4
Date: 01/22/03	

C03

Attachment 1

Justification of Parameter Values for Development of DCGLs

Resident Farmer Scenario

JUSTIFICATION OF PARAMETER VALUES FOR DEVELOPMENT OF DCGLs

Resident Farmer Scenario

Introduction

The following text provides the justification for the value chosen for each RESRAD parameter that required an input for development of the derived concentration guideline levels under the resident farmer scenario. The order and identification of headings, subheadings, and parameter names are aligned with the input screens of the RESRAD code.

Source

Transport Distribution Coefficients (cm^3/g)

The distribution coefficient describes the portioning of elements or compounds (radioactive material) in a soil column between the solid (soil) and liquid (groundwater). It is a key parameter influencing the migration of radioactive material from the surface soil to groundwater. Distribution coefficients for a given radioactive material (e.g. uranium) can vary over several orders of magnitude depending on soil type, pH, oxidation/reduction potential, and presence of other ions. Distribution coefficient is not a function of isotope (i.e. mass or specific activity) therefore a distribution coefficient was determined only with respect to the element.

Uranium

SFC sampled the soils at the Facility to determine site-specific values of the distribution coefficient. Samples were collected for each of the soil and shale zones at the Facility. A distribution coefficient was not determined for any sandstone zone since the sandstone effectively acts as an aquitard.

The values for distribution coefficient of uranium available for use in the dose assessment are those site-specific values provided in the following table[1].

Geologic Zone	Uranium distribution coefficient, cm^3/g
Unconsolidated soils	500
Unit 1 shale	33.575
Unit 2 shale	163
Unit 3 shale	37.5
Unit 4 shale	84.4

[1] Provided by Shepard-Miller, Inc., 2002, as part of ongoing hydrogeological and geochemical site characterization, unpublished at this printing.

The value used in the dose assessment for the distribution coefficient of uranium is 500 cm^3/g for the contaminated zone and for the unsaturated uncontaminated zone.

The value used in the dose assessment for the distribution coefficient of uranium is 33.575 cm^3/g for saturated zone. This application is conservative since it is the lowest of the distribution coefficients of the shale zones.

Protactinium

A site-specific distribution coefficient was not determined for protactinium. The value used in the dose assessment is a mean value assigned as an input for RESRAD[2].

The value used in the dose assessment for the distribution coefficient of protactinium is 380 cm^3/g for all soil zones.

Actinium

A site-specific distribution coefficient was not determined for actinium. The value used in the dose assessment is a mean value assigned as an input for RESRAD[2].

The value used in the dose assessment for the distribution coefficient of actinium is 825 cm^3/g for all soil zones.

Thorium

A site-specific distribution coefficient was not determined for thorium. The value used in the dose assessment model is a mean value assigned as an input for RESRAD[2].

The value used in the dose assessment for the distribution coefficient of thorium is 5884 cm^3/g for all soil zones.

Radium

A site-specific distribution coefficient was not determined for radium. The value used in the dose assessment is a mean value assigned as an input for RESRAD[2].

The value used in the dose assessment for the distribution coefficient of radium is 3533 cm^3/g for all soil zones.

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[2] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C, Table 3.9-1)

Lead

A site-specific distribution coefficient was not determined for lead. The value used in the dose assessment is a mean value assigned as an input for RESRAD[2].

The value used in the dose assessment for the distribution coefficient of lead is 2392 cm^3/g for all soil zones.

<u>Time since material placement (y)</u>

This parameter describes the duration between the placement of radioactive material in soil (contamination) and the performance of a radiological survey. It is assumed that all radioactive material in soil at the Facility is "placed" there at the same time; i.e. at the end of decommissioning and as a single source. Also, this value is not applicable when transport distribution coefficients are available[3] as they are in this case. This parameter is independent of the source of contamination in soil and therefore is determined without regard for chemical element or soil zone.

The value used in the dose assessment for elapsed time since placement of contamination is the RESRAD default of zero years for all soil zones.

<u>Groundwater concentration (pCi/L)</u>

This parameter is a measure of the concentration of the principal radionuclide in a well located at the downgradient edge of the contaminated zone. Input values are required only if the value of the parameter *time since material placement* is greater than zero. In such a case, this input is used to calculate transport distribution coefficients. This parameter is not available in this case since transport distribution coefficients are provided and time since material placement is zero.

The groundwater concentration of radionuclides is not used in the dose assessment.

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[3] Yu, C., et.al. "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil." Argonne, IL: Argonne National Laboratory. ANL/EAIS-8. April 1993. (Section 49.1)

Solubility Limit (mol/L)

The solubility equilibrium concentration is the reference saturated solubility of the radionuclide in soil. A non-zero input prompts calculation of a modified distribution coefficient based on the input. This parameter is not applicable in the case that a transport distribution coefficient is input to the model[4].

The value used in the dose assessment for solubility limit is the RESRAD default of zero mol/L for all soil zones.

Leach Rate (/y)

The leach rate is the fraction of the available radionuclide leached out from the contaminated zone per unit of time. No site-specific information is available for this parameter. In this case, an input value of zero invokes the calculation of the value for this parameter and uses the calculated value with the transport distribution coefficient provided previously.

The input for the dose assessment for leach rate is the RESRAD default of zero /y for all soil zones.

Calculation Parameters

Basic radiation dose limit (mrem/y)

The basic radiation dose limit is the effective dose equivalent from external radiation plus the committed effective dose equivalent from internal radiation. The radiation dose limit is used to derive the cleanup criteria (i.e. the derived concentration guideline levels, DCGLs). The applicable value is from Title 10 Code of Federal Regulations, Part 20, Section 1403(e).

The value used in the dose assessment for the basic radiation dose limit is 100 mrem/y.

Times for calculations (years)

These are the times in years following the radiological survey for which tabular values for single-radionuclide soil guidelines will be obtained.

The values used in the dose assessment for calculation times are the RESRAD defaults.

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[4] Yu, C., et.al. "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil." Argonne, IL: Argonne National Laboratory. ANL/EAIS-8. April 1993. (Section 32.3)

Contaminated Zone Parameters

Area of contaminated zone (m^2)

This is the size of the contaminated area at the site. It reflects the size of the area that contains the locations with radionuclide concentrations in soil clearly above background. The area is defined as the difference between the area of the current protected area (Process Area) (about 85 acres) and the area of the footprint of the proposed disposal cell (about 20 acres). The footprint of the disposal cell was subtracted to reflect the condition that the disposal cell, in the context of use of the RESRAD code, will not contribute to the source term in the soil; i.e. this area will not be subject to rainfall, wind erosion, plant uptake, etc. since the area is covered by the disposal cell. As well, the footprint of the cell will not be available for habitation.

The value used in the dose assessment for the area of the contaminated zone is 263,120 m^2 (65 acres).

Thickness of contaminated zone

This value is the distance between the uppermost and lowermost soil samples in the *area of contaminated zone* that have radionuclide concentrations clearly above background. The thickness was selected with respect to concentrations of total uranium in soil greater than an approximate background concentration. The value selected for this parameter represents an average thickness of the contaminated soil layer that currently exists in the *area of contaminated zone*. The selection of the subject thickness is described in Attachment 2.

The value used in the dose assessment for the thickness of the contaminated zone is 0.3 meters (1 foot) for the unconsolidated surface soils.

Length parallel to aquifer flow (m)

This parameter describes the maximum horizontal distance measured in the contaminated zone, from its upgradient edge to the downgradient edge, along the direction of the groundwater flow in the underlying water bearing formation.

The length chosen here is equal to the diameter of a circle of 85 acres. The 85 acre area is the size of the current protected area (Process Area). It is intended to represent the total surface area that bounds the *area of contaminated zone*. It is intended to represent the condition that there will be a large area of contaminated surface soil upgradient of the modeled area and therefore may lead to insignificant dilution from uncontaminated groundwater flowing into the contaminated zone.

The value used in the dose assessment for the length of the contaminated zone parallel to the aquifer flow is 662 m.

Cover and Contaminated Zone Hydrological Data

Cover depth (m)

This parameter describes the distance from ground surface to the top of the contaminated soil. In some areas at the Facility, the contaminated soil will not be covered with clean soil after remediation; i.e. no cover.

The value used in the dose assessment for the depth of cover is zero m.

Density of cover material (g/cm^3)

This value describes the dry (bulk) density of the cover material. This parameter is not applicable since *cover depth* is zero meters.

The density of the cover material is not used in the dose assessment.

Cover erosion rate (m/y)

This value represents the average depth of soil that is removed from the ground surface per year due to weather conditions (e.g. running water, wind). This parameter is not applicable since *cover depth* is zero meters.

The erosion rate of the cover is not used in the dose assessment.

Density of contaminated zone (g/cm^3)

This value describes the dry (bulk) density of the contaminated soils. The value for this parameter is site-specific for the unconsolidated surface soils[5].

The value used in the dose assessment for density of the contaminated zone is 1.76 g/cm^3.

[5] Provided by Shepard-Miller, Inc., 2002, as part of ongoing hydrogeological and geochemical site characterization, unpublished at this printing.

Contaminated zone erosion rate (m/y)

This value represents the average depth of soil that is removed from the ground surface per year due to weather conditions (e.g. running water, wind). The value for this parameter is chosen in accordance with guidance recommending an erosion rate for farm/garden scenario in which dose contribution from the food ingestion pathway is expected to be significant[6].

The value used in the dose assessment for erosion rate of the contaminated zone is 0.0006 m/y.

Contaminated zone total porosity (dimensionless)

This value represents the ratio of the pore volume to the total volume for the contaminated soils. The value for this parameter is an estimate for the unconsolidated surface soils. The estimate was drawn from values representing the high end for unconsolidated deposits of gravel and the low end for unconsolidated deposits of clay.[7] It is an intermediate value for unconsolidated deposits of sand or silt.

The value used in the dose assessment for total porosity of the contaminated zone is 0.3.

Contaminated zone effective porosity (dimensionless)

This value represents the ratio of the part of the pore volume where water can circulate to the total volume for the contaminated soils. An estimate was derived representing an average of mean values for sand, gravel, silt, and clay.[8]

The value used in the dose assessment for effective porosity of the contaminated zone is 0.25.

Contaminated zone hydraulic conductivity (m/y)

This parameter measures a soil's ability to transmit water when subjected to a *hydraulic gradient*. The value used in the dose assessment represents the vertical component of the

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[6] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C, Section 3.8)

[7] Yu, C., et.al. "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil." Argonne, IL: Argonne National Laboratory. ANL/EAIS-8. April 1993. (Table 3.1)

[8] Yu, C., et.al. "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil." Argonne, IL: Argonne National Laboratory. ANL/EAIS-8. April 1993. (Table 3.2)

hydraulic conductivity.[9] The value for this parameter is site-specific for the unconsolidated surface soils.[10]

The value used in the dose assessment for hydraulic conductivity of the contaminated zone is 8.9 m/y.

Contaminated zone b parameter (dimensionless)

The soil-specific b parameter is an empirical parameter used to evaluate the saturation ratio of the soil. The value used in the dose assessment is the mean value recommended for generic soil type as an input for RESRAD.[11]

The value used in the dose assessment for the contaminated zone b parameter is 3.

Humidity in air (g/cm^3)

This parameter is used only for the computation of tritium concentration in air.[12] Since tritium is not a constituent of concern at SFC, this parameter is not applicable to the dose assessment.

The humidity in air is not used in the dose assessment.

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[9] Yu, C., et.al. "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil." Argonne, IL: Argonne National Laboratory. ANL/EAIS-8. April 1993. (Section 5.3)

[10] Provided by Shepard-Miller, Inc., 2002, as part of ongoing hydrogeological and geochemical site characterization, unpublished at this printing.

[11] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C, Section 3.5)

[12] Yu, C., et. al. "Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5.0: Working Draft for Comment." Argonne, IL: Argonne National Laboratory. ANL/EAD/LD-2. September 1993. (Section 4.6.3.3)

Evapotranspiration Coefficient (dimensionless)

This parameter is the ratio of the total volume of water leaving the ground as a result of evapotranspiration to the total volume of water available within the root zone of the soil. The value for this parameter is suggested by RESRAD guidance for the case of a small family farm that is not well managed.[13]

The value used in the dose assessment for evapotranspiration coefficient is 0.5.

Wind speed (m/s)

This value is the average wind speed for a one-year period. The value used here is an average monthly value of a multiyear period for Muskogee, Oklahoma; this is the closest location to the Facility at which such measurements are recorded[14].

The value used in the dose assessment for wind speed is 4 meters per second.

Precipitation (m/y)

This value is the average rainfall for a one-year period. The value used here is an annual average of the period 1961 –1990 for Sallisaw, Oklahoma; this is the closest location to the Facility at which such measurements are recorded[15].

The value used in the dose assessment for precipitation is 1.1 meters per year.

Irrigation (m/y)

This parameter describes the average volume of water applied to the soil, per unit of surface area, per year. The value used in the dose assessment is an average of 0.2 for humid regions and 1 for arid regions.[16]

The value used in the dose assessment for irrigation is 0.6 meters per year.

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[13] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C, Section 4.3)

[14] National Oceanic and Atmospheric Administration, Preliminary Local Climatological Data (Form F-6), Davis Field, Muskogee, Oklahoma, 1999 through 2001.

[15] National Weather Service, Tulsa, Oklahoma, Station Sallisaw, Oklahoma, Climatology.

[16] Yu, C., et.al. "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil." Argonne, IL: Argonne National Laboratory. ANL/EAIS-8. April 1993. (Section 11.3)

Irrigation mode (overhead or ditch)

This parameter indicates the predominant method of irrigation. The method of irrigation used in the dose assessment was chosen based on observation of local irrigation practices.

Overhead irrigation is the irrigation mode used in the dose assessment.

Runoff coefficient (dimensionless)

This parameter represents the fraction of precipitation, in excess of the deep percolation and evapotranspiration, that becomes surface flow and ends up in surface water bodies. An estimate of the runoff coefficient for the Facility was made in accordance with the guidance from applicable literature.[17] The runoff coefficient was derived from the partial coefficients from the same guidance for "Rolling land ...", "Intermediate combinations of clay and loam", and "Woodlands".

The value used in the dose assessment for runoff coefficient is 0.4.

Watershed area for nearby stream or pond (m^2)

The watershed area parameter represents the area of the region draining into the nearby stream or pond located at the Facility. The most likely location of a pond at the Facility, with respect to the presumed resident farmer scenario, is south of the Protected Area and north of the fertilizer basins. This location is also downgradient with respect to groundwater flow at the Facility. The watershed area for this location is estimated from the anticipated post-decommissioning Facility topography. The watershed area for this location is shown on Figure G-5. The watershed area is estimated to be 142 acres.

The value used in the dose assessment for the watershed area is 575000 m^2.

Accuracy for water/soil computations

The RESRAD default is used for this dose assessment.

[17] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C, Table 4.2-1, footnote a)

Saturated Zone Hydrological Data

Density of saturated zone (g/m^3)

This value describes the dry (bulk) density of the saturated zone. The value for this parameter is site-specific for the shale zones at the Facility[18].

The value used in the dose assessment for density of the saturated zone is 2.69 g/cm^3.

Saturated zone total porosity (dimensionless)

This value represents the ratio of the pore volume to the total volume for the saturated zone. The value for this parameter is an estimate for the shale zones at the Facility. The estimate was taken from RESRAD guidance.[19]

The value used in the dose assessment for total porosity of the saturated zone is 0.4.

Saturated zone effective porosity (dimensionless)

This value represents the ratio of the part of the pore volume where water can circulate to the total volume for the saturated soils. The value for this parameter is site-specific for the shale zones.[20]

The value used in the dose assessment for effective porosity of the saturated zone is 0.1.

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[18] Provided by Shepard-Miller, Inc., 2002, as part of ongoing hydrogeological and geochemical site characterization, unpublished at this printing.

[19] Yu, C., et.al. "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil." Argonne, IL: Argonne National Laboratory. ANL/EAIS-8. April 1993. (Table 3.1)

[20] Provided by Shepard-Miller, Inc., 2002, as part of ongoing hydrogeological and geochemical site characterization, unpublished at this printing.

Saturated zone hydraulic conductivity (m/y)

This parameter measures a formation's ability to transmit water when subjected to a *hydraulic gradient.* The value used in the dose assessment represents the horizontal component of the hydraulic conductivity.[21] The value for this parameter is site-specific for the shale zones.[22]

The value used in the dose assessment for hydraulic conductivity of the saturated zone is 89 m/y.

Saturated zone hydraulic gradient (dimensionless)

The hydraulic gradient is the change in hydraulic head per unit of distance of the groundwater flow in a given direction. The value for this parameter is site-specific for the shale zones.[23]

The value used in the dose assessment for hydraulic gradient of the saturated zone is 0.08.

Saturated zone b parameter (dimensionless)

The formation-specific b parameter is an empirical parameter used to evaluate the saturation ratio of the formation. Input for the parameter is only required if the *water table drop rate* is greater than zero.[24] The water table drop rate is defined as zero in this dose assessment therefore the saturated zone b parameter is not used.

The saturated zone b parameter is not used in the dose assessment.

Water table drop rate (m/y)

The water table drop rate describes the fluctuation in the level of the water table due to temporal variations processes in the hydrologic cycle as well as extra use of water from the system. The value of this parameter is estimated from the conditions of an unconfined groundwater system and assumed lack of groundwater use (i.e. no withdrawal).

The value used in the dose assessment for water table drop rate is zero.

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[21] Yu, C., et.al. "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil." Argonne, IL: Argonne National Laboratory. ANL/EAIS-8. April 1993. (Section 5.3)

[22] Provided by Shepard-Miller, Inc., 2002, as part of ongoing hydrogeological and geochemical site characterization, unpublished at this printing.

[23] Provided by Shepard-Miller, Inc., 2002, as part of ongoing hydrogeological and geochemical site characterization, unpublished at this printing.

[24] Yu, C., et.al. "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil." Argonne, IL: Argonne National Laboratory. ANL/EAIS-8. April 1993. (Section 13.3)

Well pump intake depth (m below water table)

This parameter represents the screened depth of a well within the saturated zone. The value for this parameter is determined by the assumption that groundwater is not used (i.e. no withdrawal).

The value used in the dose assessment for well pump intake depth is 0.00001 m corresponding to the lowest value allowed by the RESRAD code.[25]

Model for Water Transport Parameters (nondispersion or mass-balance)

This parameter selects which of the two models will be used for water/soil concentration ratio calculations. The RESRAD default, based on the size of the contaminated area, is the nondispersion model.[26]

The model for water transport used in the dose assessment is the nondispersion model.

Well pumping rate (m^3/y)

The well pumping rate is the total volume of water obtained annually from the well for use by humans and livestock and for agricultural and other purposes. The value for this parameter is determined by the assumption that groundwater is not used; i.e. *groundwater fractional usage* is zero: no withdrawal).

