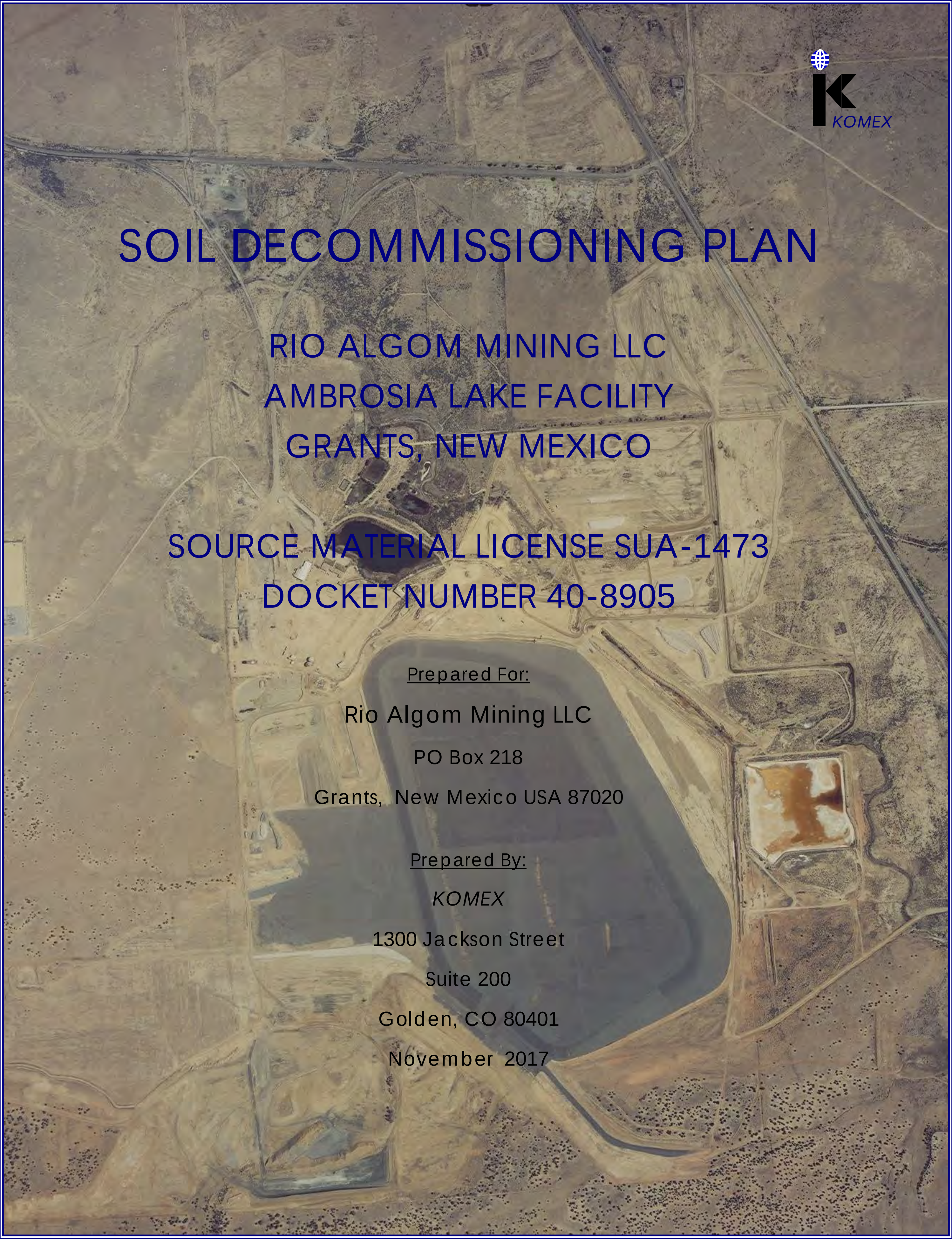

KOMEX

# SOIL DECOMMISSIONING PLAN

## RIO ALGOM MINING LLC
## AMBROSIA LAKE FACILITY
## GRANTS, NEW MEXICO

## SOURCE MATERIAL LICENSE SUA-1473
## DOCKET NUMBER 40-8905

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# LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ACL | Alternate Concentration Limit |
| ALARA | As Low As Reasonably Achievable |
| ARC | Alternate Release Criteria |
| CFR | Code of Federal Regulations |
| cm | centimeter |
| cpm | counts per minute |
| d | day |
| ft | feet |
| g | gram |
| FSS | Final Status Survey |
| Kd | soil distribution coefficient |
| kg | kilogram |
| l | liters |
| m | meters |
| mg | milligram |
| mm | millimeters |
| mrem | millirem |
| NRC | United States Nuclear Regulatory Agency |
| PMP | Probable Maximum Precipitation event |
| pCi | pico curie |

# LIST OF ACRONYMS AND ABBREVIATIONS (CONT'D)

Ra radium

RAM Rio Algom Mining LLC

RESRAD RESidual RADiation dose modeling software

RoC Radionuclide of Concern

RSO Radiation Safety Officer

Th thorium

TEDE Total Effective Dose Equivalent

U uranium

yr year

# 1.0 INTRODUCTION

This Soils Decommissioning Plan ("the plan") was revised by Rio Algom Mining LLC (RAM) and Environmental Restoration Group Inc (ERG) in November 2017 to incorporate updates to the decommissioning status for areas of the Ambrosia Lake mill facility ("the site"). Specifically, updates to the Section 4 pond area and Ponds 9 and 10 are incorporated as reflected in Sections 2.5.6 and 8.2.2.3 respectively.

The Rio Algom Mining LLC (RAM) Ambrosia Lake mill facility ("the site") is located in the Ambrosia Lake mining district in the southeastern part of McKinley County, New Mexico (**Figure 1-1**). The site is located 25 road miles north of Grants, New Mexico on Route 509, in a valley within the Ambrosia Lake portion of the Grants mineral belt, a major uranium production region. The Grants Uranium Belt, and more specifically the Ambrosia Lake mining district, contained numerous mining companies who operated two uranium ore processing mills and over 20 underground uranium mines within the Ambrosia Lake valley. Extensive surface disturbance has occurred at and near the site as a result of over 40 years of mining and milling activities throughout the valley. The locations of nearby mines are shown on **Figure 1-2**.

## 1.1 PLAN OBJECTIVES AND REPORT STRUCTURE

This Plan has been prepared in accordance with NUREG-1620[1] and addresses comments received from the U.S. Nuclear Regulatory Commission (NRC)[2] concerning the original Contaminated Soils Clean up Plan submitted in October 2000[3]. The Soil Decommissioning Plan is one component of the overall site decommissioning plan. The purpose of the Plan is to remediate the windblown tailings, effluent contaminated soils, and soils contaminated by license activities that originated from the milling operation and disposal area, and to demonstrate that the clean-up plan was successful in remediating the contaminated soils to comply with the proposed release criteria. For areas of deeper contamination attributed to

[1] U.S. Nuclear Regulatory Commission (NRC), Final Report 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, NUREG-1620, Revision 1, June 2003.

[2] Request for Additional Information Concerning the Soil Decommissioning Plan for the Quivera Mining Company Ambrosia Lake Uranium Mill Site, U.S. Nuclear Regulatory Commission, January 3, 2001.

[3] Contaminated Soil Clean Up Plan, Source Material License SUA-1473, Docket Number 40-8905, Quivera Mining Company, October 26, 2000.

licensed activities, RAM will apply Alternate Release Criteria (ARC) to allow these soils to be left in place with an appropriate cover. The ARC will achieve appropriate closure to allow for the transfer of these areas to the U.S. Department of Energy under institutional controls.

Radiological constituents of concern and the distribution of contaminants are described in Section 2 of this Plan. The development of background soil concentrations for constituents of concern is presented in Section 3. Development of the Benchmark Dose is described in Section 4. Applicable clean-up criteria to be applied to surface soils and ARC for deeper soils are described in Section 5. Development of the gamma guideline value (field clean-up criteria based on indirect measurement of radium-226 in surface soils) is presented in Section 6. The soil remediation strategy, including methods and techniques applicable for the remediation of surface soils, are described in Section 7. The application of the gamma guideline value and associated compliance demonstration are described in Section 8 – Final Status Survey. A discussion of non-radiological hazardous constituents and the soil decommissioning cost estimate and surety fund is provided in Sections 9 and 10, respectively.

This document incorporates all modifications and additions that were discussed within the NRC Requests for Additional Information letters dated May 5, 2005 and July 21, 2005; as well as items discussed during the October 27, 2005 public meeting on RAM's proposed Soil Plan.

## 1.2 HISTORY AND MILL PROCESS DESCRIPTION

Ambrosia Lake began processing uranium ore in 1958. The initial rated capacity was 3630 tons per day, but this was expanded to a maximum capacity of 7000 tons per day. Approximately 33 million tons of ore had been processed through the facility from start-up in 1958 through January 1985.

The ore was leached with sulfuric acid, and pregnant solution was separated from spent solids in a countercurrent decantation circuit utilizing cyclones, classifiers, and thickeners. Uranium was recovered from solution by solvent extraction and stripped with salt brine, and the yellowcake was precipitated from the strip solutions with ammonia. The recovery of $U_3O_8$ exceeded 96%.

The tailings disposal area was constructed in 1958 and consisted of eight ponding areas (**Figure 1-2**). Impoundments 1 and 2 were used for solids disposal, Pond 3 was a decant and seepage collection pond, and Ponds 4 through 8 were used for evaporation of liquids decanted from Impoundments 1 and 2. All starter dike and retention dikes were constructed from clayey

natural soils that were present on the site. Tailings disposal operations consisted of utilizing the upstream spigoting method which is designed to allow the tailings slurry to run down from the edge of the impoundment to the center so that the sands are deposited first, then the finer fractions are deposited as the solution is decanted off. By the end of 1984, nearly 33 million tons of tailing solids had been deposited at the site since startup and no failures allowing discharge of radioactive material outside the restricted area have occurred.

Ponds 9 and 10 were constructed in 1976. Unlike Ponds 4 through 8, these ponds included a liner. These ponds were used for same purpose as Ponds 4 through 8; i.e. evaporation of liquids decanted from Impoundments 1 and 2. Pond 10 was removed service in 1984 and allowed to dry out. The accumulated sediments and liner material were relocated to Pond 2. The area was cleaned down to bedrock (sandstone). The area then received three feet of fill material.

Utilization of the acid leach process required the sandstone ores to be ground to the natural grain size of approximately 28 mesh rather than the much finer grinding required for alkaline leach processing which typically was down to a 200 mesh. This coarser grain size along with crust formed on the deposited tailings provided greater protection from possible wind dispersion for acid leach tailings than for alkaline leach tailings.

Ambrosia Lake's mill processing facility was placed on deferred production status in early 1985 pending more favorable market conditions. The facility continued to be an active uranium production facility through December 2002 in addition to maintaining disposal capacity for an additional 16 million tons upon the approved disposal area. Reclamation of the tailings management facilities commenced in 1989 with the initiation of consolidating the top surface of Impoundment 1 along the center portion of the pile and excavation of evaporation pond residues from Pond 8.