The value used in the dose assessment for well pumping rate is zero.

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[25] Yu, C., et. al. "Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5.0: Working Draft for Comment." Argonne, IL: Argonne National Laboratory. ANL/EAD/LD-2. September 1993. (Section 4.6.3.3)

[26] Yu, C., et. al. "Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5.0: Working Draft for Comment." Argonne, IL: Argonne National Laboratory. ANL/EAD/LD-2. September 1993. (Section 4.6.3.4)

Uncontaminated Unsaturated Zone Parameters

Unsaturated zones

The uncontaminated and unsaturated zone is the portion of the uncontaminated zone that lies below the bottom of the contaminated zone and above the groundwater table. The dose assessment here assumes one unsaturated zone: the unconsolidated soil (the same unconsolidated soils of *contaminated zone*) above the shale (*saturated zone*).

Unsaturated Zone 1, Thickness (m)

This parameter describes the thickness of the uncontaminated unsaturated unconsolidated soil below the *contaminated zone* and above the *saturated zone*. The value is an average thickness of unconsolidated soil in the *area of contaminated zone* minus the *thickness of contaminated zone*. The selection of the subject thickness is described in Attachment 2.

The value used in the dose assessment for thickness of unsaturated zone 1 is 1.4 meter (4.6 feet).

Unsaturated Zone 1, Density (g/m^3)

This value describes the dry (bulk) density of unsaturated zone 1. The value for this parameter is equivalent to that of the contaminated zone.

The value used in the dose assessment for density of unsaturated zone 1 is 1.76 g/cm^3.

Unsaturated Zone 1, Total Porosity (dimensionless)

This value represents the ratio of the pore volume to the total volume for the unsaturated zone 1. The value for this parameter is equivalent to that of the contaminated zone.

The value used in the dose assessment for total porosity of the unsaturated zone 1 is 0.3.

Unsaturated Zone 1, Effective Porosity (dimensionless)

This value represents the ratio of the part of the pore volume where water can circulate to the total volume for the unsaturated zone 1 soils. This value is equivalent to that of the contaminated zone.

The value used in the dose assessment for effective porosity of the saturated zone is 0.25.

Unsaturated Zone 1, Hydraulic Conductivity (m/y)

This parameter measures a formation's ability to transmit water when subjected to a *hydraulic gradient*. The value used in the dose assessment represents the vertical component of the hydraulic conductivity.[27] The value for this parameter is site-specific for the unconsolidated surface soils.[28]

The value used in the dose assessment for hydraulic conductivity of the unsaturated zone 1 is 8.9 m/y.[29]

Unsaturated Zone 1, b parameter (dimensionless)

The formation-specific b parameter is an empirical parameter used to evaluate the saturation ratio of the formation. The value used in the dose assessment is the mean value recommended for generic soil type as an input for RESRAD.[30]

The value used in the dose assessment for the unsaturated zone 1 b parameter is 3.

Occupancy, Inhalation, and External Gamma Data

Inhalation rate (m^3/y)

The inhalation rate used in the dose assessment represents the annual average breathing rate of the average member of the resident farmer.[31] The activities accounted for include indoor, outdoor, and gardening.

The value used in the dose assessment for inhalation rate is 8400 m^3/y.

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[27] Yu, C., et. al. "Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5.0: Working Draft for Comment." Argonne, IL: Argonne National Laboratory. ANL/EAD/LD-2. September 1993.

[28] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C, Section 3.5)

[29] Provided by Shepard-Miller, Inc., 2002, as part of ongoing hydrogeological and geochemical site characterization, unpublished at this printing.

[30] Yu, C., et.al. "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil." Argonne, IL: Argonne National Laboratory. ANL/EAIS-8. April 1993. (Section 13.3)

[31] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C, Table 5.1-3)

Mass loading for inhalation (g/m^3)

This parameter represents the concentration of soil particles in air. The value used here accounts for short periods of high mass loading and sustained periods of normal farmyard activities for which the dust level may be somewhat higher than ambient.[32]

The value used in the dose assessment for mass loading for inhalation is 0.0002 g/m^3.

Exposure duration (y)

The exposure duration is the span of time, in years, during which an individual is expected to spend time on site. This parameter is evaluated as one since the results of the dose assessment are expressed per unit time (e.g. dose per year).

The value used in the dose assessment for exposure duration is one year.

Indoor dust filtration factor (dimensionless)

This parameter is also termed the shielding factor for inhalation pathway. This factor is the ratio of airborne dust concentration indoors on site to the concentration outdoors on site. It is based on the fact that a building provides shielding against entry of wind-blown dust particles. The value chosen is an estimate derived from an average of mean values from RESRAD guidance.[33]

The value used in the dose assessment for indoor dust filtration factor is 0.56.

External gamma shielding factor (dimensionless)

This factor is the ratio of the external gamma radiation level indoors on site to the radiation level outdoors on site. It is based on the fact that a building provides shielding against penetration of gamma radiation. The value used here represents a frame house constructed with a slab[34]; i.e. a reasonably conservative guess (vs brick on slab) of type of home construction on site based on current construction practices.

The value used in the dose assessment for external gamma shielding factor is 0.21.

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[32] Yu, C., et.al. "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil." Argonne, IL: Argonne National Laboratory. ANL/EAIS-8. April 1993. (Section 35.2)

[33] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C, Table 7.1-2)

[34] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C, Table 7.10-1)

Indoor time fraction (dimensionless)

The fraction of time indoors on site is the average fraction of time in a year during which an individual stays inside a house on site. The value used here is from NRC guidance. [35]

The value used in the dose assessment for indoor time fraction is 0.25.

Outdoor time fraction (dimensionless)

The fraction of time outdoors on site is the average fraction of time in a year during which an individual stays outside on site. The value used here is from NRC guidance.[36]

The value used in the dose assessment for outdoor time fraction is 0.5.

Shape of the contaminated zone

The shape factor is used to correct for a noncircular-shaped contaminated area on the basis of an ideally circular zone. The shape of the contaminated area is assumed to be circular.

The choice of circular is made in the dose assessment for the shape of the contaminated zone.

Ingestion Pathway, Dietary Data

Fruits, Vegetables (nonleafy) and grain consumption (kg/y)

This parameter describes the total quantity of these food items (contaminated and noncontaminated) consumed per year per individual. It is a composite value obtained by summing individual consumption rates for each of the food items.[37]

The value used in the dose assessment for fruit, vegetables (nonleafy) and grain consumption is 178 kg/y.

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[35] U.S. Nuclear Regulatory Commission. Draft Standard Review Plan for the Review of a Reclamation Plan for Mill Tailings Sites Under Title II of the Uranium Mill Tailings Radiation Control Act (Draft Revision 1). Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG-1620. January 2000. (Section H2.1.3, (2), (b))

[36] U.S. Nuclear Regulatory Commission. Draft Standard Review Plan for the Review of a Reclamation Plan for Mill Tailings Sites Under Title II of the Uranium Mill Tailings Radiation Control Act (Draft Revision 1). Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG-1620. January 2000. (Section H2.1.3, (2), (b))

[37] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C, Table 5.4-2)

Leafy vegetable consumption (kg/y)

This parameter describes the total quantity of this food item (contaminated and noncontaminated) consumed per year per individual. The value for this parameter was estimated to be 0.33 of a total vegetable consumption rate.[38]

The value used in the dose assessment for leafy vegetable consumption is 25 kg/y.

Milk consumption (L/y)

The milk consumption rate is the amount of fluid milk (beverage) consumed per year. The chosen value is the annual percapita consumption of beverage milk.[39]

The value used in the dose assessment for milk consumption is 101 L/y.

Meat and poultry consumption (kg/y)

This parameter describes the annual consumption of homegrown beef, poultry, and eggs. Site specific information is not available for this parameter, therefore the RESRAD default was chosen as the input.

The value used in the dose assessment for meat and poultry consumption is 63 kg/y.

Fish Consumption (kg/y)

This parameter describes the amount of fresh fish consumed per year. The value chosen for this parameter represents a worst-case scenario for an adult.[40]

The value used in the dose assessment for fish consumption is 21 kg/y.

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[38] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C, Section 5.4 and Table 5.4-2)

[39] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C, Table 5.3-2)

[40] Yu, C., et.al. "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil." Argonne, IL: Argonne National Laboratory. ANL/EAIS-8. April 1993. (Section 41.1)

Other seafood consumption

This parameter describes the annual average rate for consumption of nonfish seafood. This parameter is not applicable to the dose assessment scenario.

The value used in the dose assessment for other seafood consumption is zero kg/y.

Soil ingestion (g/y)

This parameter describes the accidental ingestion rate of soil from outdoor activities. The chosen value represents a most likely value for the outdoor lifestyle of the resident farmer scenario.[41]

The value used in the dose assessment for soil ingestion is 18.3 g/y.

Drinking water intake (L/y)

The drinking water intake rate is the average amount of water consumed by an adult per year. The drinking water pathway is not active therefore this parameter is not available.

The drinking water intake is not used in the dose assessment.

Contaminated fraction drinking water (dimensionless)

This parameter specifies the fraction of *drinking water intake* that is drawn from [groundwater] sources on site and is assumed contaminated. The balance of drinking water is assumed to be from off site sources and uncontaminated. The drinking water pathway is not active therefore this parameter is not available.

The contaminated fraction drinking water is not used in the dose assessment.

Contaminated fraction household water (dimensionless)

This parameter allows specification of the contaminated fraction of household water for use in calculating radon exposure. The radon is not active therefore this parameter is not available.

The contaminated fraction household water is not used in the dose assessment.

[41] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C, Section 5.6)

Contaminated fraction livestock water (dimensionless)

This parameter specifies the fraction of livestock drinking water that is drawn from sources on site and is assumed contaminated. The value chosen for this parameter reflects the worst-case assumption that all livestock water is drawn from contaminated on site sources.

The value used in the dose assessment for contaminated fraction livestock water is one.

Contaminated fraction irrigation water (dimensionless)

This parameter specifies the fraction of *irrigation* water that is drawn from sources on site and is assumed contaminated. The value chosen for this parameter reflects the worst-case assumption that all *irrigation* water is drawn from contaminated on site sources.

The value used in the dose assessment for contaminated fraction irrigation water is one.

Contaminated fraction aquatic food (dimensionless)

This parameter specifies the fraction of *fish consumption* that is from sources on site and is assumed contaminated. The value chosen for this parameter reflects the most-likely case assumption that half of fish consumption is from an on site contaminated pond and half is from an off site uncontaminated surface water system.

The value used in the dose assessment for contaminated fraction aquatic food is 0.5.

Contaminated fraction plant food (dimensionless)

This parameter allows specification of the fraction of contaminated intake for the *fruits, vegetables and grain consumption*, and *leafy vegetable consumption* pathways. The balance is from off site sources assumed to be uncontaminated. The value chosen for this parameter reflects a likely condition that half of the residents plant food is from uncontaminated sources.

The value used in the dose assessment for contaminated fraction plant food is 0.5.

Contaminated fraction meat (dimensionless)

This parameter allows specification of the fraction of contaminated intake for the *meat and poultry consumption* pathway. The balance is from off site sources assumed to be uncontaminated. The value chosen for this parameter reflects a likely condition that half of the residents meat is from uncontaminated sources.

The value used in the dose assessment for contaminated fraction meat is 0.5.

Contaminated fraction milk (dimensionless)

This parameter allows specification of the fraction of contaminated intake for the *milk consumption* pathway. The balance is from off site sources assumed to be uncontaminated. The value chosen for this parameter reflects a likely condition that half of the residents milk is from uncontaminated sources.

The value used in the dose assessment for contaminated fraction milk is 0.5.

Ingestion Pathway, Nondietary Data

Livestock fodder intake for meat (kg/d)

This is the daily intake of fodder for livestock kept for *meat and poultry consumption.* The RESRAD default is considered adequately representative of a resident farmer scenario with respect to the absence of site-specific information.

The value used in the dose assessment for livestock fodder intake for meat is 68 kg/d.

Livestock fodder intake for milk (kg/d)

This is the daily intake of fodder for livestock kept for *milk consumption.* The RESRAD default is considered adequately representative of a resident farmer scenario with respect to the absence of site-specific information.

The value used in the dose assessment for livestock fodder intake for milk is 55 kg/d.

Livestock water intake for meat (L/d)

This is the daily intake of water for livestock kept for *meat and poultry consumption.* The RESRAD default is considered adequately representative of a resident farmer scenario with respect to the absence of site-specific information.

The value used in the dose assessment for livestock water intake for meat is 50 L/d.

Livestock water intake for milk (kg/d)

This is the daily intake of water for livestock kept for *milk consumption.* The RESRAD default is considered adequately representative of a resident farmer scenario with respect to the absence of site-specific information.

The value used in the dose assessment for livestock water intake for milk is 160 L/d.

Livestock soil intake (kg/d)

This is the daily intake of soil for livestock kept for *meat and poultry consumption* or *milk consumption*. The RESRAD default is considered adequately representative of a resident farmer scenario with respect to the absence of site-specific information.

The value used in the dose assessment for livestock soil intake is 0.5 kg/d.

Mass loading for foliar deposition (g/m^3)

This is the air/soil concentration ratio, specified as the average mass loading of airborne contaminated soil particles in a garden during the growing season. The RESRAD default is considered adequately representative of a resident farmer scenario with respect to the absence of site-specific information.

The value used in the dose assessment for mass loading for foliar deposition is $0.0001 g/m^3$.

Depth of soil mixing layer (m)

The depth of soil mixing layer is used in calculating the depth factor for the dust inhalation and soil ingestion pathways and for foliar deposition for the ingestion pathway. The depth factor is the fraction of resuspendable soil particles at the ground surface that are contaminated. The RESRAD default is considered to represent the most likely value for the resident farmer scenario.[42]

The value used in the dose assessment for mass loading for depth of soil mixing layer is 0.15 m.

Depth of roots (m)

This parameter represents the average root depth of various plants grown in the contaminated zone. The RESRAD default is considered adequately representative of a resident farmer scenario with respect to the absence of site-specific information.

The value used in the dose assessment for mass loading for depth of roots is 0.9 m.

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[42] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C, Section 3.12)

Groundwater fractional usage drinking water (dimensionless)

This parameter allows distinction between the groundwater and surface water scenarios with respect to *drinking water*. This parameter is not available, reflecting the absence of the drinking water pathway on site (see also *contaminated fraction drinking water*).

The groundwater fractional usage drinking water is not used in the dose assessment.

Groundwater fractional usage household water (dimensionless)

This parameter allows distinction between the groundwater and surface water scenarios with respect to *household water*. This parameter is not available, reflecting the absence of the radon pathway on site (see also *contaminated fraction household water*).

The contaminated fraction household water is not used in the dose assessment.

Groundwater fractional usage livestock water (dimensionless)

This parameter allows distinction between the groundwater and surface water scenarios with respect to *livestock water*. The value of the parameter is chosen to reflect the most-likely case, based on observation of local practice, that all *livestock water* will come from surface water (see also *contaminated fraction livestock water* and *well pumping rate*).

The value used in the dose assessment for groundwater fractional usage livestock water is zero.

Groundwater fractional usage irrigation water (dimensionless)

This parameter allows distinction between the groundwater and surface water scenarios with respect to *irrigation*. The value of the parameter is chosen to reflect the most-likely case, based on observation of local practice, that all *irrigation* water will come from surface water (see also *contaminated fraction irrigation water* and *well pumping rate*).

The value used in the dose assessment for groundwater fractional usage irrigation water is zero.

Plant Factors

Wet weight crop yield for non-leafy (kg/m^2)

This is the mass (wet weight) of the edible portion of non-leafy vegetable plant food produced from a unit land area. A State-specific value was chosen for this parameter.[43]

The value used in the dose assessment for wet weight crop yield for non-leafy vegetables is 0.6 kg/m^2.

Wet weight crop yield for leafy (kg/m^2)

This is the mass (wet weight) of the edible portion of leafy vegetable plant food produced from a unit land area. The RESRAD default is considered adequately representative respect to the absence of site-specific information.

The value used in the dose assessment for wet weight crop yield for leafy vegetables is 1.5 kg/m^2.

Wet weight crop yield for fodder (kg/m^2)

This is the mass (wet weight) of the edible portion of livestock plant food produced from a unit land area. The RESRAD default is considered adequately representative respect to the absence of site-specific information.

The value used in the dose assessment for wet weight crop yield for fodder is 1.1 kg/m^2.

Length of growing season for non-leafy (y)

This is the exposure time of the non-leafy plant food to contamination during the growing season. The contaminants can get to the edible portion of the plant food through foliar deposition, root uptake and water irrigation. The RESRAD default is considered adequately representative respect to the absence of site-specific information.

The value used in the dose assessment for length of growing season of non-leafy vegetables is 0.17 year.

Length of growing season for leafy (y)

This is the exposure time of the leafy plant food to contamination during the growing season. The contaminants can get to the edible portion of the plant food through foliar deposition, root

[43] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C, Section 6.5)

uptake and water irrigation. The RESRAD default is considered adequately representative respect to the absence of site-specific information.

The value used in the dose assessment for length of growing season of leafy vegetables is 0.25 year.

Length of growing season for fodder (y)

This is the exposure time of the livestock plant food to contamination during the growing season. The contaminants can get to the edible portion of the plant food through foliar deposition, root uptake and water irrigation. The RESRAD default is considered adequately representative respect to the absence of site-specific information.

The value used in the dose assessment for length of growing season of fodder is 0.08 year.

Translocation factor for non-leafy (dimensionless)

This is the contaminant non-leafy foliage-to-food transfer coefficient. A fraction of the contaminant that retains on the foliage of the plant food will be absorbed and transferred to the edible portion of the plant food. The RESRAD default is considered adequately representative respect to the absence of site-specific information.

The value used in the dose assessment for translocation factor for non-leafy is 0.1.

Translocation factor for leafy (dimensionless)

This is the contaminant leafy foliage-to-food transfer coefficient. A fraction of the contaminant that retains on the foliage of the plant food will be absorbed and transferred to the edible portion of the plant food. The RESRAD default is considered adequately representative respect to the absence of site-specific information.

The value used in the dose assessment for translocation factor for leafy is 1.

Translocation factor for fodder (dimensionless)

This is the contaminant fodder foliage-to-food transfer coefficient. A fraction of the contaminant that retains on the foliage of fodder will be absorbed and transferred to the edible portion of the plant food. The RESRAD default is considered adequately representative respect to the absence of site-specific information.

The value used in the dose assessment for translocation factor for fodder is 1.

Weathering removal constant for vegetation (dimensionless)

The weathering process removes contaminants from foliage of the plant food. This process is characterized by a removal constant that accounts for reduction of the amount of contaminants on foliage during the exposure period. A most-likely value is chosen from RESRAD guidance for this parameter.[44]

The value used in the dose assessment for weathering removal constant for vegetation is 18.

Wet foliar interception fraction for non-leafy (dimensionless)

This is the fraction of contaminant deposited by irrigation water that retains on the foliage of non-leafy plant food. The RESRAD default is considered adequately representative respect to the absence of site-specific information.

The value used in the dose assessment for wet interception fraction for non-leafy is 0.25.

Wet foliar interception fraction for leafy (dimensionless)

This is the fraction of contaminant deposited by irrigation water that retains on the foliage of leafy plant food. A most-likely value is chosen from RESRAD guidance for this parameter.[45]

The value used in the dose assessment for wet interception fraction for leafy is 0.67.

Wet foliar interception fraction for fodder (dimensionless)

This is the fraction of contaminant deposited by irrigation water that retains on the foliage of fodder. The RESRAD default is considered adequately representative respect to the absence of site-specific information.

The value used in the dose assessment for wet interception fraction for fodder is 0.25.

Dry foliar interception fraction for non-leafy (dimensionless)

This is the fraction of contaminant deposited by airborne particulate that retains on the foliage of non-leafy plant food. The RESRAD default is considered adequately representative respect to the absence of site-specific information.

The value used in the dose assessment for dry interception fraction for non-leafy is 0.25.

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[44] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C, Section 6.6)

[45] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C, Section 6.7)

Dry foliar interception fraction for leafy (dimensionless)

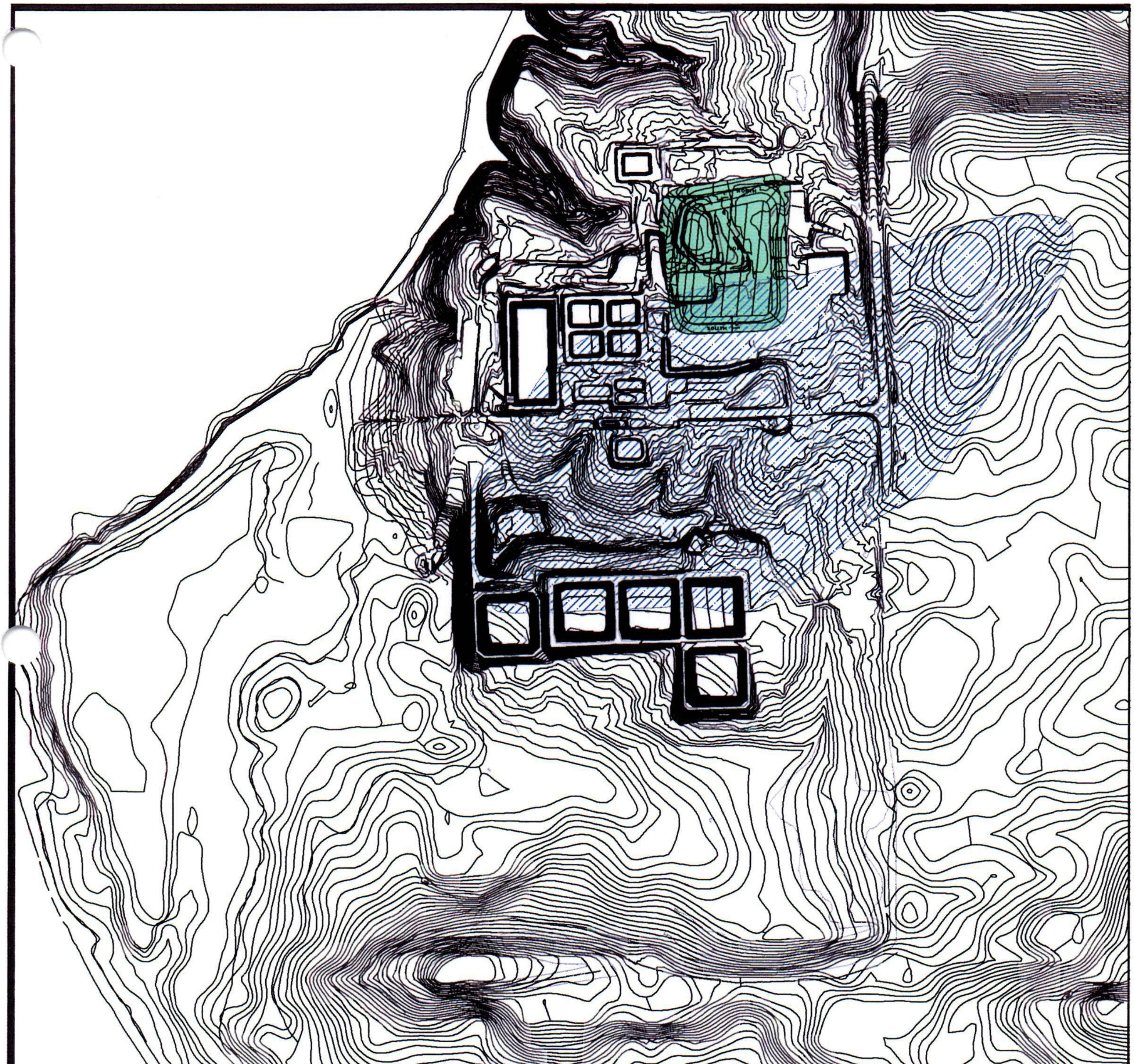
This is the fraction of contaminant deposited by airborne particulate that retains on the foliage of leafy plant food. The RESRAD default is considered adequately representative respect to the absence of site-specific information.

The value used in the dose assessment for dry interception fraction for leafy is 0.25.

Dry foliar interception fraction for fodder (dimensionless)

This is the fraction of contaminant deposited by airborne particulate that retains on the foliage of fodder. The RESRAD default is considered adequately representative respect to the absence of site-specific information.

The value used in the dose assessment for dry interception fraction for fodder is 0.25.



Cell Footprint

Watershed Area

Sequoyah Fuels Corporation
Reclamation Plan

Title: Watershed Area for Nearby Stream or Pond	
Prepared By: SFC	File Name: NRC00029A
Reviewed By: RHM	
Date: 01/22/03	Figure No. G-5

C04

Attachment 2

Selection of Thickness of Contaminated Zone and Thickness of Uncontaminated Unsaturated Zone for Development of DCGLs

Resident Farmer Scenario

SELECTION OF THICKNESS OF CONTAMINATED ZONE AND THICKNESS OF UNCONTAMINATED UNSATURATED ZONE FOR DEVELOPMENT OF DCGLs

Resident Farmer Scenario

Introduction

Two important parameters used to determine the derived concentration guideline levels (DCGLs) are the *thickness of contaminated zone* and the *uncontaminated unsaturated zone thickness*. The *thickness of contaminated zone* is an important factor in determining the total source term available to the respective model; e.g. the thicker the contaminated zone, potentially more contaminant can be removed by infiltrating water. It is also important with respect to the elapsed time for which the source term is available; e.g. the thicker the contaminated zone, the longer time before it is removed by erosion.

The *uncontaminated unsaturated zone thickness* is important with respect to movement of the contaminant into the saturated zone. The greater the thickness, the longer the travel time from the contaminated zone to the groundwater.

The following text describes selection of the thickness of each of these zones at Sequoyah Fuels Corporation (SFC) site. The selection uses information from site characterization activities as reported in the Facility Environmental Investigation Findings Report[1], the Final RCRA Facility Investigation Report[2], and the Site Characterization Report[3].

Selection Process

During site characterization efforts, soil samples were collected using two methods – hand auger and borehole. Hand auger samples are collected with hand tools and are generally 0.5 feet and sometimes up to five feet. Borehole samples are collected using drilling equipment and the borings are typically much deeper. Only borehole samples were considered here since they are most likely to extend over a depth range great enough to encompass the entire depth of contamination.

The site characterization included completion of lithological logs for each of the boreholes used in this selection process. These logs allow identification of the thickness of the unconsolidated soils (unsaturated zone) above the uppermost shale layer (saturated

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[1] "Facility Environmental Investigation Findings Report", Volume V, appendices E and F, Sequoyah Fuels Corporation, July 1991.

[2] "Final RCRA Facility Investigation Report", Volume II, Appendix C, Sequoyah Fuels Corporation, October 1996.

[3] "Site Characterization Report", Table 6, Sequoyah Fuels Corporation, March 1998.

zone). Thus, the *thickness of contaminated zone* and the *uncontaminated unsaturated zone thickness* might be determined for any particular location where boreholes exist.

Only those boreholes inside the Process Area and outside the footprint of the proposed disposal cell were considered in the selection process. The Process Area includes the vast majority of the contaminated soils. The presence of the proposed disposal cell will necessarily preclude use of the underlying soils as a potential area of human habitation and therefore from contribution to dose within the context of the model used to determine the DCGLs.

The boreholes included in the selection process are listed in Table G-8. Figure G-6 shows the location of each borehole listed in Table G-8. Figure G-6 also depicts the Process Area boundary and the footprint of the proposed disposal cell.

Thickness of Contaminated Zone

Since the predominant contaminant in soil at SFC is uranium, it was chosen as the constituent of concern on which to base the selection of *thickness of contaminated zone.* In order to assess the thickness of contamination relative to uranium, a concentration value was chosen to differentiate between contamination and background. The concentration value chosen was two times the reported laboratory detection limit for total uranium in soil. During the primary period of site characterization activities (1990 and 1991), the reported laboratory detection limit for total uranium in soil was 3.4 pCi/g (5 μg/g). Then contamination was considered present for the purpose of this selection process when the uranium concentration in a soil sample exceeded 7 pCi/g (10 μg/g).

Some boreholes were eliminated from the selection process because of bias by physical features at the Facility. For example, several boreholes were completed near the Combination Stream Drain. Contamination at depth at these locations would be removed when the Combination Stream Drain is excavated during decommissioning. Several locations were eliminated because the area where the samples were collected has been decontaminated; i.e. the soil was removed after the sampling effort. Finally, in a few locations the borehole did not extend through the contamination. The boreholes eliminated from the selection process are identified in Table G-8 by absence of a value in the column describing thickness of contaminated zone.

At locations where contamination is present and it's complete extent sampled, the *thickness of contaminated zone* was determined as the difference between the bottom of the lower most contaminated sample and the top of the uppermost contaminated sample.

Uncontaminated Unsaturated Zone Thickness

The *uncontaminated unsaturated zone thickness* was selected from a two-step process. First, the thickness of the unsaturated zone was determined for each borehole used in selection of the *thickness of contaminated zone.* This determination was made directly from review of the lithological log for the respective borehole. Second, the *uncontaminated unsaturated zone thickness* was calculated as the difference between the thickness of the unsaturated zone and the *thickness of contaminated zone*.

Some boreholes were eliminated from the selection process because no lithological logs were available for the respective location. Other boreholes were eliminated because no unconsolidated material exists between the surface (e.g. pavement) and the uppermost shale layer. Still other boreholes were eliminated from the selection process because the borehole did not completely extend through the unconsolidated soils thereby not allowing determination of the thickness. The boreholes eliminated from the selection process are identified in Table G-8 by absence of a value in the column describing thickness of the unsaturated zone.

At locations where the lithological log indicated auger refusal, the depth of auger refusal was considered to indicate the depth of bedrock. The bedrock was assumed to be the uppermost shale layer.

Results

Thickness of Contaminated Zone

Table G-8 reflects that 135 boreholes were considered for development of the *thickness of contaminated zone*. A *thickness of contaminated zone* was determined, as described previously, for 91 of these boreholes. The average *thickness of contaminated zone* for these 91 boreholes is one foot (0.3 meter).

Uncontaminated Unsaturated Zone Thickness

Table G-8 reflects that 135 boreholes were considered for development of the *uncontaminated unsaturated zone thickness*. An *uncontaminated unsaturated zone thickness* was determined, as described previously, for 83 of these boreholes. The average *uncontaminated unsaturated zone thickness* for these 83 boreholes is 4.6 feet (1.4 meter).

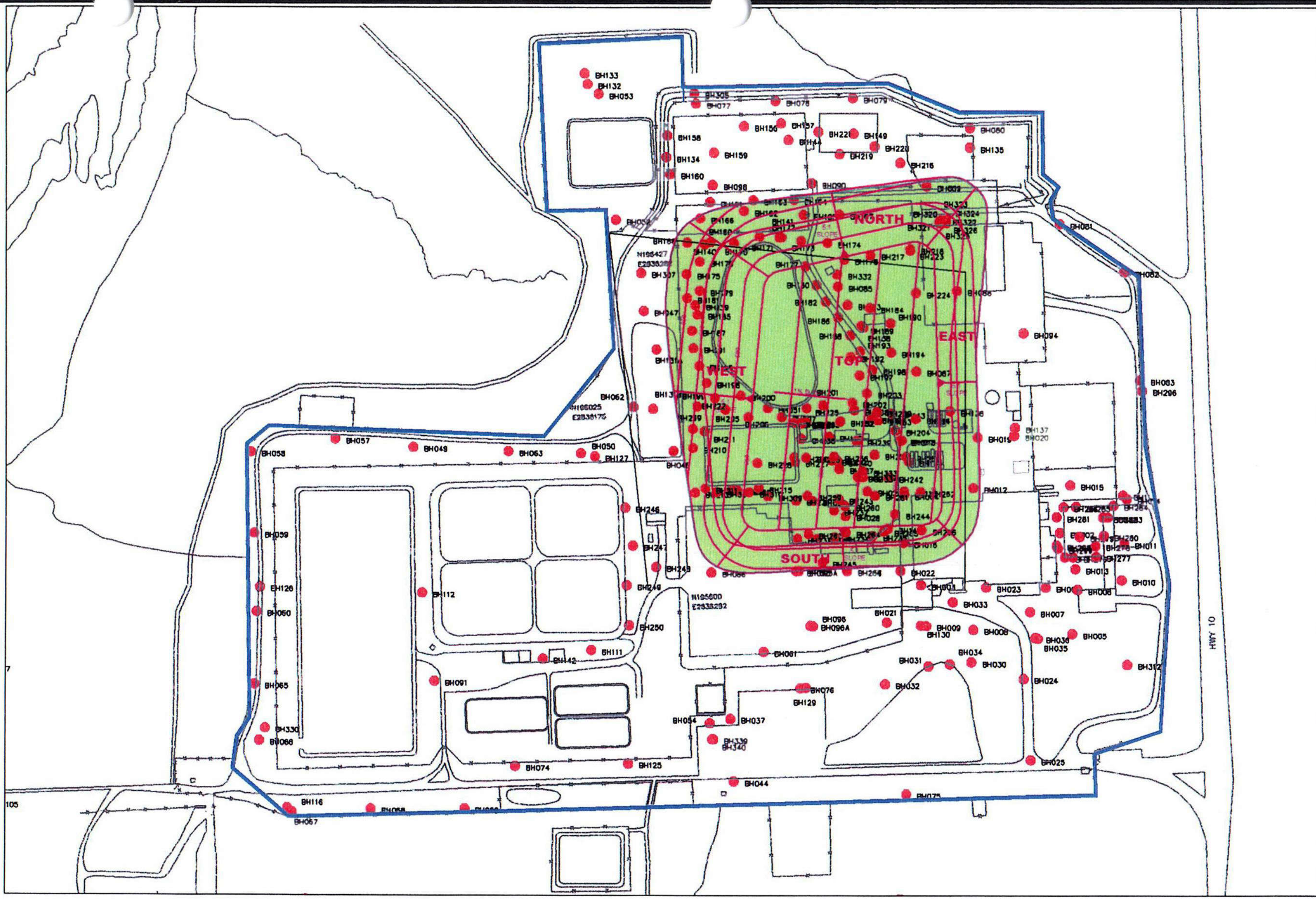
Table G-8

Selection of Thickness of Contaminated Zone and Uncontaminated Unsaturated Zone Thickness at Sequoyah Fuels Corporation

Location[1]	Thickness of Unsaturated Zone, feet	Thickness of Contaminated Zone, feet	Difference (Uncontaminated Unsaturated Zone Thickness), feet
BH001	7.6	1	6.6
BH002	-	-	-
BH003	16.4	6	10.4
BH005	5.8	0	5.8
BH006	7.6	7	0.6
BH007	1.5	0	1.5
BH008	-	-	-
BH009	-	-	-
BH010	6	0	6
BH011	7	0	7
BH013	8.5	1	7.5
BH014	8	1	7
BH015	5	1	4
BH020	-	1	-
BH021	14.5	3	11.5
BH022	16.4	0	16.4
BH023	6	1	5
BH024	5	1	4
BH025	5	1	4
BH030	5	0.5	4.5
BH031	7	0.5	6.5
BH032	9	0.5	8.5
BH033	12.7	0.5	12.2
BH034	7.5	0.5	7
BH035	5.9	0	5.9
BH036	4	0.5	3.5
BH037	-	-	-
BH038	-	-	-
BH039	-	-	-
BH040	-	-	-
BH041	-	-	-
BH044	-	-	-
BH047	8.4	0	8.4
BH049	4.5	0	4.5
BH050	7.1	2	5.1
BH052	6.5	1	5.5
BH053	9.5	1	8.5
BH054	-	-	-
BH057	3.7	0	3.7
BH058	9.8	0	9.8
BH059	3.4	0	3.4
BH060	3.5	0	3.5
BH061	-	-	-
BH062	8.9	1	7.9
BH063	7	2	5
BH065	11.4	0	11.4
BH066	12.7	0	12.7
BH067	3.5	0	3.5
BH068	5	0	5
BH069	0.5	0	0.5
BH074	6.5	0	6.5
BH075	3	1	2
BH076	4	0	4
BH077	9	0	9
BH078	7.6	0	7.6
BH079	8.5	2	6.5
BH080	4.7	1	3.7
BH081	9	0	9
BH082	11.4	1	10.4
BH083	15.7	0	15.7
BH086	9.8	4.5	5.3
BH090	-	-	-
BH091	7	2	5
BH094	8.7	0	8.7
BH096	6.8	0	6.8
BH098	8	2	6
BH111	1.5	1	0.5
BH112	9	0	9
BH116	3.7	2	1.7

Location[1]	Estimated Thickness of Unsaturated Zone, feet	Estimated Thickness of Contaminated Zone, feet	Difference (Uncontaminated Unsaturated Zone Thickness), feet
BH124	-	-	-
BH125	4.7	2	2.7
BH126	3.9	0.5	3.4
BH127	2.8	2	0.8
BH128	0.9	0	0.9
BH129	2.7	2	0.7
BH130	-	-	-
BH133	-	-	-
BH134	4.7	0	4.7
BH135	3.9	2	1.9
BH137	2.3	2	0.3
BH142	5	0	5
BH144	7.8	1	6.8
BH156	-	-	-
BH157 (SC-7)	5	2	3
BH158 (SC-15)	5	1.5	3.5
BH159	-	-	-
BH160 (SC-43)	5	0	5
BH161 (SC-73)	5	2	3
BH163	-	-	-
BH170 (SC-102)	4.5	3	1.5
BH176 (SC-115)	5	3	2
BH216 (SC-55)	5	0	5
BH219 (SC-38)	5	0	5
BH220 (SC-40)	5	0	5
BH221 (SC-23)	5	3	2
BH246	-	-	-
BH247 (SC-11)	-	1	-
BH248	-	0	-
BH249	-	-	-
BH250	-	-	-
BH275	-	-	-
BH276	-	-	-
BH278	-	-	-
BH279	-	-	-
BH280	-	-	-
BH281	-	-	-
BH282	-	-	-
BH283	-	-	-
BH284	-	-	-
BH285	-	-	-
BH286	-	-	-
BH296	-	0	-
BH297	-	-	-
BH298	-	-	-
BH299	-	-	-
BH305	-	2	-
BH307	-	-	-
BH312	-	-	-

[1]Locations are boreholes outside foot print of proposed disposal cell and inside Process Area.