Ongoing reclamation activities have occurred including excavation and disposal of unlined evaporation pond residues, contaminated soil clean-up, completion of the majority of the required reclamation for Impoundments 1 and 2, and construction of a rock apron on Impoundment 2. Demolition of the conventional milling structures and most of the support facilities were completed in February 2004. Additional activities concentrated on the construction of erosion protection features adjacent to the tailings disposal facility.

## 1.3 AREAS COVERED BY THE PLAN

Geographic areas covered by the provisions of this Plan are shown in **Figure 1-3**. The rationale for the location of certain area boundaries are provided in Sections 2 and 3 of this Plan. Areas covered by the Plan include:

- Areas of surface soil contamination impacted by windblown tailings. These areas are located downwind, toward the east and northeast (down slope).
- Haulways and roads impacted by spilled material.
- Section 4 ponds, which have been remediated and released for unrestricted use (See Section 2.5.6)
- Areas of deeper soil contamination affected by effluent from licensed activities that have been adequately characterized. These areas include unlined evaporation Ponds 4 through 8, and Pond 10. These areas will be closed through the application of ARC by comparison of the site-specific dose assessment with the Benchmark Dose (see Section 5.2 for ARC development).
- Areas of possible deeper soil contamination that currently lack adequate characterization data. These areas include the Mill Area and lined evaporation ponds including Pond 9. Other areas included are the mine water treatment pond, the saturated area immediately north of the treatment pond resulting from mine water seepage, and the former saturated zones adjacent to Pond 9 that existed prior to the installation and operation of the dewatering trench, and pipelines that contained process solutions. These areas are covered by the basic provisions and methods outlined in this Plan, but clean-up levels and compliance criteria cannot be finalized until further soil characterization and dose modeling (for ARC) can be completed. It is anticipated that separate reports will be submitted to the NRC as addenda to this Plan that contain the required soil characterization data, any dose modeling, and final status survey plans for each of the aforementioned areas.

## 1.4 AREAS NOT COVERED BY THE PLAN

Geographic areas *not* covered by the provisions of this Plan are shown in **Figure 1-3**, and include the following:

- Pond 3, which is considered part of the main disposal cell and is covered by those relevant requirements.
- Unaffected areas not impacted by windblown tailings, process solutions, or mining activities (pristine areas). Unaffected areas are located upwind of mill facilities and tailings impoundments, or beyond the area of influence of windblown tailings.
- Areas of surface soil contamination affected by mining activities. Mining operations have impacted significant areas surrounding the site to the west, north and east of the site (**Figure 1-2**). Although remediation of these areas is not covered by the Plan, identification of these areas is addressed in Section 3.4.
- Areas of possible deeper soil contamination containing non-11e.(2) materials impacted by mining operations. These areas include the surface drainages that have received mine water discharge (i.e. Puertocito Creek and Homestake mine drainage).

## 1.5 ORGANIZATIONAL RESPONSIBILITIES

Radiation surveys, sampling, analysis and data management will be performed by qualified personnel currently employed by RAM or by qualified consulting firms and contract laboratories with well-recognized analytical capabilities.

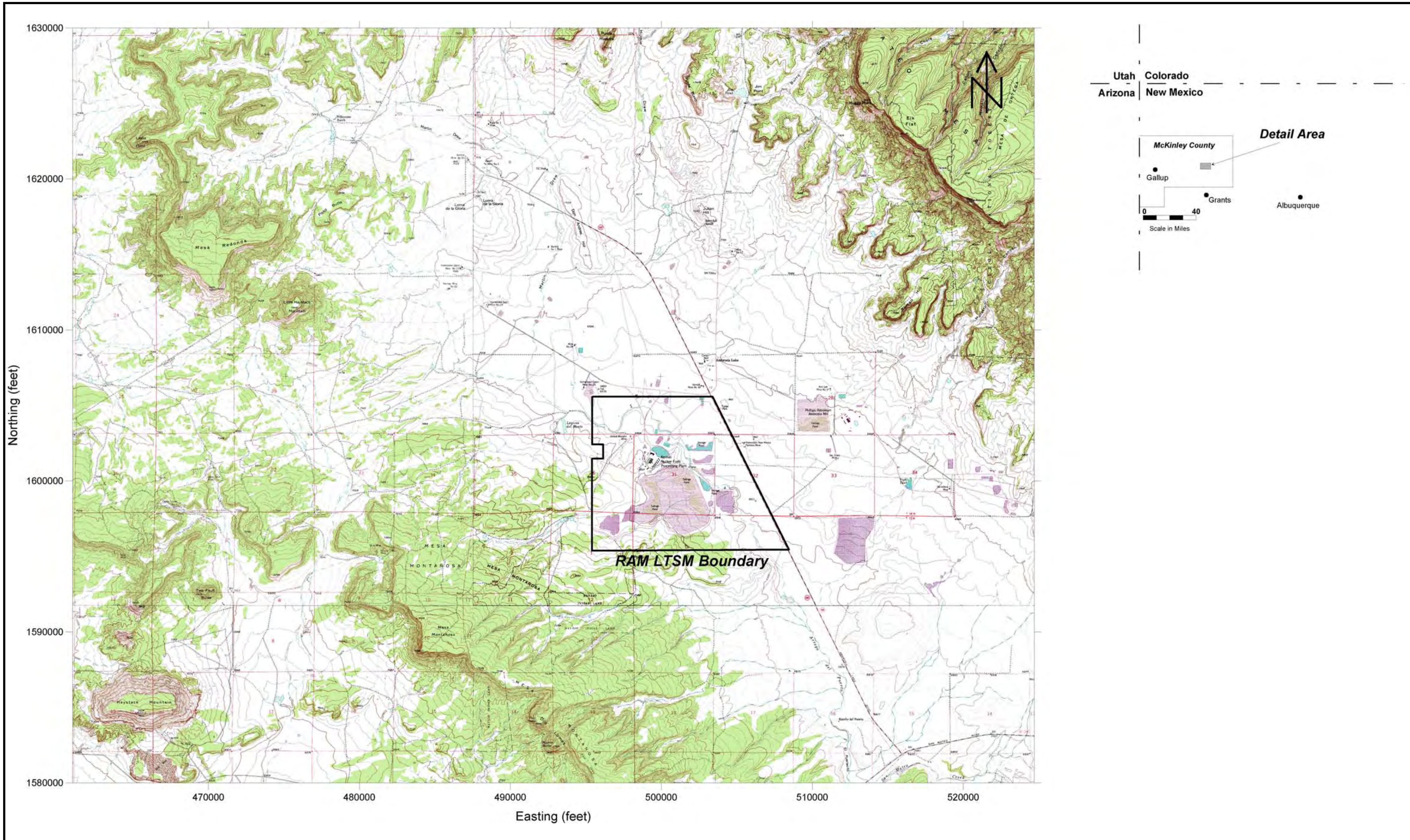
This program operates under the direction of the site Radiation Safety Officer (RSO). The RSO will have the authority to revise field survey plans as deemed necessary as work progresses. Field radiation measurements and/or sampling will be performed by trained RAM personnel or contracted to a consulting firm experienced in radiation surveys and sampling techniques.

Excavation work will be performed under the direction of the facility General Manager. The RSO will coordinate with the General Manager on any excavation work that would be required.

Quality Assurance responsibilities will rest with the Manager, Radiation Safety and Environmental Affairs.

## 1.6 LOCATION OF RECORDS

Records associated with the Soil Decommissioning Plan are located at the Rio Algom Mining LLC Ambrosia Lake Facility (**Figure 1-1**).




| | | | |
|---|---|---|---|
| KOMEX | Figure 1-1. Regional Location Map. | Project No: D0295A<br>Date: 11/09/2004<br>File Name: P:\Ambrosia Soils\NRC Report\Figures\11 x 17.ppt | FIGURE 1-1 |

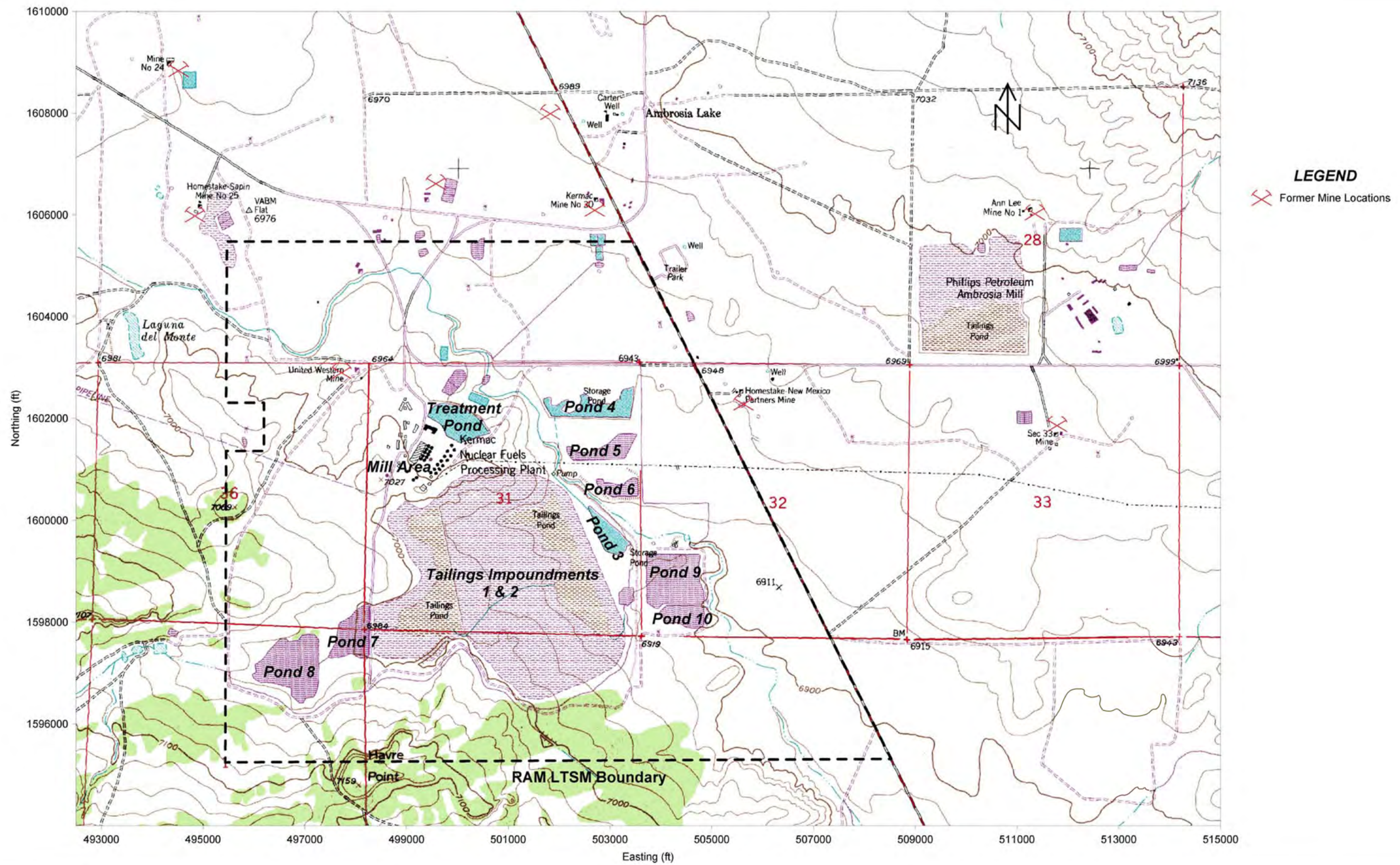



Figure 1-2. Site and Vicinity Map.

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Date: 11/30/2016

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**FIGURE 1-2**

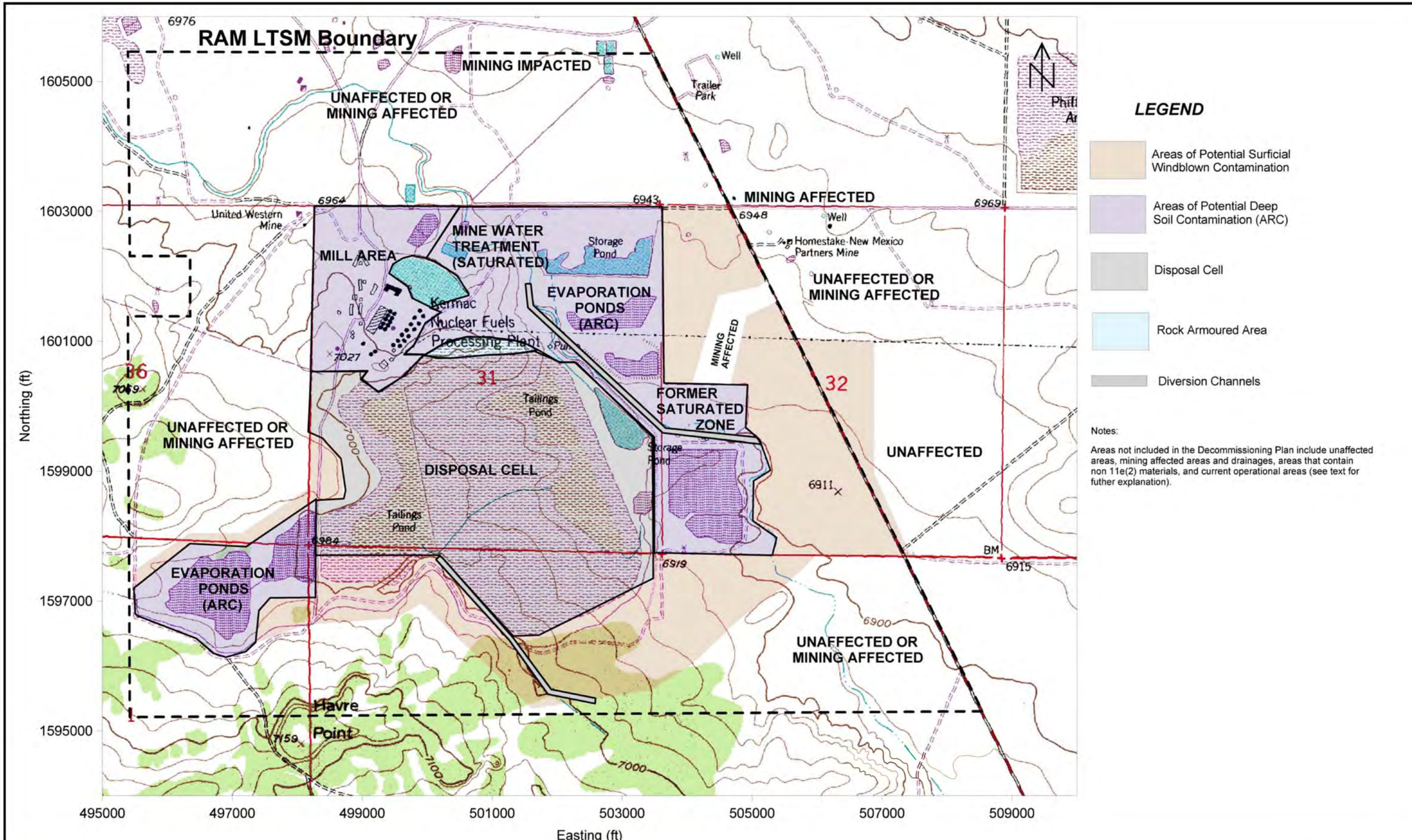


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Figure 1-3. Areas Covered by the Soil Decommissioning Plan.

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Date: 11/30/2016

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FIGURE 1-3

# 2.0 SITE CONDITIONS

Extensive surface disturbance has occurred throughout the Ambrosia Lake valley due to 40 years of mining and milling activities. Delineation of the surface area affected by licensed activities is necessary to ensure that the contaminated soil clean-up effort is appropriate. Site conditions have been evaluated by examining past land uses in the vicinity of the RAM facility, analysis of surface materials to identify potential source of origin, and determination of possible cultural resources in the area of interest.

## 2.1 RADIONUCLIDES OF CONCERN

The radionuclides of concern (RoCs) are associated with the uranium decay series and are natural uranium, thorium-230, and radium-226. These same radionuclides may also be present in the surrounding area as a result of the extensive uranium mining activities that occurred adjacent to the RAM mill facility. The probable source of the contamination can be attributed to licensed activities or non-licensed activities through evaluation of chemical characteristics unique to the source, including element ratios (Section 3.2).

## 2.2 DELINATION OF AFFECTED AREA

The affected area is defined as the area affected by licensed activities, including surface contamination from windblown tailings and deeper contamination resulting from the infiltration of mill process solutions. Commencing in 1986, RAM performed extensive gamma surveys and soil sampling for radium-226 in the immediate vicinity of the milling facility in order to delineate the extent of windblown tailings contamination that originated from RAM's facility. These surveys delineated those areas affected by windblown tailings contamination from RAM's facility as being predominately east and north of the facility. This result is as expected, as the prevailing wind direction in the valley is down slope to the north and east.

Based on the results of field gamma surveys and soil sampling data, the area potentially affected by milling operations and covered by the provisions of this Plan (i.e. **Figure 1-3**) is about 740 acres. Of this area, about 410 acres are affected by windblown tailings (surface contamination), with approximately 330 acres subject to potential deeper soil contamination and subject to ARC.

Excavation of the affected areas delineated from the surveys was initiated in 1986 and continued through 1999. Those portions of the affected area associated with current licensed

activities will be addressed following cessation of the ground water corrective action plan and will coincide with final site decommissioning activities as authorized by NRC License Condition 40(A)(1). As windblown tailings clean-up work has progressed, additional surveying and sampling has been performed to aid in determining the effectiveness of the excavation work.

In 1998, RAM incorporated an improved technique that uses a global positioning system in combination with a ratemeter instrument using a 2-inch sodium iodide detector. The system has been made more efficient by mounting the detector on an All Terrain Vehicle (ATV), and upgrading system software. The improved sensitivity of the new instrumentation and improved data management capabilities over the previous method has resulted in improved data evaluation and control over field clean-up operations.

RAM submitted the original Contaminated Soil Clean up Plan in October of 2000. Historical soils characterization data presented in the original Clean up Plan were supplemented by collection and analyses of soil samples from 124 locations in August 2003 through August 2004. The primary purpose of the supplemental soil sampling was to support the development of a reliable gamma guideline value (correlation) and background soil concentrations, and to fill data gaps identified by NRC in the RAI and subsequent public meetings.

## 2.3 SOILS DATABASE

A Microsoft® Access soils database was developed as a data management tool designed to assist data analysis and improve overall data management. Soils data were input into the database that were received in the form of Excel spreadsheets, site reports, a partial Access database, and analytical laboratory reports received in the form of image files (*.tif) and hard copy. Data were included in the database if information was available regarding the location and date on which the sample was obtained. The original sources of the data (i.e., Excel spreadsheets, laboratory data sheets) are indicated for each analytical record included in the database. After the data were imported into the database, a series of queries were developed to allow data evaluation. The Access soils database, current as of October 2004, is included on a Compact Disk in Appendix A of this Plan.

Soils data included in the database include:

- Field gamma survey data and soil sampling data collected to support the gamma correlation presented in the original Contaminated Soil Clean up Plan,

- Samples collected in areas affected by Homestake Mining Company (HMC) operations,
- Samples collected from background areas by ORISE during a 1999 site visit,
- Samples collected by RAM for background characterization presented in the original Contaminated Soil Clean up Plan,
- Section 32 samples collected after the evaporation Ponds 4, 5, and 6 were covered and the downwind area was remediated,
- Archaeological site soil samples,
- Results for zero to 6-inch samples collected with stratified samples collected from the buffer zone, and
- Recent soil samples and gamma survey data collected from August 2003 to August 2004 to support development of the gamma guideline value (correlation) and background soil concentrations presented in this Plan.

## 2.4 DELINATION OF SURFACE CONTAMINATION

In April of 2003, RAM initiated a data quality review that included examination of historical soil sampling results collected to support the gamma correlation and background assessments presented the original Contaminated Soil Clean-Up Plan. This review was initiated based on the relatively poor gamma correlation that was developed using these data, and comments received in the RAI from the NRC for the original Contaminated Soils Clean-Up Plan.

Results of the data quality review indicated that, although the historical soil sampling results were of sufficient quality for purposes of site characterization, the data could not be used to develop a reliable gamma guideline value (correlation) or for purposes of background soil concentration development. Historical soil sampling results were shown to display significant and unacceptable variability for samples analyzed by multiple laboratories that were found to use differing analytical procedures and methodologies. Based on the results of the data quality review, RAM initiated a supplemental soil sampling program in August of 2003 designed to improve data quality and thus improve the gamma correlation and background soil concentration development. Approximately 124 sample locations were included in the supplemental sampling program.

Maps were prepared using the supplemental soil sampling data that illustrate the approximate distribution of RoCs including gross gamma, radium-226, thorium-230, natural uranium, and

their applicable ratios. These maps are provided in **Figures 2-1 thru 2-10**. The supplemental soil sampling data used to construct the RoC distribution maps are provided in **Table 2-1**. Criteria used to differentiate between affected, unaffected, and mining affected areas are described in detail in Section 3.2.

Substantial additional historical soil sampling data is available and is summarized in **Table 2-2** and the site soils database (Appendix A). **Figure 2-2** shows the site 500 x 500-foot sampling grid with coordinate references used for many of the sample locations listed in **Table 2-2**.

### 2.4.1 GAMMA SURVEY

Gamma survey data illustrating the approximate current gross gamma distribution are provided in **Figure 2-1**. In general, the gamma data identify the following distinct geographic areas with specific gamma ranges:

- Low to moderate gamma values in remediated areas and areas not impacted by windblown tailings (background),
- Elevated gamma values in areas north and northeast of the site (across main access roads) impacted by former mining operations not related to RAM,
- Elevated gamma values in unremediated areas (i.e. archaeological sites),
- Elevated gamma values adjacent to remediated areas south and east of the site,
- Elevated gamma values due east of the site and immediately east of the main access road possibly related to RAM windblown tailings, and
- Elevated gamma values in areas identified as having possible deeper soil contamination (i.e. former saturated zones adjacent to Pond 9 prior to trench operation).