Location of Proposed Cell

Protected Area Boundary
(Area of Contaminated Zone)

SEQUOYAH FUELS CORPORATION Reclamation Plan	
Title: Locations Used for Selection of Thickness of Contaminated Zone and Thickness of Unsaturated Uncontaminated Zone	
PREPARED BY: SFC	Filename: NRC0068E1
Reviewed by: CH	Figure No. G-6
Date: 01/22/03	

C05

SENSITIVITY ANALYSES

RESIDENT FARMER SCENARIO
Evaluation of DCGLs

DRAINAGE 005 SCENARIO
Evaluation of annual dose

INDUSTRIAL WORKER SCENARIO
Evaluation of annual dose

SENSITIVITY ANALYSES

Introduction

To ensure that the results of the DCGL development and the dose assessments described in Appendix G are unlikely to significantly underestimate potential dose, the analyses used realistically conservative scenarios and conceptual model. As well, prudently conservative values were used for key parameters. Sensitivity analyses were subsequently completed for which the primary objective was to identify input parameters that were major contributors to variation in the calculated doses.

The sensitivity analyses were of a deterministic technique; i.e. the change in the output result of peak dose was determined with respect to a change in the independent input parameters. The sensitivity analyses were performed after completing the RESRAD calculations used to determine the DCGLs. The sensitivity analyses were performed by taking each parameter and repeating the RESRAD calculation with the parameter under test set at two previously chosen extremes. Only one parameter is varied at a time. The results of the sensitivity analyses for the three dose assessment scenarios described in Appendix G are discussed in the following sections. The input parameters analyzed, the two extremes analyzed for the respective parameter, and the effect on the peak dose are described in tables 1 through 9 for the three dose assessment scenarios described in Appendix G.

Resident Farmer

The sensitivity analysis of the resident farmer scenario was completed independently for each of the three radionuclides U-natural, Th-230, and Ra-226.

The RESRAD parameters available for input to evaluate the resident farmer scenario are listed in Table 1. The parameters evaluated in the sensitivity analysis are marked accordingly in Table 1.

Table 1

PARAMETERS OF RESIDENT FARMER SCENARIO AVAILABLE FOR SENSITIVITY ANALYSIS

PARAMETER CATEGORY	PARAMETER DESCRIPTION	SENSITIVITY ANALYSIS PERFORMED
Soil Concentrations	Transport Distribution coefficient: contaminated zone	
	Transport Distribution coefficient: unsaturated zone	
	Transport Distribution coefficient: saturated zone	
	Transport Solubility Limit	
	Transport Leach Rate	
Contaminated Zone	Area of contaminated zone	
	Thickness of contaminated zone	√
	Length parallel to aquifer flow	√
Cover and Contaminated Zone Hydrological Data	Cover depth	
	Density of contaminated zone	√
	Contaminated zone erosion rate	√
	Contaminated zone total porosity	√
	Contaminated zone effective porosity	√
	Contaminated zone hydraulic conductivity	√
	Contaminated zone b parameter	√
	Evapotranspiration coefficient	√
	Wind speed	√
	Precipitation	√
	Irrigation	√
	Runoff coefficient	√
	Watershed area for nearby stream or pond	
	Accuracy for soil/water computations	
Saturated Zone Hydrological Data	Density of saturated zone	√
	Saturated zone total porosity	√
	Saturated zone effective porosity	√
	Saturated zone hydraulic conductivity	√
	Saturated zone hydraulic gradient	√
	Water table drop rate	
	Well pump intake depth	√
	Well pumping rate	√

Table 1 (continued)

PARAMETERS OF RESIDENT FARMER SCENARIO AVAILABLE FOR SENSITIVITY ANALYSIS

PARAMETER CATEGORY	PARAMETER DESCRIPTION	SENSITIVITY ANALYSIS PERFORMED
Uncontaminated Unsaturated Zone Parameters	Unsaturated Zone Thickness	
	Unsaturated Zone Density	
	Unsaturated Zone Total Porosity	
	Unsaturated Zone Effective Porosity	
	Unsaturated Zone Hydraulic Conductivity	
	Unsaturated Zone b Parameter	
Occupancy, Inhalation, And External Gamma Data	Inhalation rate	√
	Mass loading for inhalation	√
	Exposure duration	
	Indoor dust filtration factor	√
	External gamma shielding factor	√
	Indoor time fraction	√
	Outdoor time fraction	√
Ingestion Pathway, Dietary Data	Fruit, vegetable, and grain consumption	√
	Leafy vegetable consumption	√
	Milk consumption	√
	Meat and poultry consumption	√
	Fish consumption	√
	Other seafood consumption	
	Soil ingestion	√
	Contaminated fraction Livestock water	
	Contaminated fraction Irrigation water	
	Contaminated fraction Aquatic food	√
	Contaminated fraction Plant food	
	Contaminated fraction Meat	
	Contaminated fraction Milk	
Ingestion Pathway, Nondietary Data	Livestock fodder intake for meat	√
	Livestock fodder intake for milk	√
	Livestock water intake for meat	√
	Livestock water intake for milk	√
	Livestock intake of soil	√

Table 1 (continued)

PARAMETERS OF RESIDENT FARMER SCENARIO AVAILABLE FOR SENSITIVITY ANALYSIS

PARAMETER CATEGORY	PARAMETER DESCRIPTION	SENSITIVITY ANALYSIS PERFORMED
Ingestion Pathway, Nondietary Data (cont.)	Mass loading for foliar deposition	√
	Depth of soil mixing layer	√
	Depth of roots	√
	Groundwater Fractional Usage Livestock Water	
	Groundwater Fractional Usage Irrigation Water	
Storage Times Before Use Data	Fruits, non-leafy vegetables, and grain	
	Leafy vegetables	
	Milk	
	Meat	
	Fish	
	Crustacea and mollusks	
	Well water	
	Surface water	
	Livestock fodder	
Carbon-14 Data	{ Not applicable. }	

Several parameters, although available to the RESRAD sensitivity analysis, were not evaluated. Each such parameter and the reason it was not evaluated is included in Table 2.

Table 2

Parameters of Resident Farmer Scenario Available for Sensitivity Analysis but not Evaluated

Transport Distribution Coefficient:	The scenario included the conservative condition of assuming the lowest distribution coefficient determined for the area of contaminated zone applied to the entire area of contaminated zone.
Transport Solubility Limit:	This parameter was not used by RESRAD since a distribution coefficient was provided.
Transport Leach Rate:	This parameter was not used by RESRAD since a distribution coefficient was provided.
Area of contaminated zone:	The scenario used a reasonably conservative maximum value for this parameter.
Cover depth:	The dose assessment included the conservative assumption that no cover will be applied.
Watershed area …	The dose assessment included the actual value for this parameter.
Accuracy … computations:	A sufficient value for accuracy was chosen.
Water table drop rate:	The dose assessment included the conservative assumption that the groundwater system is unconfined.
Unsaturated zone parameters:	These parameters affect only the time until exposure and not the degree of exposure under the given exposure scenario.
Exposure duration:	This parameter is not applicable since the model result is evaluated as peak dose and not total dose or risk.
Other seafood consumption:	This parameter is not applicable to conditions or scenarios of the scenario.
Contaminated fraction Livestock water:	The model input for this parameter is 1, which is the maximum or conservative assumption.

Table 2 (continued)

Parameters of Resident Farmer Scenario Available for Sensitivity Analysis but not Evaluated

Contaminated fraction Irrigation water:	The model input for this parameter is 1 which is the maximum or conservative assumption.
Contaminated fraction Plant food:	The model input for this parameter is calculated by RESRAD based on other parameters. Due to the size of the area of contaminated zone, the value used by RESRAD is 1 which is the maximum or conservative assumption.
Contaminated fraction Meat:	The model input for this parameter is calculated by RESRAD based on other parameters. Due to the size of the area of contaminated zone, the value used by RESRAD is 1 which is the maximum or conservative assumption.
Contaminated fraction Milk:	The model input for this parameter is calculated by RESRAD based on other parameters. Due to the size of the area of contaminated zone, the value used by RESRAD is 1 which is the maximum or conservative assumption.
Groundwater fractional Usage Livestock Water:	Changing the value of this parameter from zero would contradict the condition that groundwater is not an exposure pathway as a volumetric source of water.
Groundwater fractional Usage Irrigation Water:	Changing the value of this parameter from zero would contradict the condition that groundwater is not an exposure pathway as a volumetric source of water.
Storage Times Before Use:	These parameters are not applicable since the radionuclides of interest do not appreciably transform during the modeled time period.
Carbon-14:	Carbon-14 is not a radionuclide of interest in the subject dose assessment.

Several parameters were not available to the sensitivity analysis provided by the RESRAD software: they were either turned off by the software based on the active exposure pathways (e.g. "Density of cover material"; there is no cover in the model), or the software did not allow a sensitivity analysis of the parameter (e.g. "Plant Factors Wet weight crop yield"). The parameters not available to the RESRAD sensitivity analysis are listed in Table 3.

Table 3

Parameters of Resident Farmer Scenario NOT available for Sensitivity Analysis

PARAMETER CATEGORY	PARAMETER DESCRIPTION
Soil Concentrations	Transport Time since material placement
	Transport Groundwater concentration
Calculation Parameters	Basic Radiation Dose Limit
	Times for Calculation
Cover and Contaminated Zone Hydrological Data	Density of cover material
	Cover erosion rate
	Humidity in air
	Irrigation mode
Saturated Zone Hydrological Data	Saturated zone b parameter
	Model for Water Transport Parameters
Occupancy, Inhalation, And External Gamma Data	Shape of the contaminated zone
Ingestion Pathway, Dietary Data	Drinking water intake
	Contaminated fraction Drinking water
	Contaminated fraction Household water
Ingestion Pathway, Nondietary Data	Groundwater Fractional Usage Drinking water
	Groundwater Fractional Usage Household water
	Plant Factors Wet weight crop yield
	Plant Factors Length of growing season
	Plant Factors Translocation factor
	Plant Factors Weathering removal constant
	Plant Factors Wet foliar interception fraction
	Plant Factors Dry foliar interception fraction
Radon	{ All }

The results of the sensitivity analysis completed for each of the three radionuclides of interest are summarized in tables 4, 5, and 6. The basis for the range over which the sensitivity analyses were completed is described in Table 7.

Table 4
Summary of Sensitivity Analysis for Resident Farmer Scenario
U-natural = DCGL (560 pCi/g)

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER LOW	MODEL	HIGH
Transport Distribution coefficient of contaminated zone, cm^3/g (uranium)		500	---
Maximum Dose, mrem/y	---	54	---
Area of contaminated zone, m^2	---	263120	---
Maximum Dose, mrem/y	---	54	---
Thickness of contaminated zone, m	0.15	0.3	0.6
Maximum Dose, mrem/y	40	54	65
Length parallel to aquifer flow, m	441	662	993
Maximum Dose, mrem/y	54	54	54
Density of contaminated zone, g/cm^3	1.17	1.76	2.64
Maximum Dose, mrem/y	54	54	54
Contaminated zone erosion rate, m/y	0.00006	0.0006	0.006
Maximum Dose, mrem/y	54	54	54
Contaminated zone total porosity, dimensionless	0.09	0.30	1
Maximum Dose, mrem/y	54	54	54
Contaminated zone effective porosity, dimensionless	0.06	0.25	1
Maximum Dose, mrem/y	54	54	54
Contaminated zone hydraulic conductivity, m/y	4.45	8.9	17.8
Maximum Dose, mrem/y	54	54	54
Contaminated zone b parameter, dimensionless	0.6	3	15
Maximum Dose, mrem/y	54	54	54
Evapotranspiration coefficient, dimensionless	0.33	0.5	0.75
Maximum Dose, mrem/y	54	54	54
Wind Speed, m/s	2.67	4	6
Maximum Dose, mrem/y	60	54	50
Precipitation, m/y	0.73	1.1	1.65
Maximum Dose, mrem/y	54	54	54
Irrigation, m/y	0.3	0.6	1.2
Maximum Dose, mrem/y	54	54	54
Runoff coefficient, dimensionless	0.2	0.4	0.8
Maximum Dose, mrem/y	54	54	54

Table 4 (continued)
Summary of Sensitivity Analysis for Resident Farmer Scenario
U-natural = DCGL (560 pCi/g)

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER LOW	MODEL	HIGH
Watershed area for nearby stream or pond, m^2	---	575000	---
Maximum Dose, mrem/y	---	54	---
Density of saturated zone, g/m^3	1.79	2.69	4.04
Maximum Dose, mrem/y	54	54	54
Saturated zone total porosity, dimensionless	0.16	0.4	1
Maximum Dose, mrem/y	54	54	54
Saturated zone effective porosity, dimensionless	0.01	0.10	1
Maximum Dose, mrem/y	54	54	54
Saturated zone hydraulic conductivity, m/y	44.5	89	178
Maximum Dose, mrem/y	54	54	54
Saturated zone hydraulic gradient, dimensionless	0.04	0.08	0.16
Maximum Dose, mrem/y	54	54	54
Unsaturated zone 1 thickness, m	---	1.4	---
Maximum Dose, mrem/y	---	54	---
Inhalation rate, m^3/y	5383	8400	13104
Maximum Dose, mrem/y	50	54	60
Mass loading for inhalation, g/m^3	0.00004	0.0002	0.001
Maximum Dose, mrem/y	45	54	90
Indoor dust filtration factor, dimensionless	0.33	0.56	1
Maximum Dose, mrem/y	57	54	56
External gamma shielding factor, dimensionless	0.05	0.21	0.81
Maximum Dose, mrem/y	57	54	60
Indoor time fraction, dimensionless	0.17	0.25	0.38
Maximum Dose, mrem/y	52	54	60
Outdoor time fraction, dimensionless	0.33	0.5	0.75
Maximum Dose, mrem/y	42	54	70

Table 4 (continued)
Summary of Sensitivity Analysis for Resident Farmer Scenario
U-natural = DCGL (560 pCi/g)

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER LOW	MODEL	HIGH
Fruit, vegetable, and grain consumption, kg/y	148	178	214
Maximum Dose, mrem/y	52	54	56
Leafy vegetable consumption, kg/y	12.5	25	50
Maximum Dose, mrem/y	52	54	56
Milk consumption, L/y	50.5	101	202
Maximum Dose, mrem/y	52	54	56
Meat and poultry consumption, kg/y	31.5	63	126
Maximum Dose, mrem/y	53	54	55
Fish consumption, kg/y	10.5	21	42
Maximum Dose, mrem/y	54	54	54
Soil ingestion, g/y	9.15	18.3	36.6
Maximum Dose, mrem/y	52	54	56
Contamination fraction Aquatic food, dimensionless	0.25	0.5	1
Maximum Dose, mrem/y	54	54	54
Livestock fodder intake for meat, kg/d	34	68	136
Maximum Dose, mrem/y	54	54	54
Livestock fodder intake for milk, kg/d	27.5	55	110
Maximum Dose, mrem/y	54	54	54
Livestock water intake for meat, L/d	25	50	54
Maximum Dose, mrem/y	54	54	54
Livestock water intake for milk, L/d	80	160	320
Maximum Dose, mrem/y	54	54	54
Livestock intake of soil, kg/d	0.25	0.5	1
Maximum Dose, mrem/y	52	54	56
Mass loading for foliar deposition, g/m^3	0.00001	0.0001	0.001
Maximum Dose, mrem/y	54	54	54
Depth of soil mixing layer, m	0.04	0.15	0.6
Maximum Dose, mrem/y	54	54	47
Depth of roots, m	0.23	0.9	3.6
Maximum Dose, mrem/y	80	54	45

Table 5
Summary of Sensitivity Analysis for Resident Farmer Scenario
Th-230 = DCGL (64 pCi/g)

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER LOW	MODEL	HIGH
Transport Distribution coefficient of all zones, cm^3/g	---	5884	---
Maximum Dose, mrem/y	---	54	---
Area of contaminated zone, m^2	---	263120	---
Maximum Dose, mrem/y	---	54	---
Thickness of contaminated zone, m	0.15	0.3	0.6
Maximum Dose, mrem/y	20	54	135
Length parallel to aquifer flow, m	441	662	993
Maximum Dose, mrem/y	54	54	54
Density of contaminated zone, g/cm^3	1.17	1.76	2.64
Maximum Dose, mrem/y	45	54	60
Contaminated zone erosion rate, m/y	0.00006	0.0006	0.006
Maximum Dose, mrem/y	170	54	10
Contaminated zone total porosity, dimensionless	0.09	0.30	1
Maximum Dose, mrem/y	54	54	54
Contaminated zone effective porosity, dimensionless	0.06	0.25	1
Maximum Dose, mrem/y	54	54	54
Contaminated zone hydraulic conductivity, m/y	4.45	8.9	17.8
Maximum Dose, mrem/y	54	54	54
Contaminated zone b parameter, dimensionless	0.6	3	15
Maximum Dose, mrem/y	54	54	54
Evapotranspiration coefficient, dimensionless	0.33	0.5	.75
Maximum Dose, mrem/y	52	54	56
Wind Speed, m/s	2.67	4	6
Maximum Dose, mrem/y	56	54	52
Precipitation, m/y	0.73	1.1	1.65
Maximum Dose, mrem/y	52	54	56
Irrigation, m/y	0.3	0.6	1.2
Maximum Dose, mrem/y	52	54	56
Runoff coefficient, dimensionless	0.2	0.4	0.8
Maximum Dose, mrem/y	52	54	56

Table 5 (continued)
Summary of Sensitivity Analysis for Resident Farmer Scenario
Th-230 = DCGL (64 pCi/g)

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER LOW	MODEL	HIGH
Watershed area for nearby stream or pond, m^2	---	575000	---
Maximum Dose, mrem/y	---	54	---
Density of saturated zone, g/m^3	1.79	2.69	4.04
Maximum Dose, mrem/y	54	54	54
Saturated zone total porosity, dimensionless	0.16	0.4	1
Maximum Dose, mrem/y	54	54	54
Saturated zone effective porosity, dimensionless	0.01	0.10	1
Maximum Dose, mrem/y	54	54	54
Saturated zone hydraulic conductivity, m/y	44.5	89	178
Maximum Dose, mrem/y	54	54	54
Saturated zone hydraulic gradient, dimensionless	0.04	0.08	0.16
Maximum Dose, mrem/y	54	54	54
Unsaturated zone 1 thickness, m	---	1.4	---
Maximum Dose, mrem/y	---	54	---
Inhalation rate, m^3/y	5383	8400	13104
Maximum Dose, mrem/y	52	54	56
Mass loading for inhalation, g/m^3	0.00004	0.0002	0.001
Maximum Dose, mrem/y	52	54	56
Indoor dust filtration factor, dimensionless	0.33	0.56	1
Maximum Dose, mrem/y	54	54	54
External gamma shielding factor, dimensionless	0.05	0.21	0.81
Maximum Dose, mrem/y	50	54	65
Indoor time fraction, dimensionless	0.17	0.25	0.38
Maximum Dose, mrem/y	52	54	56
Outdoor time fraction, dimensionless	0.33	0.5	0.75
Maximum Dose, mrem/y	42	54	72

Table 5 (continued)
Summary of Sensitivity Analysis for Resident Farmer Scenario
Th-230 = DCGL (64 pCi/g)

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER LOW	MODEL	HIGH
Fruit, vegetable, and grain consumption, kg/y	148	178	214
Maximum Dose, mrem/y	52	54	56
Leafy vegetable consumption, kg/y	12.5	25	50
Maximum Dose, mrem/y	52	54	56
Milk consumption, L/y	50.5	101	202
Maximum Dose, mrem/y	53	54	55
Meat and poultry consumption, kg/y	31.5	63	126
Maximum Dose, mrem/y	53	54	55
Fish consumption, kg/y	10.5	21	42
Maximum Dose, mrem/y	54	54	54
Soil ingestion, g/y	9.15	18.3	36.6
Maximum Dose, mrem/y	53	54	55
Contamination fraction Aquatic food, dimensionless	0.25	0.5	1
Maximum Dose, mrem/y	54	54	54
Livestock fodder intake for meat, kg/d	34	68	136
Maximum Dose, mrem/y	54	54	54
Livestock fodder intake for milk, kg/d	27.5	55	110
Maximum Dose, mrem/y	54	54	54
Livestock water intake for meat, L/d	25	50	54
Maximum Dose, mrem/y	54	54	54
Livestock water intake for milk, L/d	80	160	320
Maximum Dose, mrem/y	54	54	54
Livestock intake of soil, kg/d	0.25	0.5	1
Maximum Dose, mrem/y	53	54	55
Mass loading for foliar deposition, g/m^3	0.00001	0.0001	0.001
Maximum Dose, mrem/y	54	54	54
Depth of soil mixing layer, m	0.04	0.15	0.6
Maximum Dose, mrem/y	50	54	56
Depth of roots, m	0.23	0.9	3.6
Maximum Dose, mrem/y	90	54	45

Table 6
Summary of Sensitivity Analysis for Resident Farmer Scenario
Ra-226 = DCGL (5.0 pCi/g)

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER LOW	MODEL	HIGH
Transport Distribution coefficient of all zones, cm^3/g	353.3	3553	35330
Maximum Dose, mrem/y	54	54	54
Area of contaminated zone, m^2	---	263120	---
Maximum Dose, mrem/y	---	54	---
Thickness of contaminated zone, m	0.15	0.3	0.6
Maximum Dose, mrem/y	40	54	75
Length parallel to aquifer flow, m	441	662	993
Maximum Dose, mrem/y	54	54	54
Density of contaminated zone, g/cm^3	1.17	1.76	2.64
Maximum Dose, mrem/y	52	54	54
Contaminated zone erosion rate, m/y	0.00006	0.0006	0.006
Maximum Dose, mrem/y	54	54	54
Contaminated zone total porosity, dimensionless	0.09	0.30	1
Maximum Dose, mrem/y	54	54	54
Contaminated zone effective porosity, dimensionless	0.06	0.25	1
Maximum Dose, mrem/y	54	54	54
Contaminated zone hydraulic conductivity, m/y	4.45	8.9	17.8
Maximum Dose, mrem/y	54	54	54
Contaminated zone b parameter, dimensionless	0.6	3	15
Maximum Dose, mrem/y	54	54	54
Evapotranspiration coefficient, dimensionless	0.33	0.5	.75
Maximum Dose, mrem/y	54	54	54
Wind Speed, m/s	2.67	4	6
Maximum Dose, mrem/y	54	54	54
Precipitation, m/y	0.73	1.1	1.65
Maximum Dose, mrem/y	54	54	54
Irrigation, m/y	0.3	0.6	1.2
Maximum Dose, mrem/y	54	54	54
Runoff coefficient, dimensionless	0.2	0.4	0.8
Maximum Dose, mrem/y	54	54	54

Table 6 (continued)
Summary of Sensitivity Analysis for Resident Farmer Scenario
Ra-226 = DCGL (5.0 pCi/g)

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER LOW	MODEL	HIGH
Watershed area for nearby stream or pond, m^2	---	575000	---
Maximum Dose, mrem/y	---	54	---
Density of saturated zone, g/m^3	1.79	2.69	4.04
Maximum Dose, mrem/y	54	54	54
Saturated zone total porosity, dimensionless	0.16	0.4	1
Maximum Dose, mrem/y	54	54	54
Saturated zone effective porosity, dimensionless	0.01	0.10	1
Maximum Dose, mrem/y	54	54	54
Saturated zone hydraulic conductivity, m/y	44.5	89	178
Maximum Dose, mrem/y	54	54	54
Saturated zone hydraulic gradient, dimensionless	0.04	0.08	0.16
Maximum Dose, mrem/y	54	54	54
Unsaturated zone 1 thickness, m	---	1.4	---
Maximum Dose, mrem/y	---	54	---
Inhalation rate, m^3/y	5383	8400	13104
Maximum Dose, mrem/y	54	54	54
Mass loading for inhalation, g/m^3	0.00004	0.0002	0.001
Maximum Dose, mrem/y	54	54	54
Indoor dust filtration factor, dimensionless	0.33	0.56	1
Maximum Dose, mrem/y	54	54	54
External gamma shielding factor, dimensionless	0.05	0.21	0.81
Maximum Dose, mrem/y	52	54	62
Indoor time fraction, dimensionless	0.17	0.25	0.38
Maximum Dose, mrem/y	53	54	55
Outdoor time fraction, dimensionless	0.33	0.5	0.75
Maximum Dose, mrem/y	45	54	68

Table 6 (continued)
Summary of Sensitivity Analysis for Resident Farmer Scenario
Ra-226 = DCGL (5.0 pCi/g)

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER LOW	MODEL	HIGH
Fruit, vegetable, and grain consumption, kg/y	148	178	214
Maximum Dose, mrem/y	52	54	56
Leafy vegetable consumption, kg/y	12.5	25	50
Maximum Dose, mrem/y	52	54	56
Milk consumption, L/y	50.5	101	202
Maximum Dose, mrem/y	53	54	55
Meat and poultry consumption, kg/y	31.5	63	126
Maximum Dose, mrem/y	53	54	55
Fish consumption, kg/y	10.5	21	42
Maximum Dose, mrem/y	54	54	54
Soil ingestion, g/y	9.15	18.3	36.6
Maximum Dose, mrem/y	53	54	55
Contamination fraction Aquatic food, dimensionless	0.25	0.5	1
Maximum Dose, mrem/y	54	54	54
Livestock fodder intake for meat, kg/d	34	68	136
Maximum Dose, mrem/y	97	54	102
Livestock fodder intake for milk, kg/d	27.5	55	110
Maximum Dose, mrem/y	97	54	102
Livestock water intake for meat, L/d	25	50	54
Maximum Dose, mrem/y	54	54	54
Livestock water intake for milk, L/d	80	160	320
Maximum Dose, mrem/y	54	54	54
Livestock intake of soil, kg/d	0.25	0.5	1
Maximum Dose, mrem/y	54	54	105
Mass loading for foliar deposition, g/m^3	0.00001	0.0001	0.001
Maximum Dose, mrem/y	54	54	54
Depth of soil mixing layer, m	0.04	0.15	0.6
Maximum Dose, mrem/y	54	54	54
Depth of roots, m	0.23	0.9	3.6
Maximum Dose, mrem/y	95	54	38

Table 7
Value and Basis of Multiplier for Sensitivity Analysis Range

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER MODEL	MULTIPLIER
Transport Distribution coefficient of all zones, cm^3/g (uranium)	500 / 33.575	N/A
Basis for value of multiplier	This is the low end of a site-specific range	
Area of contaminated zone, m^2	263120	N/A
Basis for value of multiplier	This is the 65 acre contaminated area.	
Thickness of contaminated zone, m	2.0	N/A
Basis for value of multiplier	The model input is an upper bound.	
Length parallel to aquifer flow, m	662	1.5
Basis for value of multiplier	An upper bound based on size of the site.	
Density of contaminated zone, g/cm^3	1.76	1.5
Basis for value of multiplier	A maximum expected variation.	
Contaminated zone erosion rate, m/y	0.0006	10
Basis for value of multiplier	Arbitrary as an order of magnitude.	
Contaminated zone total porosity, dimensionless	0.3	3.3
Basis for value of multiplier	A maximum possible variation.	
Contaminated zone effective porosity, dimensionless	0.25	4
Basis for value of multiplier	A maximum possible variation.	
Contaminated zone hydraulic conductivity, m/y	8.9	2
Basis for value of multiplier	A maximum expected variation.	
Contaminated zone b parameter, dimensionless	3	5
Basis for value of multiplier	Reflects an upper limit of RESRAD.	
Evapotranspiration coefficient, dimensionless	0.5	1.5
Basis for value of multiplier	A maximum expected variation.[1]	
Wind Speed, m/s	4	1.5
Basis for value of multiplier	A maximum expected variation.	
Precipitation, m/y	1.1	1.5
Basis for value of multiplier	A maximum expected variation.	
Irrigation, m/y	0.6	2
Basis for value of multiplier	An upper bound reflecting arid conditions.[2]	
Runoff coefficient, dimensionless	0.4	2
Basis for value of multiplier	A maximum expected variation.[1]	

Table 7 (continued)
Value and Basis of Multiplier for Sensitivity Analysis Range

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER MODEL	MULTIPLIER
Watershed area for nearby stream or pond, m^2	575000	N/A
Basis for value of multiplier	This is the actual size of the watershed.	
Density of saturated zone, g/m^3	2.69	1.5
Basis for value of multiplier	A maximum expected variation.	
Saturated zone total porosity, dimensionless	0.4	2.5
Basis for value of multiplier	A maximum possible variation.	
Saturated zone effective porosity, dimensionless	0.1	10
Basis for value of multiplier	A maximum possible variation.	
Saturated zone hydraulic conductivity, m/y	89	2
Basis for value of multiplier	A maximum expected variation.	
Saturated zone hydraulic gradient, dimensionless	0.08	2
Basis for value of multiplier	A maximum expected variation.	
Unsaturated zone 1 thickness, m	3	2
Basis for value of multiplier	A maximum expected variation.	
Inhalation rate, m^3/y	8400	1.56
Basis for value of multiplier	A maximum expected variation.[1]	
Mass loading for inhalation, g/m^3	0.0002	5
Basis for value of multiplier	A maximum expected variation.[2]	
Indoor dust filtration factor, dimensionless	0.56	1.78
Basis for value of multiplier	A maximum expected variation.[1]	
External gamma shielding factor, dimensionless	0.21	3.86
Basis for value of multiplier	A maximum expected variation.[1]	
Indoor time fraction, dimensionless	0.25	1.5
Basis for value of multiplier	A maximum expected variation.	
Outdoor time fraction, dimensionless	0.50	1.5
Basis for value of multiplier	A maximum expected variation.	

Table 7 (continued)
Value and Basis of Multiplier for Sensitivity Analysis Range

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER MODEL	MULTIPLIER
Fruit, vegetable, and grain consumption, kg/y	178	1.2
Basis for value of multiplier	A maximum expected variation.[1]	
Leafy vegetable consumption, kg/y	25	2
Basis for value of multiplier	Arbitrary.	
Milk consumption, L/y	101	2
Basis for value of multiplier	A maximum expected variation.[1]	
Meat and poultry consumption, kg/y	63	2
Basis for value of multiplier	Arbitrary.	
Fish consumption, kg/y	21	2
Basis for value of multiplier	Arbitrary.	
Soil ingestion, g/y	18.3	2
Basis for value of multiplier	A maximum expected variation.[1]	
Contamination fraction Aquatic food, dimensionless	0.5	2
Basis for value of multiplier	A maximum possible variation.	
Livestock fodder intake for meat, kg/d	68	2
Basis for value of multiplier	Arbitrary.	
Livestock fodder intake for milk, kg/d	55	2
Basis for value of multiplier	Arbitrary.	
Livestock water intake for meat, L/d	50	2
Basis for value of multiplier	Arbitrary.	
Livestock water intake for milk, L/d	160	2
Basis for value of multiplier	Arbitrary.	
Livestock intake of soil, kg/d	0.5	2
Basis for value of multiplier	Arbitrary.	
Mass loading for foliar deposition, g/m^3	0.0001	10
Basis for value of multiplier	Arbitrary as an order of magnitude.	
Depth of soil mixing layer, m	0.15	4
Basis for value of multiplier	A maximum expected variation.[1]	
Depth of roots, m	0.9	4
Basis for value of multiplier	A maximum expected variation.[1]	

[1] U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. (Attachment C)

[2] Yu, C., et.al. "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil." Argonne, IL: Argonne National Laboratory. ANL/EAIS-8. April 1993.

The results of the sensitivity analysis of the resident farmer scenario, as presented in the preceding tables, are discussed in the following sections. The discussion is confined to those parameters of the Ra-226 benchmark dose analysis for which a reasonable change in input caused the dose to be less than the benchmark dose (54 mrem/y) by a significant amount (more than 25%; i.e. the dose was less than 43 mrem/y). A sensitivity analysis was not completed for the three radionuclides of interest in combination because this condition is inherently accounted for by application of the unity rule during implementation of the DCGLs.

The annual dose for radium-226 was found to be significantly sensitive to two parameters: thickness of contaminated zone and depth of roots. Radium –226 is present on site at only a few small areas. The model inputs for area of contaminated zone and thickness of contaminated zone are extremely conservative with respect to actual conditions. In other words, the model grossly overestimates the potential contribution of Ra-226 to annual dose, even considering application of the unity rule. Also, the areas where Ra-226 is present will be several feet underground upon completion of reclamation thereby eliminating most or all of the exposure pathways. No adjustment to the scenario is warranted with respect to these parameters.

Drainage 005

The single sensitivity analysis completed for the Drainage 005 scenario included the three radionuclides U-natural, Th-230, and Ra-226 together. The results of the sensitivity analysis are summarized in Table 7. Those parameters for which the sensitivity analysis result is labeled "Not applicable" were not available for evaluation because they were turned off by the software based on the active exposure pathways.

Table 8

Summary of Sensitivity Analysis for Drainage 005 Dose Assessment
Existing average radionuclide concentrations
(U-nat = 94 pCi/g, Th-230 = 44 pCi/g, Ra-226 = 1.4 pCi/g)

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER LOW	MODEL	HIGH
Transport Distribution coefficient of all zones, cm^3/g	500, 588, 353	500,5884,3533	500, 58840,35330
Maximum Dose, mrem/y	0.2	0.2	0.2
Area of contaminated zone, m^2	270	540	1080
Maximum Dose, mrem/y	0.2	0.2	0.2
Thickness of contaminated zone, m	0.01	0.1	1
Maximum Dose, mrem/y	0	0.2	0.3
Length parallel to aquifer flow, m	Not applicable		
Maximum Dose, mrem/y			
Density of contaminated zone, g/cm^3	1.17	1.76	2.64
Maximum Dose, mrem/y	0.2	0.2	0.2
Contaminated zone erosion rate, m/y	0.00006	0.0006	0.006
Maximum Dose, mrem/y	0.1	0.2	0.2
Contaminated zone total porosity, dimensionless	0.09	0.2	1
Maximum Dose, mrem/y	0.2	0.2	0.2
Contaminated zone effective porosity, dimensionless	0.06	0.25	1
Maximum Dose, mrem/y	0.2	0.2	0.2
Contaminated zone hydraulic conductivity, m/y	4.45	8.9	17.8
Maximum Dose, mrem/y	0.2	0.2	0.2
Contaminated zone b parameter, dimensionless	0.2	3	30
Maximum Dose, mrem/y	0.2	0.2	0.2
Evapotranspiration coefficient, dimensionless	0.23	0.5	0.75
Maximum Dose, mrem/y	0.2	0.2	0.2
Wind Speed, m/s	1.67	4	6
Maximum Dose, mrem/y	0.2	0.2	0.3
Precipitation, m/y	0.73	1.1	1.65
Maximum Dose, mrem/y	0.2	0.2	0.2
Irrigation, m/y	-----	0	1
Maximum Dose, mrem/y	-----	0.2	0.2
Runoff coefficient, dimensionless	-----	0	0.9
Maximum Dose, mrem/y	-----	0.2	0.2

Table 8 (continued)
Summary of Sensitivity Analysis for Drainage 005 Dose Assessment
Existing average radionuclide concentrations
(U-nat = 94 pCi/g, Th-230 = 44 pCi/g, Ra-226 = 1.4 pCi/g)

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER LOW	MODEL	HIGH
Watershed area for nearby stream or pond, m^2	Not applicable		
Maximum Dose, mrem/y			
Density of saturated zone, g/m^3	1.79	2.69	4.04
Maximum Dose, mrem/y	0.2	0.2	0.2
Saturated zone total porosity, dimensionless	0.16	0.4	1
Maximum Dose, mrem/y	0.2	0.2	0.2
Saturated zone effective porosity, dimensionless	0.01	0.10	1
Maximum Dose, mrem/y	0.2	0.2	0.2
Saturated zone hydraulic conductivity, m/y	44.5	89	178
Maximum Dose, mrem/y	0.2	0.2	0.2
Saturated zone hydraulic gradient, dimensionless	0.04	0.08	0.16
Maximum Dose, mrem/y	0.2	0.2	0.2
Unsaturated Zone 1 Thickness, m	Not applicable		
Maximum Dose, mrem/y			
Inhalation rate, m^3/y	5383	8400	13104
Maximum Dose, mrem/y	0.1	0.2	0.2
Mass loading for inhalation, g/m^3	0.00004	0.0002	0.001
Maximum Dose, mrem/y	0.1	0.2	0.7
Indoor dust filtration factor, dimensionless	Not applicable		
Maximum Dose, mrem/y			
External gamma shielding factor, dimensionless	Not applicable		
Maximum Dose, mrem/y			
Indoor time fraction, dimensionless	Not applicable		
Maximum Dose, mrem/y			
Outdoor time fraction, dimensionless	0.01	0.042	0.17
Maximum Dose, mrem/y	0.1	0.2	0.7

Table 8 (continued)
Summary of Sensitivity Analysis for Drainage 005 Dose Assessment
Existing average radionuclide concentrations
(U-nat = 94 pCi/g, Th-230 = 44 pCi/g, Ra-226 = 1.4 pCi/g)

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER LOW	MODEL	HIGH
Fruit, vegetable, and grain consumption, kg/y	Not applicable		
Maximum Dose, mrem/y			
Leafy vegetable consumption, kg/y	Not applicable		
Maximum Dose, mrem/y			
Milk consumption, L/y	Not applicable		
Maximum Dose, mrem/y			
Meat and poultry consumption, kg/y	Not applicable		
Maximum Dose, mrem/y			
Fish consumption, kg/y	Not applicable		
Maximum Dose, mrem/y			
Soil ingestion, g/y	9.15	18.3	36.5
Maximum Dose, mrem/y	0.2	0.2	0.2
Contamination fraction Aquatic food, dimensionless	Not applicable		
Maximum Dose, mrem/y			
Livestock fodder intake for meat, kg/d	Not applicable		
Maximum Dose, mrem/y			
Livestock fodder intake for milk, kg/d	Not applicable		
Maximum Dose, mrem/y			
Livestock water intake for meat, L/d	Not applicable		
Maximum Dose, mrem/y			
Livestock water intake for milk, L/d	Not applicable		
Maximum Dose, mrem/y			
Livestock intake of soil, kg/d	Not applicable		
Maximum Dose, mrem/y			
Mass loading for foliar deposition, g/m^3	Not applicable		
Maximum Dose, mrem/y			
Depth of soil mixing layer, m	0.025	0.1	---
Maximum Dose, mrem/y	0.2	0.2	---
Depth of roots, m	Not applicable		
Maximum Dose, mrem/y			

The following parameters, although available to RESRAD sensitivity analysis for Drainage 005, were not evaluated:

Transport Solubility Limit:	This parameter was not used by RESRAD since a distribution coefficient was provided.
Transport Leach Rate:	This parameter was not used by RESRAD since a distribution coefficient was provided.
Cover depth:	The dose assessment included the conservative assumption that no cover will be applied.
Exposure duration:	This parameter is not applicable since the model result is evaluated as peak dose and not total dose or risk.
Carbon-14:	Carbon-14 is not a radionuclide of interest in the subject dose assessment.