### 2.4.2 GAMMA CORRELATION DATA

As described in Section 2.4.1, 124 grids were sampled between August 2003 and August of 2004 to support the development of the gamma guideline value (correlation) and soil background concentrations. The 10m by 10m grid locations selected for soil sample collection and gamma measurement are shown in **Figure 2-3**, and are tabulated in **Table 2-1**. Samples collected specifically for the purposes of gamma correlation development were selected to ensure a range of gamma measurements and radium-226 concentrations. A map showing the distribution of ATV gamma measurements for these samples are shown in **Figure 2-4**.

### 2.4.3 RADIUM-226

The distribution of radium-226 is provided in **Figure 2-5**. Areas of elevated radium-226 include mining affected areas and unremediated areas including the Homestake mine drainage.

### 2.4.4 THORIUM-230

The distribution of thorium-230 is provided in **Figure 2-6**. Elevated thorium-230 is observed in mining-affected areas (i.e., the Homestake mine drainage), and in unremediated windblown-tailings-affected areas.

### 2.4.5 URANIUM-238

The distribution of uranium-238 is provided in **Figure 2-7**. Elevated uranium-238 is apparent in former mining areas north and northeast of RAM access roads and in the unremediated Homestake mine drainage.

### 2.4.6 ELEMENT RATIOS

Radium-226/thorium-230 ratio in soils at the site is illustrated in **Figure 2-8**. Ratios calculated for the soils generally occur in two groups, above and below a ratio of approximately 0.4. Areas with radium-226/thorium-230 ratios less than 0.4 are localized in the Homestake mine area (northeast of the main access road) and associated drainage. Samples with ratios higher than 0.4 include windblown areas, mining affected areas, and natural background areas.

The distribution of radium-226/uranium-238 ratios is illustrated in **Figure 2-9**. The calculated ratios fell into two groups, which can be separated at a value of approximately 4.75. Areas with ratios below about 4.75 represent areas that are mining affected or indicative of natural background conditions. Areas with radium-226/uranium-238 above this value are generally indicative of windblown tailings, although a few mining-affected background samples had ratios above 4.75 (see Section 3.2).

The distribution of thorium-230/uranium-238 is illustrated in **Figure 2-10**. The thorium-230/uranium-238 ratios fell into three populations. Mining affected areas and natural background areas generally have ratios less than 2.5 (the two lowest populations), while windblown-tailings affected areas have ratios generally higher than 1.1 (the two higher populations).

## 2.5 DELINATION OF DEEPER SOIL CONTAMINATION

The extent of contamination, both horizontal and vertical, must be quantified for each distinct area in order to establish a source term for ARC development (dose assessment). The resulting source term will be a representative (or conservative) concentration of acceptable confidence for each primary radionuclide comprising the residual contamination. The most recently available analytical results for soil samples were compiled for each of the known areas of deep contamination.

Data currently exist for Ponds 4 through 8, and 10 that can be used in the development of the dose assessment and ARC development for these areas. As a conservative measure, maximum concentrations of RoCs observed in soil samples collected from evaporation ponds (Ponds 4 through 8) were used as source terms in the dose modeling.

### 2.5.1 PONDS 4, 5, AND 6

Evaporation Ponds 4, 5 and 6 were evaluated individually but reflect a contiguous area of the site that should be considered together for purposes of the dose assessment. The analytical results for soil samples from Ponds 4, 5, and 6 are provided in **Tables 2-3 through 2-8**.

Evaporation Ponds 4, 5 and 6 are each comprised of two units: the soils around the northern edges the ponds (a.k.a. halos) and the soils marking the footprint of the ponds. The halos generally mark an extent of pond liquids or perhaps local windblown material from the ponds. The halos would be expected to exhibit surface contamination. The footprint is assumed to mark the extent of deposition of sediments in the pond. The soils in the footprint would be expected to have higher concentrations of contaminants, and contamination would be expected below the surface soil.

The statistical evaluation of Ponds 4, 5, and 6 halo data reveals quite a bit of variability in soil concentration as shown by the large standard deviation and large confidence interval about the average. However, this variability is predominately caused by samples at locations 4A, 5C, 5D, 6A and 6C. In general, the halo sample locations qualitatively show little or no presence of contamination.

Samples within the footprints of Ponds 4, 5 and 6 indicate contamination to about three feet below the surface of the remaining footprint. The statistical variability of the footprint samples

improve substantially when the results indicating non-impacted soil are not included in the statistics.

### 2.5.2 PONDS 7 AND 8

The analytical results for soil samples from Ponds 7 and 8 are provided in **Tables 2-9 and 2-10**. The statistical evaluation of the sample data from Ponds 7 and 8 reveals a small relative error of the confidence interval about the average; i.e. good precision and accuracy of the average.

### 2.5.3 POND 9

The analytical results for soil samples from Ponds 9 are provided in **Tables 8-4**.

### 2.5.4 POND 10

The Pond 10 remediation occurred in 1994. As the pond material was excavated, bedrock was encountered at shallow depth in most areas, which made sampling difficult and resulted in fewer samples at 6-12" depth. Additional excavation would have essentially been in bedrock. Since any further clean-up would have been into underlying bedrock, further excavation was deemed impractical. The equipment being used would be ruined and the language in the Criterion 6 standard applies to concentrations in unconsolidated soils. Additionally, NRC has communicated to RAM that NRC does not envision licensees to excavate bedrock.

Thirty-one locations were sampled for Ra-226 at the 0-6" depth and 26 locations at 6-12" depth. Based on the on-site lab analysis, the 15 pCi/g plus background clean-up was achieved (**Table 2-11**). A gamma survey was completed of the pond bottom and appears to support Ra-226 clean-up has been achieved. Based on these results, clean fill material consisting of excavated soil/rock from the nearby diversion channel was placed over Pond 10.

Following the previous remediation of Pond 10, a composite soil sample was developed from the soil samples previously collected from the Pond 10 area. The analytical results of this composite sample were 6.41, 444, 41.8 pCi/g for Ra-226, Th-230, and U-total, respectively for the 0-6" sample. The 6-12" composite sample had 1.12, 66, and 19.9 pCi/g for Ra-226, Th-230, and U-total, respectively.

With NRC requiring a new plan for the site pursuant to the revised Criterion 6, and with the knowledge that elevated Th-230 and uranium is likely present despite meeting clean-up goals

for Ra-226, Alternate Release Criteria (ARC) are proposed for Pond 10 as a practical solution that is protective of human health and the environment.

In response to a NRC request, RAM submitted 18 soil samples to General Engineering Laboratories for analysis of uranium-238, thorium-230 and radium-226. These samples were archived samples from the 1994 sampling program on Pond 10 that was limited to radium-226 analysis.

A total of 12 samples were analyzed from the 0-6" layer; and 6 samples from the 6-12" level were also sent for analysis. **Table 2-12** provides the analytical results received from the lab for the samples. Some uranium-238 results were not provided by the laboratory due to interferences associated with definitively identifying energy peaks for isotopes with low gamma energy.

The analytical results for radium-226 concentrations conform to the Criterion 6 concentrations for radium-226. The results for Pond 10 are indicative of the same condition that was observed within the other evaporation ponds where concentrations of other radionuclides remain elevated at depth. As a result of these factors combined with the fact that NRC required RAM to develop and submit a new soil decommissioning plan for the site pursuant to the revised Criterion 6, Alternate Release Criteria (ARC) are proposed for Pond 10 as a practical solution that is protective of human health and the environment.

### 2.5.5 MILL AREA

Currently, no data is available for this area to describe the extent and concentration of contamination.

### 2.5.6 SECTION 4 PONDS

The Section 4 ponds were used to evaporate liquid wastes generated from RAM's acid leach uranium ore processing mill, located approximately two miles northwest of the ponds. The ponds were constructed in two phases with the northern ponds (Ponds 11–15) constructed in 1976 and the southern ponds (Ponds 16-21) constructed in 1979. The ponds provided an evaporative surface area of 256 acres with a total holding capacity of 1570 acre-feet. Additional wastewater streams received at the Section 4 Ponds included ion-exchange plant wastewater which consisted of backwash solutions and resin regeneration solutions, yellowcake precipitation process-generated acidic decant solutions, groundwater collected as part of the

alluvial remediation plan, as well as other mill process solutions. The ponds remained in active service through April 2004.

Decommissioning of the ponds started in the fourth quarter of 2004 with the excavation and consolidation of pond material in the northern and southern ponds. The material was consolidated by evaporating the residual pond liquids and mixing contaminated soils from the berms and beneath the liners. Following dewatering and consolidation of material in the northern ponds to ensure geotechnical stability, the consolidated material in the southern ponds was relocated to the northern pond area for storage. This activity is described in a letter from RAM to the NRC dated October 11, 2004 (ML043020255) and was approved by Amendment 18 of Source Material License SUA-1473 (SUA-1473), dated September 24, 1990 (9010120084).

In 2004, RAM changed its strategy regarding Section 4 pond decommissioning from an in-place closure in the northern pond area to relocation of the material to a disposal area located at the north end of Tailings Impoundment 2. The updated decommissioning requirements are addressed in two documents: 1) the Relocation Plan-Lined Evaporation Ponds at Rio Algom Mining, LLC's Ambrosia Lake Facility, and 2) The Soil Decommissioning Plan. The first was approved in June 24, 2005 by Amendment 55 to SUA-1473 (ML051780207). The second was approved in August 16, 2006 by Amendment 57 to SUA-1473 (ML061940224). The material from the Section 4 ponds, initially estimated to be nearly 2 million cubic yards, required an expansion of the Tailings Impoundment 2. This expansion design was approved December 10, 2007 by Amendment 58 to SUA-1473 (ML073050340).

A highway crossing over New Mexico State Highway 509 was required to facilitate safe relocation of the Section 4 pond material to Tailings Impoundment 2. This crossing was completed in November 2005 (ML081550380). The Lined Pond Closure Project (Amendment 55) was initiated in 2007 and all Section 4 pond materials were relocated for disposal in Tailings Impoundment 2 by November 2007 (ML081550380). The removal of the pipeline from Pond 9 to the Section 4 ponds and its associated contaminated material was completed in May 2009 (ML091810951).

Radiation surveys and soil sampling commenced following relocation of the excavated material. Radiation surveys and soil sampling were completed by May 2009. The NRC commissioned Oak Ridge Institute for Science and Education (ORISE) to conduct confirmatory sampling of the Section 4 ponds area in September 2009 (ML092740569). ORISE conducted the confirmatory radiation survey and soil sampling from September 21-24, 2009. A report was

submitted to the NRC on February 12, 2010, which concluded that survey results indicated further investigation and possibly remediation were necessary before the release limits could be satisfied.

Pursuant to the recommendations of the confirmatory survey report by ORISE, RAM commissioned Two Lines, Inc. (Two Lines) to review Section 4 soil data and associated reports. In December 2010 a report titled "Review of Section 4 Soil Data and Associated Reports Related to the Soil Decommissioning Plan" (Two Lines, 2010) was provided to RAM. The conclusion of this report was no further remedial action was necessary and that the former Section 4 ponds area should be considered for unrestricted release. This report was submitted to the NRC on February 9, 2011 (ML110470268) with a request by RAM that the NRC reconsider its position that the former Section 4 ponds area did not meet the soil cleanup levels in Table 5-1.

The NRC responded to the February 9, 2011 RAM submittal with a letter dated May 12, 2011 (ML111030388). In this letter the NRC concluded that to demonstrate compliance with the soil cleanup levels in Table 5-1 using the method in the Two Lines report, RAM would need to apply for a license amendment to use cleanup levels for radium, thorium and uranium with their background values subtracted out and show what the new benchmark dose would be. The application would also have to include a discussion of how to treat the apparent "hot spots" in the former Section 4 ponds area.

By July 2014 an additional 85,000 cubic yards of contaminated material was removed from the former Section 4 ponds area. This removal focused on "hot spots" in response to the NRC's letter dated May 12, 2011 discussed above. Soil samples were collected by RAM and submitted to a third-party environmental laboratory for analysis. RAM provided this data to the NRC. Following the additional soil removal, the NRC commissioned ORAU to perform a re-confirmation of the former Section 4 ponds area. ORAU collected gamma survey data and soil samples from August 17-20, 2015. ORAU's assessment was summarized in a report dated November 17, 2015 (ML15337A392). This report concluded that the former Section 4 ponds area did not meet the soil cleanup levels. In November of 2017 RAM submitted a license amendment request for unconditional release of the former Section 4 ponds area. A component of this request was an updated dose assessment to evaluate compliance with the radium benchmark dose using the soil data collected by ORAU. This alternate method for demonstrating compliance with cleanup requirements is described in Section 5.0 below. The conclusion of this dose assessment was that doses for the modeled scenarios are below the radium benchmark dose of 18 mrem per year using either median or mean concentrations of

the long-lived radionuclides, therefore meeting the requirements of the radium-226 benchmark dose of Criterion 6 (6) of 10 CFR 40 Appendix A.

## 2.6 DELINATION OF UNAFFECTED AND MINING-AFFECTED AREAS

Areas that are not expected to contain radioactive contamination attributable to licensed activities and that have not been impacted by non-11e.(2) mining activities will be classified as unaffected areas (natural background). Unaffected areas are located generally upwind or cross-gradient of the site and possess natural background concentrations of RoCs and gamma radiation levels. Criteria used to differentiate between affected, unaffected, and mining-affected areas are discussed in detail in Section 3.1 (background assessment).

## 2.7 CULTURAL RESOURCES EVALUATION

Archaeological resources from the Anasazi culture have been identified near the site. Other archaeological resources undoubtedly exist in the area and are susceptible to potential impacts from site reclamation activities. Resources surveys performed in the vicinity of the site have identified sites that are potentially eligible for inclusion on the National Register of Historic Places.

In December 2005, a Data Recovery Plan was developed that provides a detailed description of how RAM intends to protect the previously identified sites during remediation activities. Attachment A includes a comprehensive plan that will be implemented under the direction of a qualified cultural resources consulting firm. Initiation of the activities described within the Data Recovery Plan will only proceed upon Plan acceptance by the State Historic Preservation Office following consultation with NRC.

**Table 2-1. Soils Data for Gamma Correlation and Background Soils Assessment (August 2003 – August 2004)**

| Location Name | Location Type | Gamma ATV cpm | Gamma Walking cpm | Ra-226 pCi/g | Th-230 pCi/g | | U-238 pCi/g |
|---|---|---|---|---|---|---|---|
| Komex-1 | windblown/undisturbed | 37601 | 36702 | 8.06 | 11.70 | | 4.48 |
| Komex-2 | windblown/undisturbed | 42755 | 42568 | 7.84 | 10.40 | < | 0.98 |
| Komex-3 | windblown/undisturbed | 36465 | 35769 | 3.63 | 4.78 | < | 1.88 |
| Komex-4 | windblown/undisturbed | 40477 | 39697 | 7.44 | 7.52 | < | 0.68 |
| Komex-5 | windblown/undisturbed | 44703 | 43374 | 8.20 | 10.30 | < | 0.06 |
| Komex-6 | windblown/undisturbed | 43157 | 42794 | 7.47 | 11.30 | | 2.90 |
| Komex-7 | windblown/undisturbed | 43345 | 38900 | 4.98 | 3.70 | < | 1.60 |
| Komex-8 | windblown/undisturbed | 43092 | 37056 | 7.74 | 9.83 | | 3.21 |
| | replicate | | | 8.69 | 10.30 | | 2.82 |
| | split | | | 7.98 | 11.70 | < | 4.04 |
| Komex-9 | windblown/undisturbed | 51743 | 44612 | 4.83 | 15.80 | < | 1.60 |
| Komex-10 | windblown/undisturbed | 43906 | 39205 | 9.32 | 6.67 | < | 1.12 |
| Komex-11 | windblown/undisturbed | 43737 | 39034 | 5.73 | 5.21 | < | 1.48 |
| Komex-12 | windblown/undisturbed | 45051 | 40443 | 7.24 | 5.31 | | 1.47 |
| | replicate | | | 8.68 | 6.26 | < | 1.77 |
| Komex-13 | windblown/undisturbed | 41722 | 41075 | 8.84 | 14.90 | < | 2.89 |
| Komex-14 | windblown/undisturbed | 45862 | 44209 | 11.80 | 16.30 | | 2.22 |
| Komex-15 | windblown/undisturbed | 44680 | 44169 | 10.70 | 14.60 | < | 2.29 |
| Komex-16 | windblown/undisturbed | 52918 | 49795 | 9.52 | 18.70 | | 2.53 |
| | split | | | 10.00 | 20.40 | | 6.03 |
| Komex-17 | windblown/undisturbed | 48786 | 40820 | 6.30 | 13.20 | < | 1.38 |
| Komex-18 | windblown/undisturbed | 46308 | 39726 | 6.12 | 9.91 | < | 1.82 |
| Komex-19 | windblown/undisturbed | 46231 | 40506 | 6.38 | 10.60 | | 2.12 |
| | split | | | 8.57 | 11.60 | < | 1.67 |
| Komex-20 | windblown/undisturbed | 48601 | 42775 | 6.33 | 9.45 | | 3.57 |
| Komex-21 | background | 11789 | 11613 | 0.65 | 0.688 | < | 0.61 |
| Komex-22 | background | 12051 | 11627 | 0.76 | 0.9660 | < | 1.00 |
| Komex-23 | background | 11447 | 11486 | 0.70 | 0.882 | < | 0.57 |
| Komex-24 | background | 17813 | 18065 | 0.90 | 1.67 | | 2.96 |
| Komex-25 | background | 17109 | 17060 | 1.25 | 1.66 | | 2.40 |
| Komex-26 | background | 17915 | 17645 | 1.63 | 2.40 | | 4.88 |
| Komex-27 | background | 17488 | 17805 | 1.13 | 1.80 | | 1.49 |
| Komex-28 | background | 18856 | 18153 | 1.71 | 3.40 | | 1.88 |
| Komex-29 | background | 18400 | 18027 | 1.32 | 2.07 | < | 1.10 |
| Komex-30 | background | 17747 | 17562 | 1.53 | 2.21 | | 1.57 |

## Table 2-1. Soils Data for Gamma Correlation and Background Soils Assessment (August 2003 – August 2004)

| Location Name | Location Type | Gamma ATV cpm | Gamma Walking cpm | Ra-226 pCi/g | Th-230 pCi/g | | U-238 pCi/g |
|---|---|---|---|---|---|---|---|
| Komex-31 | background | 16605 | 16487 | 1.00 | 2.95 | | 0.76 |
| Komex-32 | background | 16057 | 15752 | 1.35 | 1.22 | | 1.77 |
| Komex-33 | background | 18728 | 18750 | 1.98 | 3.29 | | 1.69 |
| | split | | | 1.94 | 3.00 | | 1.53 |
| Komex-34 | background | 18992 | 19386 | 1.42 | 3.43 | | 2.10 |
| Komex-35 | background | 18116 | 17675 | 2.28 | 2.41 | | 2.14 |
| Komex-36 | background | 18894 | 18728 | 1.63 | 9.75 | | 2.59 |
| Komex-37 | background | 19411 | 18839 | 1.40 | 2.66 | | 2.16 |
| Komex-38 | background | 19016 | 18953 | 1.86 | 2.70 | | 1.68 |
| Komex-39 | background | 19865 | 20915 | 1.57 | 1.72 | | 1.59 |
| Komex-40 | background | 18085 | 19083 | 1.02 | 0.92 | | 2.99 |
| | replicate | | | 1.29 | 1.30 | | 0.94 |
| Komex-41 | background | 21008 | 21999 | 3.57 | 3.74 | | 3.79 |
| Komex-42 | background | 22543 | 23503 | 4.54 | 5.18 | < | 0.90 |
| | split | | | 5.37 | 4.66 | < | 2.41 |
| Komex-43 | background | 18968 | 19722 | 2.02 | 2.70 | < | 0.87 |
| Komex-44 | background | 17910 | 18887 | 1.62 | 3.06 | < | 1.94 |
| Komex-45 | background | 15811 | 16024 | 2.83 | 3.04 | < | 0.41 |
| Komex-46 | background | 16646 | 16882 | 2.81 | 3.50 | < | 2.30 |
| Komex-47 | background | 18327 | 18466 | 2.11 | 3.81 | < | 1.52 |
| Komex-48 | background | 20079 | 20214 | 4.89 | 4.41 | < | 1.47 |
| Komex-49 | background | 20030 | 20256 | 3.69 | 5.11 | | 4.54 |
| Komex-50 | background | 18502 | 18434 | 3.04 | 3.99 | < | 1.95 |
| | split | | | 3.50 | 3.08 | | 1.41 |
| Komex-51 | mining | 93067 | 100149 | 28.20 | 89.70 | | 19.80 |
| | split | | | 24.70 | 40.70 | | 19.10 |
| Komex-52 | mining | 84344 | 88049 | 19.80 | 85.30 | | 16.70 |
| Komex-53 | mining | 57616 | 53880 | 4.34 | 23.30 | | 7.66 |
| Komex-54 | mining | 42161 | 42090 | 5.27 | 25.80 | | 12.40 |
| Komex-55 | mining | 59483 | 56136 | 23.80 | 35.80 | | 16.20 |
| | split | | | 23.30 | 39.00 | | 17.50 |
| Komex-56 | mining | 37343 | 37431 | 5.54 | 53.20 | | 3.45 |
| Komex-57 | mining | 94352 | 88232 | 24.90 | 32.80 | < | 4.32 |
| Komex-58 | mining | 54419 | 53115 | 6.87 | 18.60 | < | 2.80 |
| Komex-59 | mining | 65307 | 65842 | 6.44 | 17.40 | | 2.94 |
| Komex-60 | mining | 81113 | 84019 | 23.80 | 60.20 | | 12.60 |