Several parameters were not available to the sensitivity analysis provided by the RESRAD software: they were either turned off by the software based on the active exposure pathways (e.g. "Density of cover material"; there is no cover in the model), or the software did not allow a sensitivity analysis of the parameter (e.g. "Irrigation mode").

The results indicate the annual dose to be particularly insensitive, with respect to the difference between the annual dose and the annual dose limit, to all parameters.

Industrial Worker

The single sensitivity analysis completed for the industrial worker scenario included the three radionuclides U-natural, Th-230, and Ra-226 together. The results of the sensitivity analysis are summarized in Table 8. Those parameters for which the sensitivity analysis result is labeled "Not applicable" were not available for evaluation because they were turned off by the software based on the active exposure pathways.

Table 9

Summary of Sensitivity Analysis for Industrial Worker Dose Assessment
U-nat = DCGL, Th-230 = DCGL, Ra-226 = DCGL
(U-nat = 560 pCi/g, Th-230 = 64 pCi/g, Ra-226 = 5.0 pCi/g)

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER LOW	MODEL	HIGH
Transport Distribution coefficient of all zones, cm^3/g	500, 584, 353	500,5884,3533	500, 58840,35330
Maximum Dose, mrem/y	2	2	2
Area of contaminated zone, m^2	---	263120	---
Maximum Dose, mrem/y	---	2	---
Thickness of contaminated zone, m	---	2	---
Maximum Dose, mrem/y	---	2	---
Length parallel to aquifer flow, m	Not applicable		
Maximum Dose, mrem/y			
Density of contaminated zone, g/cm^3	1.17	1.76	2.64
Maximum Dose, mrem/y	2	2	2
Contaminated zone erosion rate, m/y	0.00006	0.0006	0.006
Maximum Dose, mrem/y	2	2	2
Contaminated zone total porosity, dimensionless	0.09	0.2	1
Maximum Dose, mrem/y	2	2	2
Contaminated zone effective porosity, dimensionless	0.06	0.25	1
Maximum Dose, mrem/y	2	2	2
Contaminated zone hydraulic conductivity, m/y	4.45	8.9	17.8
Maximum Dose, mrem/y	2	2	2
Contaminated zone b parameter, dimensionless	0.6	3	15
Maximum Dose, mrem/y	2	2	2
Evapotranspiration coefficient, dimensionless	0.33	0.5	0.75
Maximum Dose, mrem/y	2	2	2
Wind Speed, m/s	2.67	4	6
Maximum Dose, mrem/y	2	2	2
Precipitation, m/y	0.73	1.1	1.65
Maximum Dose, mrem/y	2	2	2
Irrigation, m/y	---	0	---
Maximum Dose, mrem/y	---	2	---
Runoff coefficient, dimensionless	0.2	0.4	0.8
Maximum Dose, mrem/y	2	2	2

Table 9 (continued)
Summary of Sensitivity Analysis for Industrial Worker Dose Assessment
U-nat = DCGL, Th-230 = DCGL, Ra-226 = DCGL
(U-nat = 560 pCi/g, Th-230 = 64 pCi/g, Ra-226 = 5.0 pCi/g)

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER LOW	MODEL	HIGH
Watershed area for nearby stream or pond, m^2	Not applicable		
Maximum Dose, mrem/y			
Density of saturated zone, g/m^3	Not applicable		
Maximum Dose, mrem/y			
Saturated zone total porosity, dimensionless	Not applicable		
Maximum Dose, mrem/y			
Saturated zone effective porosity, dimensionless	Not applicable		
Maximum Dose, mrem/y			
Saturated zone hydraulic conductivity, m/y	Not applicable		
Maximum Dose, mrem/y			
Saturated zone hydraulic gradient, dimensionless	Not applicable		
Maximum Dose, mrem/y			
Unsaturated Zone 1 Thickness, m	Not applicable		
Maximum Dose, mrem/y			
Inhalation rate, m^3/y	5383	8400	13104
Maximum Dose, mrem/y	2	2	2
Mass loading for inhalation, g/m^3	0.00004	0.0002	0.001
Maximum Dose, mrem/y	2	2	3
Indoor dust filtration factor, dimensionless	Not applicable		
Maximum Dose, mrem/y			
External gamma shielding factor, dimensionless	Not applicable		
Maximum Dose, mrem/y			
Indoor time fraction, dimensionless	Not applicable		
Maximum Dose, mrem/y			
Outdoor time fraction, dimensionless	---	0.015	0.06
Maximum Dose, mrem/y	---	2	9

Table 9 (continued)
Summary of Sensitivity Analysis for Industrial Worker Dose Assessment
U-nat = DCGL, Th-230 = DCGL, Ra-226 = DCGL
(U-nat = 560 pCi/g, Th-230 = 64 pCi/g, Ra-226 = 5.0 pCi/g)

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER LOW	MODEL	HIGH
Fruit, vegetable, and grain consumption, kg/y	Not applicable		
Maximum Dose, mrem/y			
Leafy vegetable consumption, kg/y	Not applicable		
Maximum Dose, mrem/y			
Milk consumption, L/y	Not applicable		
Maximum Dose, mrem/y			
Meat and poultry consumption, kg/y	Not applicable		
Maximum Dose, mrem/y			
Fish consumption, kg/y	Not applicable		
Maximum Dose, mrem/y			
Soil ingestion, g/y	9.15	18.3	36.6
Maximum Dose, mrem/y	2	2	2
Contamination fraction Aquatic food, dimensionless	Not applicable		
Maximum Dose, mrem/y			
Livestock fodder intake for meat, kg/d	Not applicable		
Maximum Dose, mrem/y			
Livestock fodder intake for milk, kg/d	Not applicable		
Maximum Dose, mrem/y			
Livestock water intake for meat, L/d	Not applicable		
Maximum Dose, mrem/y			
Livestock water intake for milk, L/d	Not applicable		
Maximum Dose, mrem/y			
Livestock intake of soil, kg/d	Not applicable		
Maximum Dose, mrem/y			
Mass loading for foliar deposition, g/m^3	Not applicable		
Maximum Dose, mrem/y			
Depth of soil mixing layer, m	0.04	0.15	0.6
Maximum Dose, mrem/y	2	2	2
Depth of roots, m	Not applicable		
Maximum Dose, mrem/y			

The following parameters, although available to RESRAD sensitivity analysis, were not evaluated:

Transport Solubility Limit:	This parameter was not used by RESRAD since a distribution coefficient was provided.
Transport Leach Rate:	This parameter was not used by RESRAD since a distribution coefficient was provided.
Cover depth:	The dose assessment included the conservative assumption that no cover will be applied.
Exposure duration:	This parameter is not applicable since the model result is evaluated as peak dose and not total dose or risk.
Carbon-14:	Carbon-14 is not a radionuclide of interest in the subject dose assessment.

Several parameters were not available to the sensitivity analysis provided by the RESRAD software: they were either turned off by the software based on the active exposure pathways (e.g. "Density of cover material"; there is no cover in the model), or the software did not allow a sensitivity analysis of the parameter (e.g. "Irrigation mode").

The results indicate the annual dose to be particularly insensitive, with respect to the difference between the annual dose and the annual dose limit, to all parameters.

APPENDIX H

Disposal Cell Design
Siting Study For On-site Disposal Cell

PROJECT 4: DISPOSAL CELL DESIGN
SITING STUDY FOR ON-SITE DISPOSAL CELL
MORRISON KNUDSEN CORPORATION
SEPTEMBER 1996

1.0 PURPOSE

This report presents the results of a siting study for an on-site disposal cell for disposal of wastes from the planned decommissioning of the Sequoyah Fuels Corporation (SFC) Facility near Gore, Oklahoma. The siting study provides information in accordance with the SFC Scope of Work for Project 4, "Disposal Cell Design" dated April 24, 1996, and the subsequent proposal by Morrison Knudsen Corporation (MK) dated June 1996.

The siting study focuses on the suitability of four alternative on-site locations identified generally as follows:

- Process Area
- Fertilizer Pond Area
- North Hill
- South Hill

The site locations and vicinity are shown on Figure 1.

The sites are evaluated on the basis of criteria established as part of this siting study, including applicable regulations, potentially applicable regulations (in the case of possible disposal of hazardous wastes), and MK experience with design and construction of disposal cells for long-term waste isolation. Favorable and unfavorable conditions and factors are summarized for each site. Site characteristics that are considered the same (as documented or assumed herein) for all sites are also summarized.

The siting study is organized as follows:

- Purpose
- Evaluation Criteria
- Site Descriptions
- Comparative Analysis of Sites
- Conclusions

2.0 EVALUATION CRITERIA

2.1 General

Evaluation criteria are summarized below to give the basis for assessing the suitability of the four alternative sites. The siting evaluation criteria are drawn from the following sources:

- 10 CFR[1] Part 40, Appendix A, "Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Waste Produced by the Extraction or Concentration of Source Material from Ores Processed Primarily for their Source Material Content.
- 40 CFR Part 192, Subpart D, "Standards for Management of Uranium Byproduct Materials Pursuant to Section 84 of the Atomic Energy Act of 1954, as Amended." (as referenced by 10 CFR Part 40, Appendix A).
- 40 CFR Part 264, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities", Subparts B, G, and N (related to the possibility of hazardous waste disposal in the SFC disposal cell).
- Administrative Rules of Oklahoma, Titles 252 and 785 (related to the possibility of hazardous waste disposal in the SFC disposal cell).
- MK experience on the Weldon Spring Site Remedial Action Project, Uranium Mill Tailings Remedial Action Project, and other projects.

Some criteria are not expected to be factors that differentiate between sites, and these are also discussed below.

2.2 Disposal of Uranium Byproduct Material

Criteria related to siting for disposal of uranium byproduct material, from 10 CFR Part 40, Appendix A, and 40 CFR Part 192, are summarized in Table 1, Part 1: Disposal of Uranium Byproduct Material. These are the primary regulations applicable to the disposal of wastes from the SFC facility. The longevity design standard (Criteron 6, 10 CFR Part 40, Appendix A) is stated only in general terms. Compliance with the longevity standard for control of radiological hazards is typically accomplished by determining the adequacy of the specific site and specific design for disposal of wastes.

2.3 Possible Disposal of Hazardous Waste

Siting criteria related to the possible disposal of hazardous waste (e.g., arsenic) in the SFC disposal cell are summarized in Table 1, Part 2: Hazardous Waste Disposal. The criteria are derived mostly from 40 CFR Part 264, which is incorporated by reference both by 40 CFR Part 192, Subpart D, and by the Administrative Rules of Oklahoma, Title 252, Chapter 200. Documentation is needed for a possible statement that the facility is

1. Code of Federal Regulations

not impacted by criterion 23, [Administrative Rules of Oklahoma, Title 252, chapter 200, Article 11-4(d)].

2.4 General Siting Guidelines

Additional general siting guidelines are given in Table 1, Part 3: General Guidelines. These guidelines address practicality, and cost, and provide some detailed guidance for meeting the regulatory requirements presented in of Table 1 Part 1.

2.5 Non-Differentiating Site Factors

Several factors and categories of factors are assumed to be the same or essentially the same for the four sites under consideration. These factors are not expected to differentiate one site from another, and are summarized as follows:

- Evaluation criteria Nos. 6, 9, 10, 11, 16, 18, 20, 21, 22, 23, 24, 27, 29, 30, and 36 listed in Table 1.
- Avoidance of areas with special or unique attributes (state and national parks, wildlife refuges, etc.)
- Community impacts (with the exception of the highway crossing for access to the south hill site)

Other factors not considered in this siting study are potential impacts on siting from compliance with the National Environmental Policy Act (NEPA) e.g., potential impacts due to critical habitat and botanically sensitive areas, archeological and historical resources, and wetlands permits.

It is also assumed that solid waste as defined in 40 CFR Part 258 will either 1) not be placed in the on-site disposal cell, or, 2) if such disposal occurs, it will not impose additional restrictions on siting.

3.0 SITE DESCRIPTIONS

3.1 General

The SFC Facility is located primarily in Section 21, T12N, R12E, in Sequoyah County, Oklahoma. The terrain is gently rolling in character with occasional steep slopes. Geology of the SFC Facility area is generally described as surface alluvial and terrace deposits overlying bedrock of the Atoka Formation (Ref. 1). The terrace deposits are generally silts and clays, with some containing varying amounts of sand and gravel. The Atoka Formation beneath the Facility consists of irregularly bedded units of sandstone, siltstone, and shale, with a total thickness of approximately 390 feet. Additional details about the Facility and surrounding area are given in Ref. 1.

3.2 Process Area Site

The Process Area site is located primarily north and northwest of the main process building (Fig. 2). The area contains uranium-contaminated soils and bedrock which may require excavation and disposal in the cell, depending on any leave-in-place criteria which may be applied. (Whether or not the soil and bedrock needs to be excavated can have serious impacts on a siting decision, as discussed below). Limits of the site are assumed to be the following:

- The administration building
- The substation and uncontaminated area to the north of the substation
- Existing drainages on the north and northwest
- Raffinate storage basins (Clarifiers 1A and 2A) on the west
- Nearby limits of the Process Area as shown in Ref. 1, Fig. 3

Terrace deposits at the Process Area site range between approximately 0-14 feet thick (Ref.1, Fig. 13). The uppermost bedrock is primarily shale (Ref.1, Fig. 15)

3.3 Fertilizer Ponds Area Site

The Fertilizer Ponds Area site is located south of the Process Area (Figs. 1 and 3). Currently, five ponds are located at the site. The site area under consideration is the area covered by the ponds and some adjacent area. Limits of the site are assumed to be the following:

- The stormwater reservoir to the north
- The Facility boundary on the east (State Highway 10)
- The existing drainage on the south and west of the area.

Terrace deposits in the Fertilizer Ponds Area site ranged between approximately 1 to 12 feet in thickness prior to pond construction (Ref.1, Fig. 13). The uppermost bedrock in the area is sandstone at some locations and shale at others (Ref. 1, Fig. 15).

3.4 North Hill Site

The north hill site is located on the Facility north of the Process Area (Figs. 1 and 4). The site area is on top of a small hill. Limits of the site are assumed to be the following:

- Facility boundaries on the north and west (Corps of Engineers property) and the east (State Highway 10).
- Steeper slopes on the north and east sides of the hill
- The existing drainage southwest of the hilltop
- The northern limit of the Process Area

The site is not characterized as well as the SFC Industrial Area, but some drilling was performed in the area for subsurface investigation and characterization purposes. Terrace deposits in the North Hill site are approximately 3 feet thick (Ref. 1, Fig. 17). The uppermost bedrock in the area is primarily sandstone (Ref. 1, Fig. 15).

3.5 South Hill Site

The South Hill site is located in the southeast corner of Section 22, T12N, R21E, in Sequoyah County. The site is on a prominent hill north of Interstate Highway 40 (I-40) and east of State Highway 10 (Figs. 1 and 5). The site is on land owned by SFC approximately one mile southeast of the Facility boundary. The area was previously investigated for the possible disposal of raffinate sludge. Limits of the site are assumed to be the following:

- Sequoyah Fuels International Corporation (SFIC) property boundary on the south (Interstate 40)
- Steeper slopes surrounding the site

The site is not characterized as well as the SFC Industrial Area. The geology of the site was investigated in 1979 by drilling 15 holes (Ref. 2). Soil consists mostly of highly weathered bedrock of a maximum thickness of approximately 10 feet, but generally 5 feet or less. Bedrock is sandstone, siltstone, and shale of the Atoka formation. The uppermost bedrock is generally shale with some sandstone. The uppermost groundwater zone was described in 1979 as perched and potentially due primarily to seepage of water from a stock pond that was drained in 1978. As is the case at the Facility, the sandstone units act as aquitards which can cause perched water zones.

4.0 COMPARATIVE ANALYSIS OF SITES

4.1 General

Results of a comparison of the four sites with the evaluation criteria and with each other are given herein. Favorable and unfavorable conditions are summarized for each site in Table 2, except that conditions which are similar for each site are presented separately below. A disposal cell footprint is shown on Figures 2 through 5 for each site, based on the following assumptions for all the sites:

A. Capacity for waste of 8 million cubic feet.

B. Exterior side slopes of 5(H):1(V)

C. Square or rectangular footprint, for construction simplicity and minimization of area of footprint (where a square minimizes area better than a rectangle).