## Table 2-1. Soils Data for Gamma Correlation and Background Soils Assessment (August 2003 – August 2004)

| Location Name | Location Type | Gamma ATV cpm | Gamma Walking cpm | Ra-226 pCi/g | Th-230 pCi/g | | U-238 pCi/g |
|---|---|---|---|---|---|---|---|
| | replicate | | | 38.70 | 41.40 | | 10.40 |
| Komex-61 | Mining | 111381 | 115077 | 94.30 | 149.00 | | 89.80 |
| Komex-62 | mining | 87068 | 88273 | 27.10 | 62.40 | | 11.30 |
| Komex-63 | mining | 89606 | 89827 | 22.50 | 41.50 | | 8.93 |
| Komex-64 | mining | 66270 | 69484 | 12.60 | 38.60 | | 6.61 |
| Komex-65 | mining | 67600 | 67996 | 12.50 | 19.40 | | 9.57 |
| Komex-66 | mining | 63041 | 67090 | 10.80 | 24.70 | | 10.80 |
| Komex-67 | mining | 109414 | 105547 | 42.10 | 77.20 | | 19.20 |
| Komex-68 | mining | 87241 | 90062 | 28.70 | 29.60 | | 19.30 |
| | split | | | 24.10 | 26.20 | | 15.30 |
| Komex-69 | mining | 81430 | 78451 | 19.80 | 29.30 | | 15.20 |
| Komex-70 | mining | 79024 | 77895 | 26.30 | 40.10 | | 13.40 |
| Komex-71 | mining background | 36687 | 35502 | 2.37 | 2.87 | | 3.27 |
| Komex-72 | mining background | 87144 | 99589 | 32.50 | 23.9 | | 16.40 |
| Komex-73 | mining background | 44062 | 46400 | 11.90 | 11.4 | < | 4.72 |
| Komex-74 | mining background | 24183 | 22382 | 4.50 | 3.95 | | 2.34 |
| Komex-75 | mining background | 28897 | 27607 | 7.72 | 9.25 | | 6.88 |
| Komex-76 | mining background | 16862 | 15812 | 0.86 | 1.66 | | 2.67 |
| Komex-77 | mining background | 14432 | 13541 | 0.49 | 0.889 | < | 0.83 |
| | split | | | 0.66 | 0.45 | < | 0.77 |
| Komex-78 | mining background | 29577 | 29740 | 0.70 | 0.796 | | 0.99 |
| Komex-79 | mining background | 30595 | 31675 | 2.56 | 2.23 | < | 1.56 |
| Komex-80 | mining background | 26890 | 25575 | 2.59 | 2.49 | | 3.39 |
| Komex-81 | mining background | 26933 | 25700 | 4.35 | 1.03 | < | 2.79 |
| Komex-82 | mining background | 23390 | 21563 | 1.10 | 1.75 | < | 1.10 |
| Komex-83 | mining background | 37399 | 36280 | 3.36 | 4.40 | | 2.04 |
| Komex-84 | mining background | 34720 | 39636 | 2.44 | 2.75 | | 3.40 |
| Komex-85 | mining background | 59452 | 59640 | 1.27 | 1.79 | | 2.29 |
| Komex-86 | mining background | 84193 | 80738 | 38.80 | 27.8 | | 27.00 |
| Komex-87 | mining background | 43827 | 42544 | 8.97 | 10.1 | | 5.01 |
| Komex-88 | mining background | 57366 | 55309 | 5.77 | 2.39 | | 5.38 |
| Komex-89 | mining background | 32255 | 31381 | 1.44 | 1.37 | < | 2.06 |
| Komex-90 | mining background | 16251 | 15662 | 0.55 | 0.751 | < | 0.99 |
| Komex-91 | mining drainage | 50228 | 46202 | 12.80 | 28.3 | < | 0.56 |
| Komex-92 | mining drainage | 67661 | 62946 | 42.00 | 36.4 | | 14.50 |
| Komex-93 | mining drainage | 31660 | 28371 | 4.67 | 13.0 | | 9.48 |

**Table 2-1. Soils Data for Gamma Correlation and Background Soils Assessment (August 2003 – August 2004)**

| Location Name | Location Type | Gamma ATV cpm | Gamma Walking cpm | Ra-226 pCi/g | Th-230 pCi/g | | U-238 pCi/g |
|---|---|---|---|---|---|---|---|
| Komex-94 | mining drainage | 47608 | 44544 | 9.42 | 24.5 | < | 0.83 |
| Komex-95 | mining drainage | 56982 | 57536 | 18.90 | 16.8 | | 5.69 |
| Komex-96 | mining drainage | 49051 | 46659 | 3.45 | 14.6 | | 3.72 |
| | split | | | 3.25 | 9.18 | | 3.26 |
| Komex-97 | mining drainage | 44264 | 45123 | 9.11 | 15.5 | | 6.53 |
| Komex-98 | mining drainage | 56053 | 53541 | 8.84 | 26.7 | < | 1.41 |
| Komex-99 | mining drainage | 41482 | 38025 | 9.63 | 17.5 | | 5.88 |
| Komex-100 | mining drainage | 69664 | 68403 | 99.00 | 76.0 | | 12.70 |
| Komex-101 | mining | 77639 | 73919 | 4.80 | 4.41 | | 6.13 |
| Komex-102 | mining | 56561 | 57668 | 7.93 | 5.53 | | 9.32 |
| Komex-103 | mining | 86706 | 85676 | 33.80 | 45.20 | | 14.60 |
| Komex-104 | mining | 130756 | 149177 | 96.00 | 146.00 | | 119.00 |
| Komex-105 | mining | 71932 | 739956 | 7.81 | 6.65 | | 4.55 |
| Komex-106 | mining | 66489 | 68118 | 21.80 | 25.50 | < | 3.33 |
| Komex-107 | mining | 569568 | 554967 | 350.00 | 505.00 | | 275.00 |
| Komex-108 | mining | 84810 | 81812 | 4.23 | 5.06 | | 4.21 |
| Komex-109 | mining | 81792 | 65974 | 17.60 | 27.30 | | 20.00 |
| Komex-110 | mining | 23175 | 24420 | 2.79 | 3.29 | | 5.33 |
| Komex-111 | mining drainage | 28188 | 34835 | 22.00 | 11.70 | | 4.86 |
| Komex-112 | windblown/undisturbed | 39248 | 40601 | 7.02 | 6.91 | < | 1.77 |
| Komex-113 | windblown/undisturbed | 37800 | 37413 | 2.97 | 5.52 | < | 2.21 |
| Komex-114 | windblown/undisturbed | 30782 | 31944 | 4.21 | 4.89 | < | 1.22 |
| Komex-115 | windblown/undisturbed | 37487 | 37309 | 5.90 | 7.62 | | 4.28 |
| Komex-116 | windblown/undisturbed | 40498 | 41191 | 5.90 | 12.60 | < | 1.51 |
| Komex-117 | windblown/undisturbed | 37773 | 37803 | 5.21 | 11.10 | < | 1.60 |
| Komex-118 | windblown/undisturbed | 39796 | 43754 | 4.65 | 8.53 | < | 0.28 |
| Komex-119 | windblown/undisturbed | 43294 | 43135 | 7.92 | 12.10 | < | 1.80 |
| Komex-120 | windblown/undisturbed | 40989 | 43015 | 6.79 | 7.88 | < | 2.74 |
| Komex-121 | windblown/undisturbed | 29948 | 29929 | 4.38 | 4.25 | | 2.87 |
| Komex-122 | mining | 35330 | 32260 | 3.15 | 5.50 | < | 0.83 |
| Komex-123 | mining | 34798 | 33662 | 3.01 | 2.46 | < | 2.18 |
| Komex-124 | mining | 67367 | 64595 | 10.20 | 8.60 | | 2.50 |

## Table 2-2. Historical Data For Surface Soils

| Location | Sample Date | Walking Gamma cpm | Ra-226 pCi/g | Th-230 pCi/g | Uranium-total pCi/g |
|---|---|---|---|---|---|
| 32 STRAT#1 | 5/1/2001 | | 4.64 | 5.39 | 1.64 |
| 32 STRAT#2 | 5/1/2001 | | 4.06 | 4.19 | 1.16 |
| 32 STRAT#3 | 5/1/2001 | | 2.28 | 2.08 | 0.84 |
| AA-10 | 5/1/2001 | 22081 | 2.09 | 1.77 | 0.93 |
| AA-11 | 6/22/2000 | 35208 | 2.52 | 2.06 | 1.83 |
| AA-11-SE | 5/4/2001 | 28329 | 3.42 | 2.82 | 1.74 |
| AA-12-SE | 5/14/2001 | | 14.1 | 17.6 | 6.5 |
| AA-13-SE | 5/14/2001 | 32500 | 3.93 | 3.69 | 1.51 |
| AA-14-SE | 5/14/2001 | 32487 | 3.18 | 2.87 | 1.19 |
| AA-15-SE | 5/14/2001 | 32870 | 4.85 | 5.71 | 0.14 |
| AA-16-SE | 5/14/2001 | 33751 | 6.13 | 8.36 | 1.87 |
| AA-9 | 6/22/2000 | 23687 | 1.04 | 0.9 | 0.35 |
| AB-11 | 6/22/2000 | 28811 | 0.83 | 0.64 | 0.9 |
| AB-11-SE | 5/14/2001 | 24101 | 3.08 | 2.56 | 0.87 |
| AB-12-SE | 5/14/2001 | 29916 | 4.91 | 4.9 | 2.51 |
| AB-13-SE | 5/14/2001 | 27414 | 4.42 | 4.41 | 0.01 |
| AB-9 | 8/1/2000 | 22625 | 2.93 | 3.67 | 1.38 |
| Background - section 20 | 11/10/1999 | | 4.2 | 6.2 | 4 |
| Background - section 20 | 11/10/1999 | | 4.9 | | |
| Background - section 20 | 11/10/1999 | | 4.4 | | |
| Background - section 20 | 11/10/1999 | | 5.1 | | |
| Background - section 29 | 11/10/1999 | | 6.5 | 10 | 5 |
| Background - section 29 | 11/10/1999 | | 7.3 | | |
| Background - section 29 | 11/10/1999 | | 7.1 | | |
| Background - section 32 | 11/10/1999 | | 5 | 5.8 | 3.4 |
| Background - section 32 | 11/10/1999 | | 4.5 | | |
| Background - section 32 | 11/10/1999 | | 4.8 | | |
| Buffer - south end | 11/10/1999 | | 22.3 | 14 | 3.4 |
| Buffer - south end | 11/10/1999 | | 16.2 | 30 | 4.2 |
| Buffer - south end | 11/10/1999 | | 15.4 | | |
| Buffer - south end | 11/10/1999 | | 13.7 | | |
| Buffer - south end | 11/10/1999 | | 18.1 | | |
| Buffer - south end | 11/10/1999 | | 10.6 | | |
| Buffer zone - southeast | 11/10/1999 | | 13.2 | 30 | 5.4 |
| Buffer zone - southeast | 11/10/1999 | | 11.2 | | |
| Buffer zone - southeast | 11/10/1999 | | 14.5 | | |
| HMC-3 | 7/28/1998 | 41331 | 41.8 | 2.8 | 9.55 |
| HMC-3 | 7/28/1998 | 42843 | 24.4 | 29.9 | 9.84 |
| HMC-3 | 7/28/1998 | 54590 | 4.6 | 32.8 | 15.8 |
| HMC-5 | 7/28/1998 | 57787 | 10.4 | 8.5 | 6.24 |
| Mid Section 1 | 4/1/1997 | | 1.1 | 0.82 | 0.707 |
| Mid Section 1 | 4/1/1997 | | 0.8 | | |
| mid Section Line 1/36 | 4/1/1997 | | 1.6 | | |
| mid Section Line 1/6 | 4/1/1997 | | 0.7 | 1.57 | 0.515 |

## Table 2-2. Historical Data For Surface Soils

| Location | Sample Date | Walking Gamma cpm | Ra-226 pCi/g | Th-230 pCi/g | Uranium-total pCi/g |
|---|---|---|---|---|---|
| mid Section Line 1/6 | 4/1/1997 | | 1.2 | | |
| mid Section Line 24/25 | 4/1/1997 | | 2.8 | | |
| mid Section Line 25/36 | 4/1/1997 | | 1.5 | | |
| mid Section Line 4/5 | 4/1/1997 | | 7.5 | | |
| mid Section Line 5/6 | 4/1/1997 | | 5.4 | | |
| Q-18 | 6/22/2000 | | 3.96 | 5.84 | 2.57 |
| Q-21 | 6/22/2000 | 36944 | 1.71 | | |
| Q-7 | 6/22/2000 | 14204 | 1.73 | 2.68 | 0.45 |
| Quarter Section Line 9/16 | 4/1/1997 | | 2 | 2.03 | 2.25 |
| Quarter Section Line 9/16 | 4/1/1997 | | 3.5 | | |
| R-18 | 6/22/2000 | | 0.8 | 1.54 | 1 |
| R-20 | 6/22/2000 | | 3.02 | 35.7 | 2.25 |
| R-21 | 8/1/2000 | 35358 | 4.26 | 11.1 | 5.98 |
| R-6 | 6/22/2000 | 22914 | 2.9 | 0.81 | 1.03 |
| R-7 | 6/22/2000 | 10340 | 0.28 | 0.23 | 0.15 |
| S-18 | 6/22/2000 | | 1.88 | 5.7 | 1.03 |
| S-21 | 5/1/2001 | 27956 | 2.92 | 6.15 | 2.51 |
| S-22 | 6/22/2000 | 32755 | 3.77 | 7.19 | 5.15 |
| S-7 | 6/22/2000 | 12083 | 0.45 | 0.4 | 0.19 |
| S-8 | 8/1/2000 | 12915 | 2.18 | 3.86 | 0.74 |
| Section Corner 1/2/11/12 | 4/1/1997 | | 0.8 | | |
| Section Corner 1/2/35/36 | 4/1/1997 | | 1.8 | | |
| Section Corner 12/13/18/7 | 4/1/1997 | | 1.8 | | |
| Section Corner 13/14/23/24 | 4/1/1997 | | 3.2 | | |
| Section Corner 13/18/19/24 | 4/1/1997 | | 1.5 | | |
| Section Corner 14/15/22/23 | 4/1/1997 | | 20.2 | | |
| Section Corner 16/17/20/21 | 4/1/1997 | | 3.4 | | |
| Section Corner 17/18/19/20 | 4/1/1997 | | 4.3 | | |
| Section Corner 19/20/29/30 | 4/1/1997 | | 9.3 | | |
| Section Corner 20/21/28/29 | 4/1/1997 | | 3.6 | | |
| Section Corner 22/23/26/27-U | 4/1/1997 | | 10.5 | 0.88 | 0.515 |
| Section Corner 22/23/26/27-Y | 4/1/1997 | | 2.4 | | |
| Section Corner 22/23/26/27-Y | 4/1/1997 | | 0.8 | | |
| Section Corner 23/24/25/26 | 4/1/1997 | | 4.4 | | |
| Section Corner 24/25/19/30 | 4/1/1997 | | 3.7 | 2.09 | 1.61 |
| Section Corner 24/25/19/30 | 4/1/1997 | | 2.3 | | |
| Section Corner 25/25/35/36 | 4/1/1997 | | 0.6 | | |
| Section Corner 25/25/35/36 | 4/1/1997 | | 2.1 | 0.3 | 0.772 |
| Section Corner 26/27/34/35 | 4/1/1997 | | 3.7 | | |
| Section Corner 3/4/9/10 | 4/1/1997 | | 1.3 | | |

## Table 2-2. Historical Data For Surface Soils

| Location | Sample Date | Walking Gamma cpm | Ra-226 pCi/g | Th-230 pCi/g | Uranium-total pCi/g |
|---|---|---|---|---|---|
| Section Corner 34/35/2/3 | 4/1/1997 | | 2.1 | | |
| Section Corner 4/5/8/9 | 4/1/1997 | | 2.2 | 0.47 | 0.579 |
| Section Corner 4/5/8/9 | 4/1/1997 | | 0.7 | | |
| Section Corner 5/6/7/8 | 4/1/1997 | | 1.5 | | |
| Section Corner 6/7/1/12 | 4/1/1997 | | 1.2 | | |
| SHPO-1 | 4/26/2001 | | 16.8 | 27.4 | 0.26 |
| SHPO-2-N | 4/26/2001 | | 5.72 | 9.32 | 1.48 |
| SHPO-2-S | 4/26/2001 | | 3.51 | 11 | 1.54 |
| T-16-SE | 7/25/2001 | 32140 | 3.6 | 61 | 2.3 |
| T-17-SE | 7/25/2001 | 21965 | 4 | 81 | 2 |
| T-18-SE | 7/25/2001 | 22039 | 3.1 | 78 | 3.2 |
| T-19-SE | 7/25/2001 | 17357 | 1.6 | 71 | 1.8 |
| T-20-SE | 7/25/2001 | 18932 | 2.3 | 36 | 1.2 |
| T-21 | 6/22/2000 | 23005 | 0.76 | 2.29 | 0.55 |
| T-21-SE | 7/25/2001 | 16412 | 0.9 | 4.1 | 0.94 |
| T-22 | 5/1/2001 | 35172 | 3.6 | 10.1 | 2.28 |
| T-7 | 8/1/2000 | 16529 | 2.69 | 4.08 | 0.69 |
| T-8 | 6/22/2000 | 18795 | 2.18 | 8.89 | 1.54 |
| U-10 | 6/22/2000 | 25161 | 3.46 | 5.13 | 1 |
| U-15 | 6/22/2000 | | 17 | 22.7 | 0.96 |
| U-16 | 6/22/2000 | 29165 | 0.91 | 3.08 | 0.77 |
| U-17 | 7/25/2001 | 17533 | 1.3 | 8.5 | 4.2 |
| U-18 | 7/25/2001 | 14446 | 0.98 | 2.4 | 0.74 |
| U-18-SE | 7/25/2001 | 19267 | 1.2 | 5.8 | 0.8 |
| U-19 | 7/25/2001 | 14848 | 0.77 | 3.8 | 0.64 |
| U-19-SE | 7/25/2001 | 14278 | 0.78 | 2.2 | 0.65 |
| U-20 | 7/25/2001 | 13811 | 0.62 | 1.3 | 0.64 |
| U-20-SE | 7/25/2001 | 13488 | 0.82 | 3.3 | 0.74 |
| U-21 | 7/25/2001 | 13777 | 0.66 | 1.7 | 0.64 |
| U-21-SE | 7/25/2001 | 15834 | 0.88 | 3.4 | 0.87 |
| U-22 | 6/22/2000 | 31502 | 3.13 | 15.8 | 1.13 |
| U-6 | 5/1/2001 | 25948 | 2.21 | 1.27 | 0.39 |
| U-7 | 5/1/2001 | 18459 | 1.12 | 0.93 | 0.29 |
| V-10 | 6/22/2000 | 25113 | 5.03 | 6.68 | 0.74 |
| V-15 | 6/22/2000 | | 0.47 | 0.84 | 0.64 |
| V-15 | 6/22/2000 | | 0.54 | 1.1 | 0.74 |
| V-15 | 6/22/2000 | | 0.34 | | |
| V-16 | 6/22/2000 | 39364 | 4.33 | 12.4 | 10.6 |
| V-17 | 8/1/2000 | 24622 | 0.97 | 3.86 | 0.55 |
| V-18 | 6/22/2000 | 20156 | 0.55 | 1.01 | 2.32 |

## Table 2-2. Historical Data For Surface Soils

| Location | Sample Date | Walking Gamma cpm | Ra-226 pCi/g | Th-230 pCi/g | Uranium-total pCi/g |
|---|---|---|---|---|---|
| V-19 | 7/25/2001 | 17070 | 1.5 | 9.4 | 0.94 |
| V-20 | 7/25/2001 | 14691 | 0.95 | 4.5 | 0.64 |
| V-21 | 7/25/2001 | 17690 | 1.4 | 24 | 1.2 |
| V-7 | 5/1/2001 | 31981 | 2.67 | 2.02 | 0.64 |
| V-8 | 5/1/2001 | 38081 | 3.82 | 2.84 | 0.71 |
| V-9 | 6/22/2000 | 13036 | 0.48 | 1.46 | 0.14 |
| W-10 | 6/22/2000 | 19721 | 1.4 | 4.49 | 0.48 |
| W-10 | 6/22/2000 | | 1.79 | 5.39 | 0.58 |
| W-11 | 6/22/2000 | | 2.23 | 55.9 | 0.84 |
| W-15 | 6/22/2000 | | 3.81 | 19.7 | 3.12 |
| W-17 | 6/22/2000 | | 6.49 | 4.5 | 4.95 |
| W-18 | 8/1/2000 | | 7.06 | 22.5 | 6.21 |
| W-19 | 6/22/2000 | 25169 | 1.47 | 9.03 | 1.09 |
| W-21 | 6/22/2000 | 47754 | 5.1 | 13.2 | 5.24 |
| W-8 | 5/1/2001 | 27559 | 1.82 | 1.62 | 0.39 |
| W-9 | 5/1/2001 | 23070 | 2.47 | 2.13 | 0.74 |
| X-11 | 6/22/2000 | 24662 | 1.02 | 0.65 | 1.03 |
| X-12 | 8/1/2000 | 27673 | 3.61 | 3.63 | 1.54 |
| X-12-SE | 5/4/2001 | 21319 | 1.66 | 1.26 | 1.23 |
| X-13 | 6/22/2000 | 25057 | 0.62 | 0.48 | 0.61 |
| X-13-SE | 5/4/2001 | 19466 | 1.07 | 0.83 | 0.77 |
| X-14 | 6/22/2000 | 23121 | 0.78 | 0.51 | 0.64 |
| X-14-SE | 5/4/2001 | 18083 | 0.88 | 0.79 | 0.43 |
| X-15 | 6/22/2000 | 23930 | 0.54 | 0.71 | 0.42 |
| X-15-SE | 5/4/2001 | 23214 | 1.72 | 1.48 | 1.22 |
| X-16 | 6/22/2000 | 22205 | 0.77 | 1.43 | 1.09 |
| X-16-SE | 5/4/2001 | 22445 | 1.82 | 2.28 | 1 |
| X-17 | 6/22/2000 | 20973 | 0.69 | 0.81 | 0.61 |
| X-17-SE | 5/4/2001 | 27271 | 2.01 | 2.27 | 1.48 |
| X-18-SE | 5/14/2001 | | 7.5 | 17.8 | 2.99 |
| X-19 | 6/22/2000 | | 8.7 | 15.1 | 22.8 |
| X-9 | 5/1/2001 | 28117 | 2.72 | 2.11 | 0.64 |
| Y-10 | 8/1/2000 | 22139 | 2.21 | 2.1 | 1.38 |
| Y-11 | 6/22/2000 | 25739 | 1.84 | 1.67 | 0.74 |
| Y-11-SE | 5/4/2001 | 19646 | 1.12 | 0.75 | 0.87 |
| Y-12 | 6/22/2000 | 24229 | 3.12 | 2.73 | 1.26 |
| Y-12 | 6/22/2000 | | 1.86 | | |
| Y-12-SE | 5/4/2001 | 30633 | 6.03 | 5.79 | 1.53 |
| Y-13 | 8/1/2000 | 17782 | 0.63 | 0.43 | 0.35 |
| Y-13-SE | 5/4/2001 | 36793 | 3.66 | 3.19 | 0.84 |