The assumptions above provide a reasonable basis for comparisons between the sites and with the evaluation criteria. Detailed evaluation of optimum layout design is beyond the scope of this study.

4.2 Similar Conditions for All Sites

Several key site conditions are similar for all four sites evaluated in this study. These similar conditions are expected to have either the same or negligible impact on the comparisons between the sites or with the evaluation criteria. All the sites have the following similar conditions:

A. Remoteness from populated areas.

B. None of the sites overlie terrace, alluvial, or bedrock aquifers, and none are located in recharge areas or potential recharge areas for bedrock aquifers (Ref. 1).

C. Low potential for perched groundwater rise to saturate waste, either due to existing conditions or by use of engineered drainage facilities to divert perched water.

D. Groundwater in the terrace groundwater system is considered Class IIIA (due to low yield).

E. Near-surface occurrence of non-rippable rock (sandstone) that tends to make complete below-grade disposal impracticable.

F. Site constraints that require cell sideslopes to be as steep as possible, while complying with long-term protection requirements.

G. Ground motions due to Maximum Credible Earthquake (MCE) at all sites are similar.

H. Sufficient distance from faults that could preclude construction of the disposal cell at any site. (i.e., nearby capable faults are absent and a design for stability against MCE motions is practicable at all sites.)

I. Bedrock provides adequate foundation support.

J. Post-closure use of any of the sites will be adequately controlled.

K. Exclusion from Probable Maximum Flood (PMF) flood zones. All sites are located above Elevation 500 feet Mean Sea Level (MSL), and the crest elevation for the dam impounding Robert S. Kerr Reservoir is lower, at Elevation 483 feet MSL.

L. Ultimate gully erosion potential is limited by hard sandstone bedrock units, i.e., the depth to sandstone bedrock is the only differentiating factor between sites with regard to maximum depth of potential gullies.

M. All sites have a low potential to effectively compete with other nearby locations for higher uses.

N. None of the sites are located within potential areas of subsidence.

O. None of the sites are located above potential mineral resources.

4.3 Key Issues

Several key issues are evident from a comparison of the four sites. The key issues that differentiate the sites from each other are as follows:

- Available area for disposal facilities, which affect practicability of accommodating operations and any increases in quantities for disposal.
- Proximity to alluvial terrace aquifer.
- Upstream rainfall catchment area
- Leave-in-place criteria
- Site access
- Erosion potential
- Leachate management, including treatment and discharge, during cell construction
- Cost

The Process Area site is affected mostly by the potential to leave some uranium (and possibly other) contamination beneath the cell. If leaching by local surface infiltration is a principal pathway that controls leave-in-place criteria, construction of the cell will reduce long-term infiltration. The reduction in infiltration may be sufficient to allow greater concentrations of contaminants to be left. The cell would also act as an effective barrier to physical removal of contaminated materials and radon gas flux. On the other hand, if all contaminated materials need to be placed in the cell, costs could increase significantly for a process area location. Excavation of contaminated materials would leave an uneven surface that would have to be smoothed and shaped with backfill. Backfilling complexity would depend on whether or not a liner system is required, avoidance of any perched groundwater, and other groundwater protection issues. Additionally, either staged cell construction or double handling of contaminated materials would also be required. In terms of the other factors listed above, the Process Area site has some of the most favorable conditions. Site access, leachate management, and upstream rainfall catchment area conditions are clearly favorable. Erosion protection from gully intrusion is also more favorable, although possibly only to a small degree. More sandstone units between the site and the Illinois River (Ref. 1, Fig. 15) and a detailed analysis may show that the potential maximum depth of gully erosion in the shale may be the least of any of the sites.

The Fertilizer Pond Area site is primarily uncontaminated and has been graded for pond construction. The site is unlikely to be affected significantly by leave-in-place criteria since uranium concentrations are generally less than 40 µg/g (Ref.1, Fig.44). The site is bordered on the downslope sides by more shale and less outcroppings of sandstone than the other sites. A detailed analysis of potential gully depths may show that increased cost of erosion protection for this purpose is needed relative to the process area. The site is closer to the terrace alluvial aquifer adjacent to the Illinois River, and groundwater flow velocities are suspected of being greater than at the other sites.

The North Hill site has less potential for long-term perched water in the terrace groundwater system because a disposal cell will occupy most of the recharge area. The site is uncontaminated and the cell could be constructed without scheduling required decontamination and backfilling first. The North Hill site may be restricted in area to the point that increased excavation depth (for below-grade disposal) is needed relative to the process area or fertilizer pond area sites. Relocation of power transmission lines would probably be needed to minimize long-term potential for human intrusion during transmission line maintenance and to maintain site security.

The South Hill site has several unfavorable conditions relative to the other sites. It is restricted by steep slopes and near-surface shale bedrock that may be more susceptible to greater erosion potential, including deeper gully erosion, than the other three sites. Site access is more difficult for long-term surveillance as well as during construction. Steep slopes to the north and east, and the I-40 right-of-way, limit the shape of the cell footprint to a rectangle (which covers more area than a square, all other factors being equal, per unit volume of waste.)

5.0 CONCLUSIONS

A. Evaluation of the four sites indicates that all sites are suitable, to varying degrees, for long-term disposal of uranium byproduct materials. This conclusion is dependent on the following:

   1. Additional evaluation of potential for groundwater contamination (and subsequent surface water contamination via groundwater seeps).

   2. Detailed geomorphological analysis of the south hill site, to address questions of erodibility of shale bedrock that could cause the site to be impracticable for long-term isolation of wastes.

   3. Other evaluations not within the scope of this siting study (e.g. NEPA compliance)

B. All of the sites possess favorable conditions for most of the critical conditions. This conclusion is based on the following:

   1. Seismological conditions: The area is seismically inactive.

   2. Geomorphology: Ongoing mass wasting processes are not evident. Gully erosion potential is limited by hard sandstone bedrock. Channel shifting processes do not effect any site.

   3. Hydrology: All sites lie well above a PMF level. All sites have very small or negligible upstream rainfall catchment areas.

   4. Groundwater: None of the sites overlie alluvial terrace or bedrock aquifers. None of the sites are located in recharge areas or potential recharge areas for bedrock aquifers. Groundwater levels in deeper systems at any site will not rise to the point where wastes can be inundated. Shallow perched

groundwater can either be avoided or diverted by engineered drains. Sandstone units act as aquitards between all sites and underlying groundwater zones.

5. Foundation: None of the sites are underlain by highly compressible soils or other materials. Cell foundations at any site can be constructed predominantly on bedrock.

C. The following key issues should be resolved to support selection between the four candidate sites [SFC may choose to consider these issues outside of this report].

   1. Whether hazardous waste will require disposal in the cell.
   2. Leave-in-place criteria for the radioactive wastes.
   3. Required cell capacity.
   4. Additional analyses of erosion potential for all sites, but particularly the South Hill site.

6.0 REFERENCES

1. Sequoyah Fuels, February 2, 1996, Draft Site Characterization Report
2. Kerr-McGee Nuclear Corporation, 27 July and August 1979 (approximate date), Environmental Report for Sequoyah Facility Raffinate Sludge Disposal. (Draft distributed by Kerr-McGee for internal review July 27, 1979, includes the May 1979 “Exhibit A, Hydrologic Assessment, Raffinate Sludge Burial Site, Kerr-McGee Sequoyah Facility.” Subsequent copy of the report provided by SFC contains August 1979 version of “Hydrologic Assessment...” but the report itself is not dated)

TABLE 1: Evaluation Criteria for Siting Study, (Sheet 1 of 5)

No.	Source	Criteria	Comments
	PART 1: DISPOSAL OF URANIUM BYPRODUCT MATERIAL		
1	10 CFR Part 40, Appendix A	Ability of the site to accommodate expected disposal volume and potential increased capacities without degradation in long-term stability and other performance factors.	Relates to potential for increases in quantities of waste for disposal, depending on cleanup criteria and implementation of cleanup. Summarized from "Introduction".
2		Licensees or applicants may propose alternatives to specific requirements in this Appendix. The Commission may find that levels of stabilization, containment, and protection are "...equivalent to, to the extent practicable, or more stringent than the level which would be achieved by the requirements of this Appendix and the standards promulgated by the Environmental Protection Agency in 40 CFR Part 192, Subparts D and E."	This criterion may allow flexibility in siting, subject to regulatory approval, at sites that do not meet the specific requirements. Summarized from "Introduction"
3		General goal or broad objective in siting and design decisions is permanent isolation of tailings and associated contaminants, without ongoing maintenance. The following must be considered: - Remoteness from populated areas - Hydrologic and other natural conditions as they contribute to continued immobilization and isolation of contaminants from groundwater sources - Potential for minimizing erosion, disturbance, and dispersion by natural forces over the long term. Overriding consideration must be given to siting features affecting long term impacts, as opposed to engineering design, short-term convenience or benefits such as minimization of transportation or land acquisition costs.	Summarized from Criterion 1

TABLE 1: Evaluation Criteria for Siting Study, (Sheet 2 of 5)

4		Prime option for disposal of tailings is below grade. If full below grade burial is not practicable, exposed embankment size and slope steepness must be minimized to the extent reasonably achievable or appropriate.	Summarized from Criterion 3. Blasting rock at excessive cost may make this option impracticable
5		Minimize upstream rainfall catchment area.	Summarized from Criterion 4a.
6		Topographic features should provide good wind protection.	Criterion 4b.
7		Embankment and cover slopes must be relatively flat. In general, slopes should not be steeper than 5(H):1(V). If slopes steeper than 5(H):1(V) are proposed, justification is required.	Summarized from Criterion 4c. Affects potential layouts for disposal cell.
8		Overall stability, erosion potential, and geomorphology of surrounding terrain must be evaluated to avoid ongoing or potential processes which would lead to impoundment instability.	Summarized from Criterion 4d.
9		Impoundment may not be located near a capable fault that would cause a maximum credible earthquake (MCE) larger than the impoundment could withstand. ("Capable fault" defined in Section III (g) of Appendix A, 10 CFR Part 100, i.e., (a) movement at least once in the past 35,000 years, or (b) recurring movement within the past 500,000 years, or (c) demonstrated macro-seismicity, or (d) adequate structural relationship to faults defined above.)	Summarized from Criterion 4e.
10		Where feasible, impoundment design should promote deposition in order to enhance the thickness of the cover over time.	Summarized from Criterion 4f. Not considered a primary goal for siting (forces which move material can vary between deposition and erosion, depending on intensity; water transporting sediment onto cover will also tend to increase infiltration through cover; etc.)
11		Foundation must be capable of providing adequate support to prevent failure of the liner.	Summarized from Criterion 5 A(2)(b). (Liner exemption possible pursuant to Criterion 5A (3).)
12		The waste disposal area design must control radiological hazards "for 1000 years, to the extent reasonably achievable, and, in any case, for at least 200 years,...".	Summarized from Criterion 6-(1) Also a requirement in 40 CFR 192, Subpart D.

13		Design requirements for longevity apply to any portion of a disposal site unless Ra-226 is not greater than background level by 5 pCi/g for the first 15 cm below the surface and by 15 pCi/g averaged over 15-cm thick layers more than 15 cm below the surface.	Summarized from Criterion 6-(6). Also a requirement in 40 CFR Part 192, Subpart D.
14		The final disposition of tailings, residual radioactive material, or wastes at milling sites should be such that ongoing active maintenance is not necessary to preserve isolation.	Summarized from Criterion 12.
	PART 2: HAZARDOUS WASTE DISPOSAL		
15	40 CFR Part 192, Subpart D	Uranium byproduct disposal areas must comply with the closure performance standard in 40 CFR 264.111 with respect to nonradiological hazards.	Summarized from Part 192.32 (b).
16	40 CFR Part 264	Disposal facilities must not be located within 61 meters (200 feet) of a fault which has had displacement in Holocene time.	Summarized from Part 264.18 (a).
17		The disposal facility must be closed in a manner that minimizes the need for further maintenance.	Summarized from Part 264.111
18		Post closure use of property must never be allowed to disturb the integrity of the final cover, liner(s), or any other other component of the containment system, or function of the monitoring system.	Summarized from Part 264.117 (c).
19	Administrative Rules of Oklahoma, Title 252, Chapter 200	Landfill disposal shall not occur within 200 feet of the site perimeter (buffer zone).	Summarized from 200-9-4
20		Disposal facility cannot be located over or through an unconsolidated alluvial or terrace deposit aquifer or through a bedrock aquifer or their recharge areas.	Summarized from 200-11-4(a)(2)
21		Disposal facility cannot be located within one-quarter mile of any public or private water supply well, except for wells on applicant's property or permanently abandoned wells plugged by the applicant.	Summarized from 200-11-4(b)
22		Disposal facility cannot be located in a 100 year floodplain.	Summarized From Part 200-11-4(c)

TABLE 1: Evaluation Criteria for Siting Study, (Sheet 4 of 5)

23		Disposal site cannot be located within one mile of the conservation pool elevation of any reservoir which supplies water for a public water supply or within one mile of any scenic river.	Summarized from Part 200-11-4(d). Robert S. Kerr Reservoir is designated as "Public and Private Water Supply beneficial use" in the Administrative Rules of Oklahoma, Title 785, Chapter 45, Appendix A. If exemption is possible, approval of the exemption should be obtained.
	PART 3: GENERAL GUIDELINES		
24		Avoid heterogeneous or very compressible foundations which produce unacceptable differential settlements.	
25		Disposal site should not be located on highly erodible soil or rock.	
26		Locate disposal site above the PMF (or dam break flood) level, if possible.	Tends to reduce cost of protective measures and improve long-term stability.
27		Locate disposal site away from active channels.	Long-term erosion and shifting of channels tends to increase threat of undercutting or eroding cell.
28		Locate disposal site away from escarpments and steep slopes subject to erosion or mass wasting processes.	
29		Avoid subsidence areas caused by natural or human causes.	
30		Avoid known or potential mineral resources.	
31		Locate disposal facility over existing contaminated materials if it will reduce the need to treat or remove materials (by reducing infiltration and migration potential, etc.), or, conversely, locate disposal cell away from contaminated areas if necessary to reduce impact on construction scheduling and material handling.	Depends on acceptable results from risk analysis. If the contaminated material must go into cell, double-handling may result.

TABLE 1: Evaluation Criteria for Siting Study, (Sheet 5 of 5)

32		Avoid existing facilities if excessive costs are needed to double-handle demolition debris.	
33		The site should have sufficient space to accommodate closure operations.	
34		Locate disposal site within reasonable haul distance of borrow materials.	
35		Locate disposal site as close as practical to bulk of material to be placed in the disposal cell.	
36		Avoid sites with potential for higher uses (prime farmland, hubs of transportation networks, etc.)	

TABLE 2: Summary of Favorable and Unfavorable Conditions at Each Site, (Sheet 1 of 4)

Site	Favorable Conditions	Unfavorable Conditions	Comments
Process Area	1. Most waste is located nearby 2. Located farther from steeper slopes than the other three sites. 3. May be possible to leave some waste in place, protected by stability of overlying cell (if waste is not a groundwater contaminant source) 4. Proximity and lateral extent of hard sandstone bedrock limits the potential for long-term erosion to undercut the disposal cell. 5. Site activities reduce the potential for impacts from NEPA compliance. 6. Very small upslope catchment area for runoff.	1. Some waste at site needs double handling for disposal in the cell. 2. Site constraints on expansion of disposal cell footprint include the following: a. SFC Facility boundary to the east b. Transformer station c. Drainages to the north and northwest 3. Proximity of sandstone bedrock tends to increase costs to build a uniform, readily constructible cell foundation.	1. Staged construction of a disposal cell may reduce double-handling of waste, but may also be more costly overall. 2. Expansion of the disposal cell footprint could occur if additional quantities of waste require disposal, or if cell slopes need to be less steep than assumed.

TABLE 2: Summary of Favorable and Unfavorable Conditions at Each Site, (Sheet 2 of 4)

Fertilizer Ponds Area	1. Little, if any, waste would require double handling. 2. Proximity and lateral extent of hard sandstone bedrock limits the potential for long-term erosion to undercut the disposal cell. 3. Upslope catchment area for runoff is minimized.	1. Haul distance for waste is greater than for the Process Area and North Hills Sites. 2. Proximity of sandstone bedrock tends to increase costs to build a uniform, readily constructible cell foundation. 3. Site constraints on expansion of disposal cell footprint include the following: a. SFC Facility boundary to the east. b. The drainage located south and west of the area. 4. The site is closest to the terrace alluvial aquifer next to the Illinois River, and groundwater velocity in the upper groundwater beneath the site may be higher than the other sites.	1. Staged construction of a disposal cell may reduce double-handling of waste, but may also be more costly overall. 2. Expansion of the disposal cell footprint could occur if additional quantities of waste require disposal, or if cell slopes need to be less steep than assumed.

TABLE 2: Summary of Favorable and Unfavorable Conditions at Each Site, (Sheet 3 of 4)

North Hill Site	1. Upslope catchment area for runoff is minimized. 2. Proximity and lateral extent of hard sandstone bedrock limits the potential for long-term erosion to undercut the disposal cell. 3. Site can be prepared without any decontamination. 4. Site is relatively near the sources of waste.	1. Proximity of hard sandstone bedrock tends to increase costs to build a uniform, readily constructible cell foundation. 2. Steep slopes in proximity to edge of disposal cell increase potential for long-term erosion to undercut the disposal cell. 3. Site constraints on expansion of the disposal cell footprint include the following: a. SFC Facility boundary to the north and east b. Steeper slopes to the north and east. c. The drainage located southwest of the site. 4. Power lines may require relocation.	1. Staged construction of a disposal cell may reduce double-handling of waste, but may also be more costly overall. 2. Expansion of the disposal cell footprint could occur if additional quantities of waste require disposal, or if cell slopes need to be less steep than assumed.

TABLE 2: Summary of Favorable and Unfavorable Conditions at Each Site, (Sheet 4 of 4)

South Hill Site	1. Upstream catchment area for runoff is minimized. 2. Proximity and lateral extent of hard sandstone bedrock limits the potential for long-term erosion to undercut the disposal cell. 3. Site can be prepared without any decontamination.	1. Proximity of hard sandstone bedrock tends to increase costs to build a uniform, readily constructible cell foundation. 2. Waste haulage to site requires crossing State Highway 10 and a longer distance than the other three sites. 3. Site constraints on expansion of the disposal cell footprint include the following: a. SFC property boundary to the south. b. Steeper slopes which surround the site. 4. Leachate transfer, treatment, and discharge is more complex. Transfer of untreated leachate across non-industrial areas and state Highway 10 may be problematic. 5. Site is adjacent to Interstate 40.	1. Staged construction of a disposal cell may reduce double-handling of waste, but may also be more costly overall. 2. Expansion of the disposal cell footprint could occur if additional quantities of waste require disposal, or if cell slopes need to be less steep than assumed.

Figure 1: Vicinity Map and Site Locations

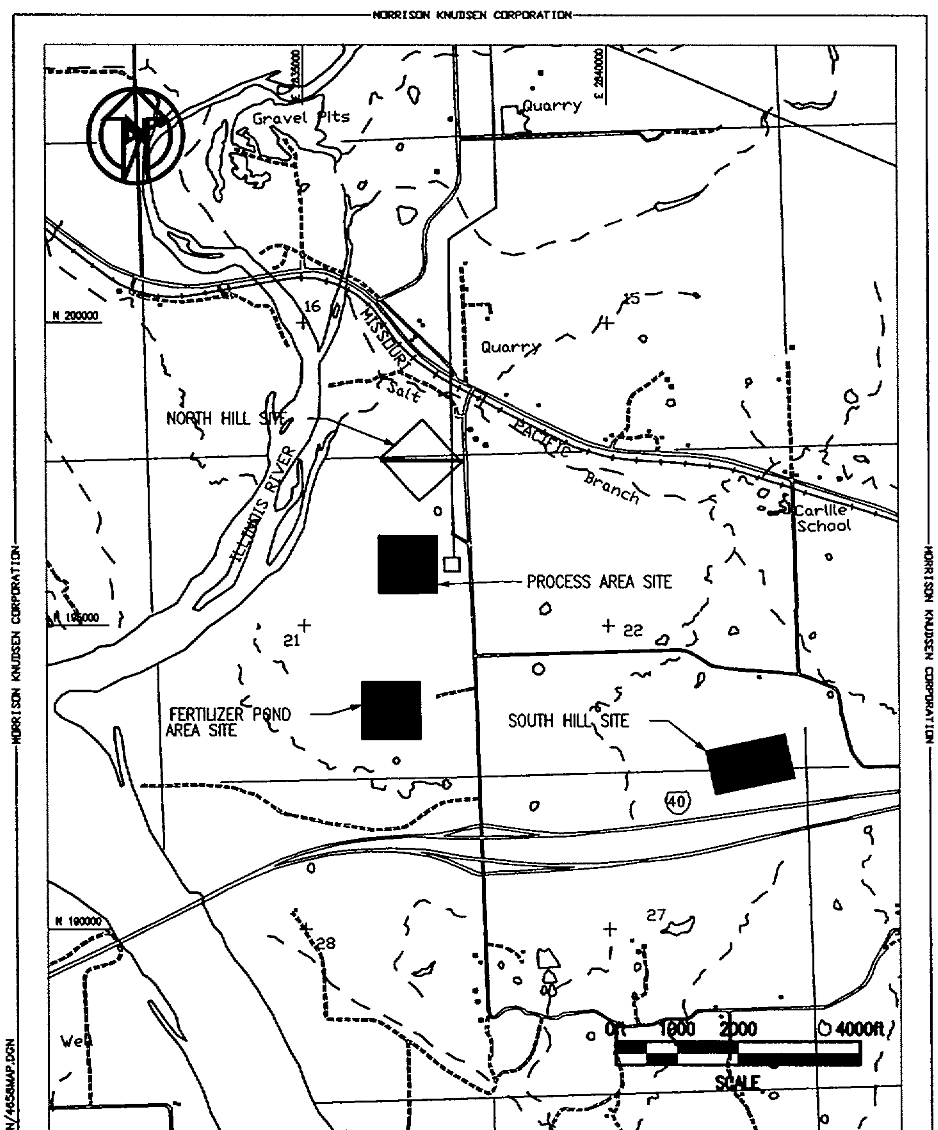


FIGURE 1
VICINITY MAP AND SITE LOCATIONS

FIGURE

Figure 2: Process Area Site

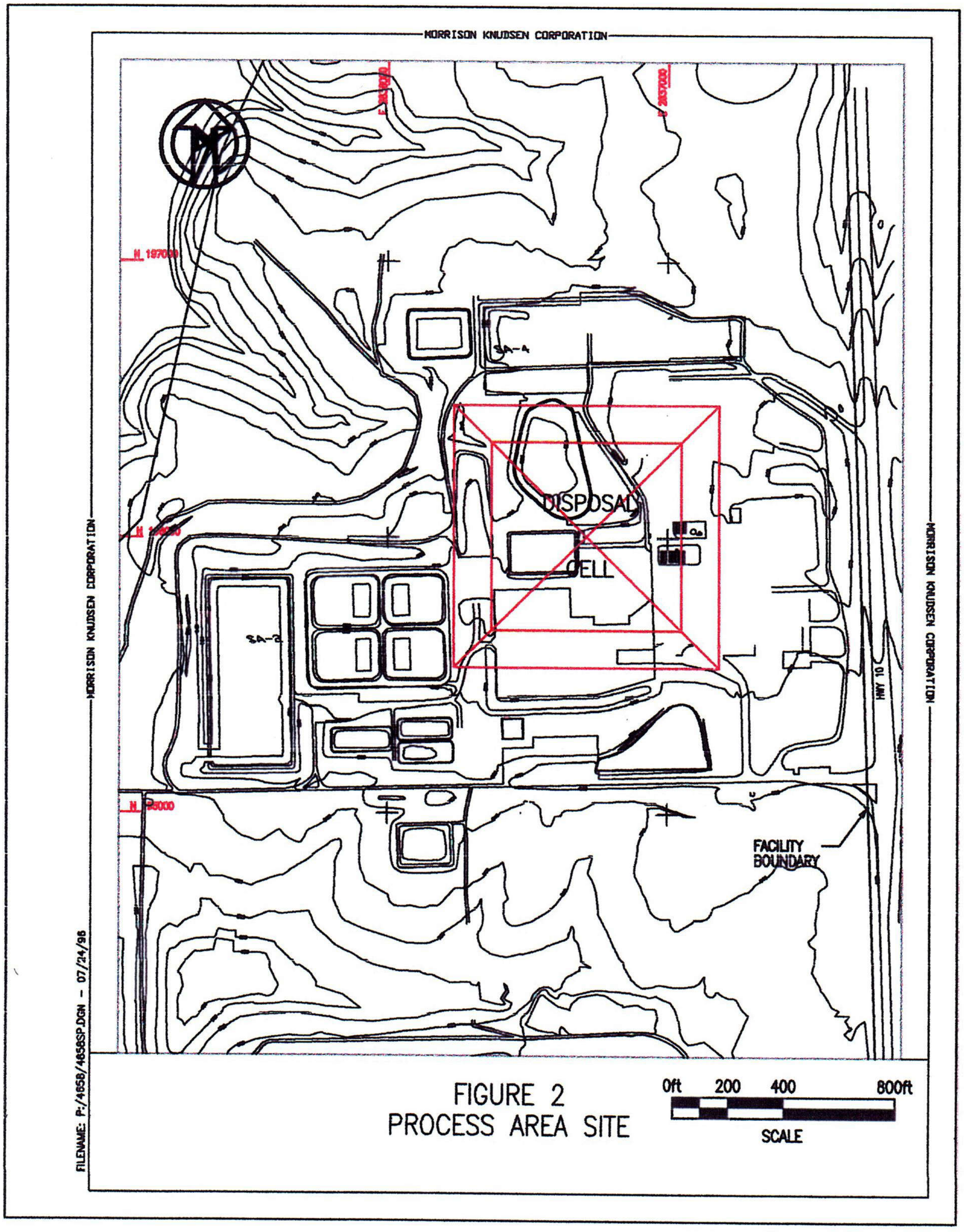


FIGURE 2
PROCESS AREA SITE

C06

Figure 3: Fertilizer Pond Area Site

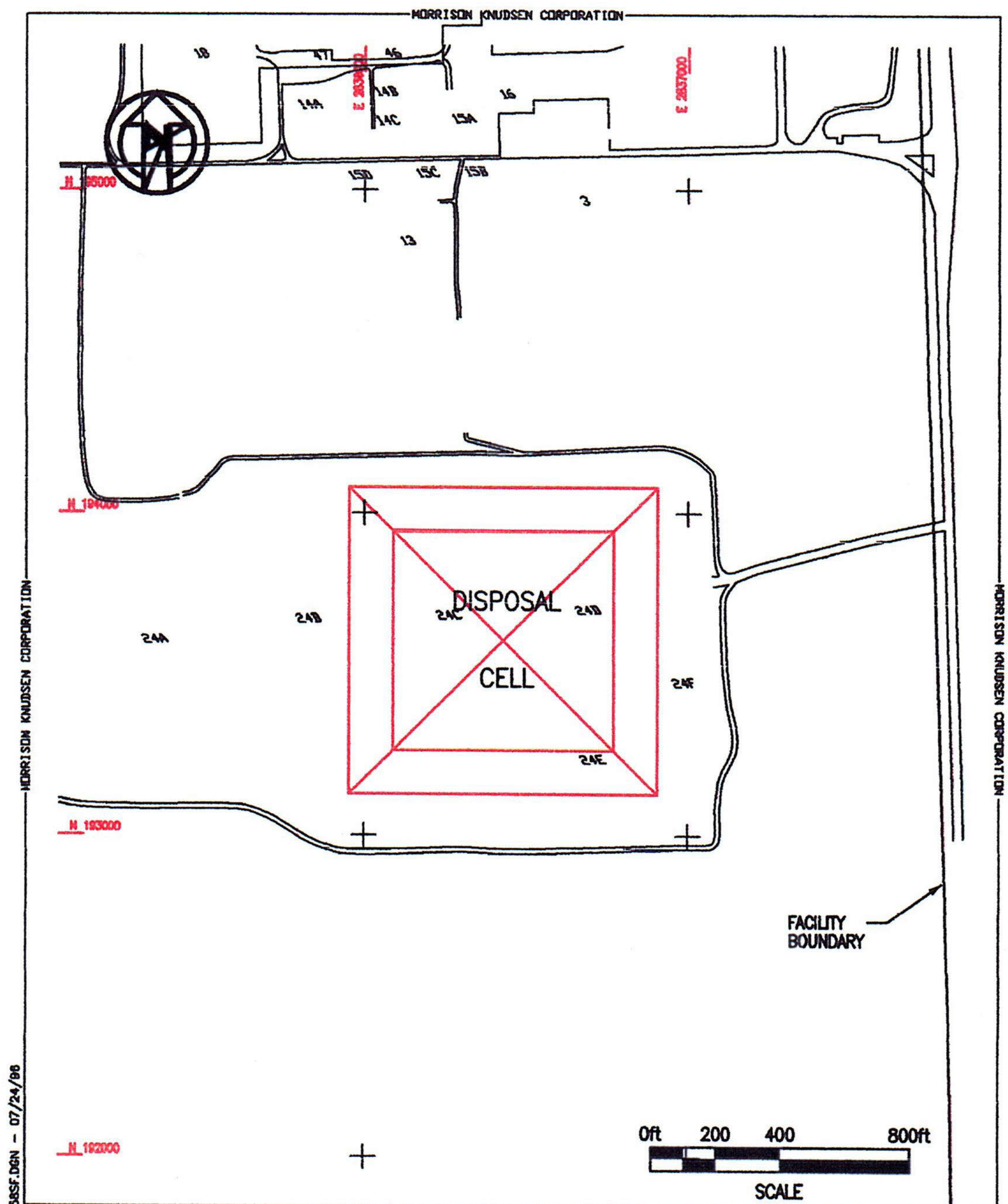
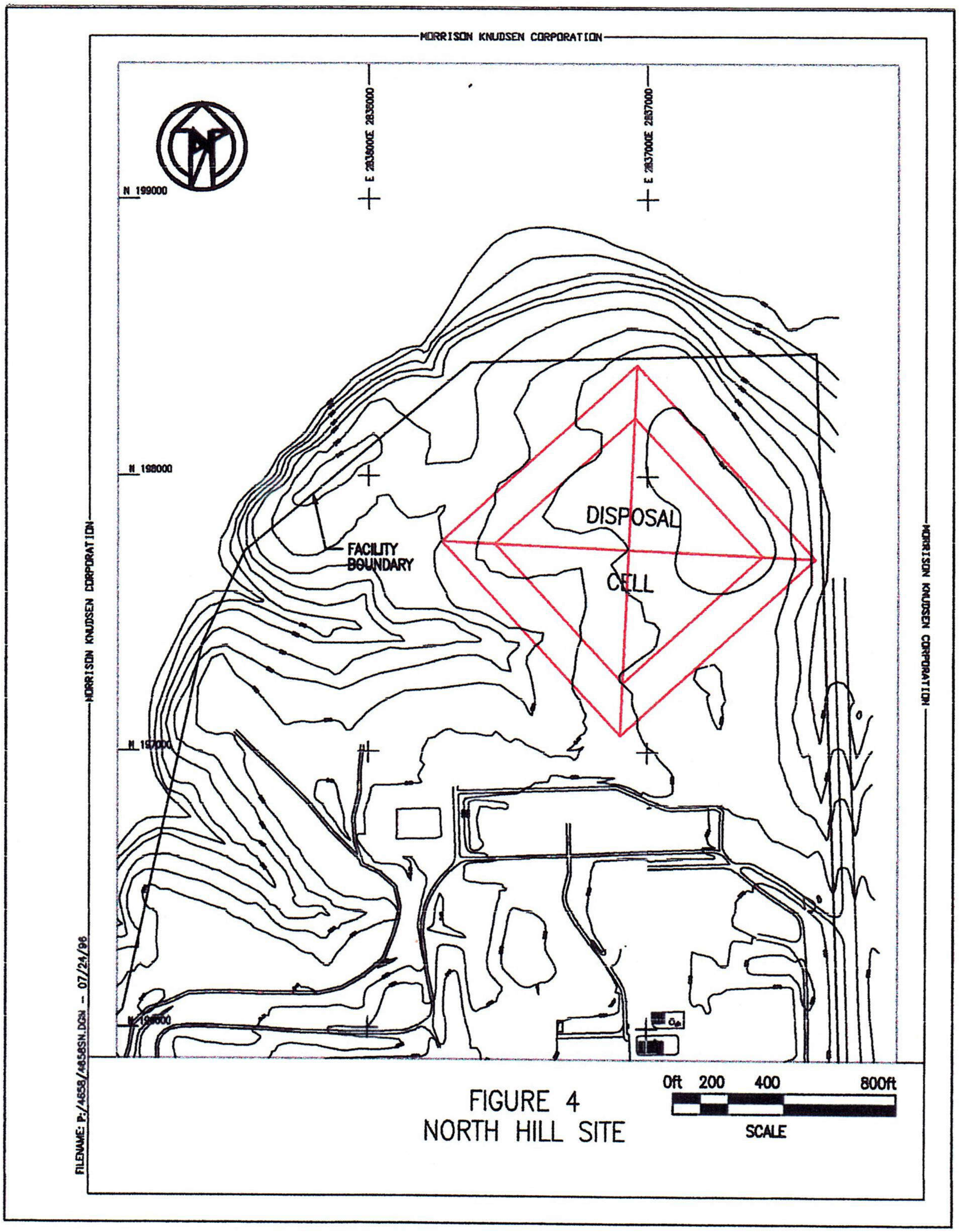


FIGURE 3
FERTILIZER POND AREA SITE

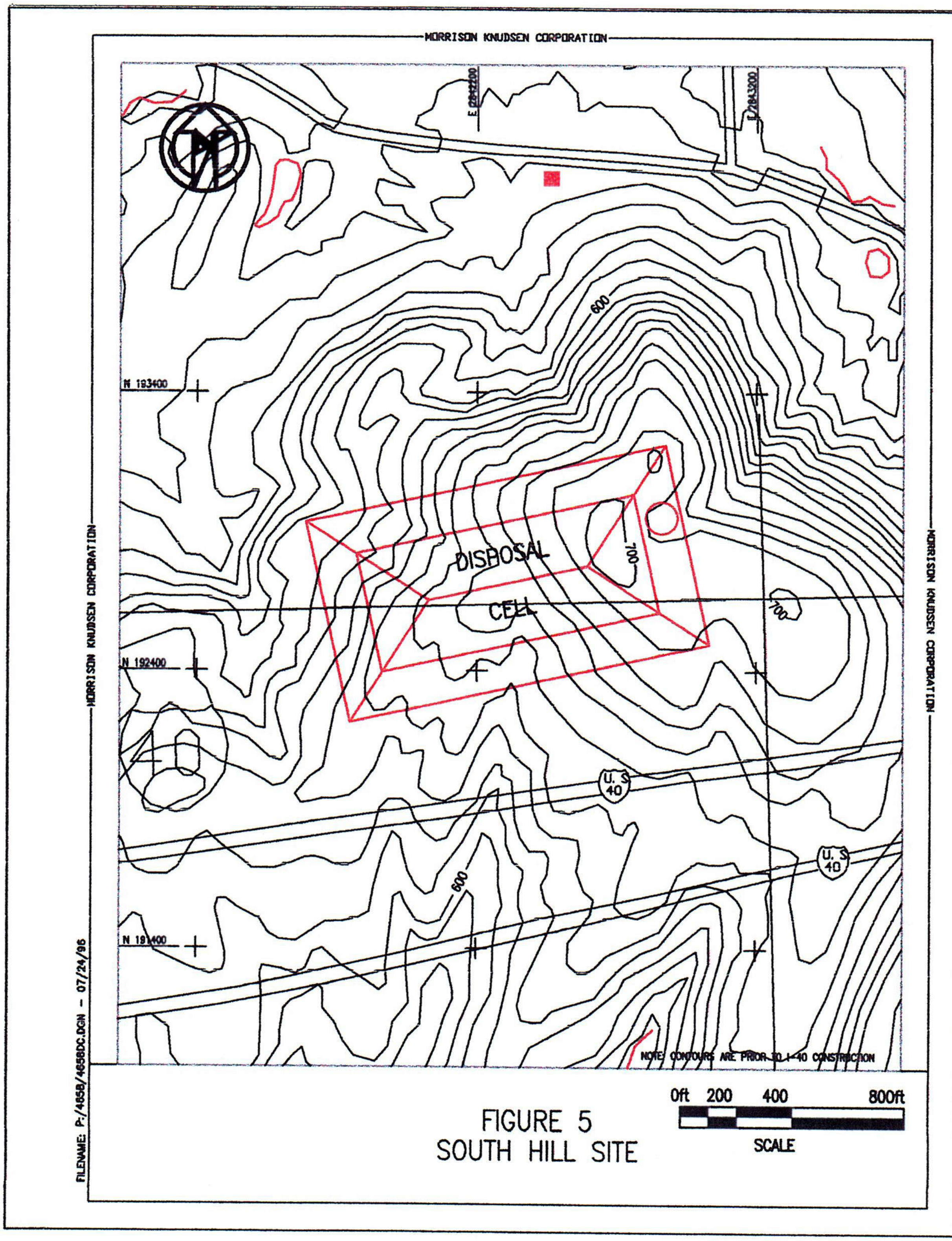
C07

Figure 4: North Hill Site



C08

Figure 5: South Hill Site



C09