### Table 2-2. Historical Data For Surface Soils

| Location | Sample Date | Walking Gamma cpm | Ra-226 pCi/g | Th-230 pCi/g | Uranium-total pCi/g |
|---|---|---|---|---|---|
| Y-14 | 6/22/2000 | 24752 | 1.95 | 2.62 | 0.87 |
| Y-14-SE | 5/4/2001 | 38182 | 3.11 | 3.51 | 0.81 |
| Y-15 | 6/22/2000 | 41148 | 3.85 | 5.63 | 1.32 |
| Y-15-SE | 5/4/2001 | 46061 | 7.14 | 8.85 | 2.6 |
| Y-16-SE | 5/14/2001 | | 11.2 | 14.4 | 0.19 |
| Y-17 | 6/22/2000 | 40763 | 2.14 | 4.38 | 1.35 |
| Y-17-SE | 5/14/2001 | | 8.33 | 12.8 | 0.01 |
| Y-18-SE | 5/14/2001 | | 6.21 | 13.5 | 2.22 |
| Z-10 | 6/22/2000 | 28072 | 2.43 | 2.42 | 0.84 |
| Z-11 | 6/22/2000 | 36407 | 1.87 | 1.91 | 0.96 |
| Z-11-SE | 5/4/2001 | 34437 | 3.55 | 3.19 | 1.38 |
| Z-12 | 6/22/2000 | 38998 | 3.14 | 3.47 | 1.12 |
| Z-12-SE | 5/4/2001 | 34687 | 4.66 | 4.65 | 1.32 |
| Z-13-SE | 5/4/2001 | 33160 | 2.11 | 2.11 | 0.72 |
| Z-14-SE | 5/14/2001 | | 12.8 | 12.2 | 4.92 |
| Z-15 | 6/22/2000 | 42899 | 2.31 | 2.4 | 1.48 |
| Z-15-SE | 5/14/2001 | 39039 | 5.96 | 7.05 | 2.35 |
| Z-16-SE | 5/14/2001 | | 7.56 | 11.5 | 2.44 |
| Z-17-SE | 5/14/2001 | 32528 | 5.18 | 7.3 | 1.48 |
| Z-9 | 6/22/2001 | 24702 | 2.33 | 1.71 | 0.87 |

**Table 2-3. Analytical Results of Soil Samples from Perimeter of Evaporation Pond 4.**

| Sample location | Sample date | Sample depth top (ft) | Sample depth bottom (ft) | Ra-226 (pCi/g) | Th-230 (pCi/g) | U-total (pCi/g) |
|---|---|---|---|---|---|---|
| POND 4 HALO PIT 4A | 6/5/2001 | 0 | 1 | 13.3 | 1590 | 13 |
| POND 4 HALO PIT 4A | 6/5/2001 | 1 | 2 | 3.63 | 516 | 51.1 |
| POND 4 HALO PIT 4A | 6/5/2001 | 2 | 3 | 0.74 | 2.95 | 54 |
| POND 4 HALO PIT 4A | 6/5/2001 | 3 | 4 | 0.52 | 1.97 | 33.1 |
| POND 4 HALO PIT 4A | 6/5/2001 | 4 | 5 | 0.58 | 2.57 | 28.5 |
| POND 4 HALO PIT 4B | 6/5/2001 | 0 | 1 | 0.43 | 1.86 | 2.02 |
| POND 4 HALO PIT 4B | 6/5/2001 | 1 | 2 | 0.77 | 1.22 | 1.84 |
| POND 4 HALO PIT 4B | 6/5/2001 | 2 | 3 | 0.81 | 1.66 | 2.42 |
| POND 4 HALO PIT 4B | 6/5/2001 | 3 | 4 | 0.59 | 1.03 | 0.83 |
| POND 4 HALO PIT 4B | 6/5/2001 | 4 | 5 | 0.75 | 2.24 | 0.91 |
| POND 4 HALO PIT 4C | 6/5/2001 | 0 | 1 | 1.14 | 2.57 | 1.06 |
| POND 4 HALO PIT 4C | 6/5/2001 | 1 | 2 | 1.23 | 1.46 | 1.11 |
| POND 4 HALO PIT 4C | 6/5/2001 | 2 | 3 | 0.64 | 0.71 | 0.75 |
| POND 4 HALO PIT 4C | 6/5/2001 | 3 | 4 | 0.83 | 0.69 | 0.67 |
| POND 4 HALO PIT 4C | 6/5/2001 | 4 | 5 | 0.74 | 0.77 | 0.72 |
| POND 4 HALO PIT 4D | 6/5/2001 | 0 | 1 | 0.59 | 2.45 | 0.45 |
| POND 4 HALO PIT 4D | 6/5/2001 | 1 | 2 | 0.48 | 0.49 | 0.29 |
| POND 4 HALO PIT 4D | 6/5/2001 | 2 | 3 | 0.41 | 0.29 | 0.35 |
| POND 4 HALO PIT 4D | 6/5/2001 | 3 | 4 | 0.4 | 0.32 | 0.38 |
| POND 4 HALO PIT 4D | 6/5/2001 | 4 | 5 | 0.39 | 0.34 | 0.37 |
| POND 4 HALO PIT 4E | 6/5/2001 | 0 | 1 | 1.97 | 22.7 | 3.57 |
| POND 4 HALO PIT 4E | 6/5/2001 | 1 | 2 | 0.77 | 2.71 | 2.16 |
| POND 4 HALO PIT 4E | 6/5/2001 | 2 | 3 | 0.4 | 0.54 | 1.68 |
| POND 4 HALO PIT 4E | 6/5/2001 | 3 | 4 | 0.52 | 0.88 | 1.91 |
| Average | | | | 1 | 90 | 8 |
| Standard Deviation | | | | 3 | 336 | 16 |
| Count | | | | 24 | 24 | 24 |
| Upper 80% Confidence Level (two-tailed) | | | | 2 | 80 | 13 |
| % error of average at Upper 80% Confidence Level | | | | 52 | 101 | 51 |

**Table 2-4. Analytical Results of Soil Samples from Footprint of Evaporation Pond 4.**

| Sample location | Sample date | Sample depth top (ft) | Sample depth bottom (ft) | Ra-226 (pCi/g) | Th-230 (pCi/g) | U-total (pCi/g) |
|---|---|---|---|---|---|---|
| POND 4-A | 4/18/1997 | 0 | 0.5 | 11 | 1010 | 2 |
| POND 4-A | 7/1/1997 | 0.5 | 1 | 31 | 825 | 35 |
| POND 4-A | 11/1/1998 | 2 | 2 | 21 | 1730 | 1 |
| POND 4-A | 11/1/1998 | 3 | 3 | 12 | 1040 | 2 |
| POND 4-A | 11/1/1998 | 4 | 4 | 19 | 1660 | 6 |
| POND 4-A | 11/1/1998 | 5 | 5 | 4 | 479 | 2 |
| POND 4-A | 11/1/1998 | 6 | 6 | 3 | 391 | 3 |
| POND 4-A | 11/1/1998 | 7 | 7 | 2 | 1 | 68 |
| POND 4-A | 11/1/1998 | 8 | 8 | 2 | 32 | 5 |
| POND 4-B | 4/18/1997 | 0 | 0.5 | 17 | 1810 | 2 |
| POND 4-B | 7/1/1997 | 0.5 | 1 | 12 | 1310 | 2 |
| POND 4-B | 7/1/1997 | 1 | 1.5 | 14 | 1250 | 1 |
| POND 4-B | 7/1/1997 | 1.5 | 2 | 12 | 1260 | 2 |
| POND 4-C | 4/18/1997 | 0 | 0.5 | 22 | 2410 | 3 |
| POND 4-C | 7/1/1997 | 0.5 | 1 | 29 | 2380 | 7 |
| POND 4-D | 4/18/1997 | 0 | 0.5 | 15 | 1360 | 30 |
| POND 4-D | 7/1/1997 | 0.5 | 1 | 60 | 3600 | 12 |
| POND 4-E | 4/18/1997 | 0 | 0.5 | 60 | 3770 | 27 |
| POND 4-E | 7/1/1997 | 0.5 | 1 | 62 | 3290 | 9 |
| POND 4-E | 7/1/1997 | 1 | 1.5 | 62 | 4470 | 13 |
| POND 4-E | 7/1/1997 | 1.5 | 2 | 40 | 2620 | 49 |
| Average | | | | 24 | 1748 | 13 |
| Standard Deviation | | | | 21 | 1247 | 18 |
| Count | | | | 21 | 21 | 21 |
| Upper 80% Confidence Level (two-tailed) | | | | 30 | 2108 | 19 |
| % error of average at Upper 80% Confidence Level | | | | 25 | 21 | 39 |

**Table 2-5. Analytical Results of Soil Samples from Perimeter of Evaporation Pond 5.**

| Sample location | Sample date | Sample depth top (ft) | Sample depth bottom (ft) | Ra-226 (pCi/g) | Th-230 (pCi/g) | U-total (pCi/g) |
|---|---|---|---|---|---|---|
| POND 5 HALO PIT 5A | 6/5/2001 | 0 | 1 | 0.58 | 2.38 | 0.43 |
| POND 5 HALO PIT 5A | 6/5/2001 | 1 | 2 | 0.35 | 0.64 | 0.44 |
| POND 5 HALO PIT 5A | 6/5/2001 | 2 | 3 | 0.61 | 0.76 | 0.52 |
| POND 5 HALO PIT 5A | 6/5/2001 | 3 | 4 | 0.92 | 1.25 | 0.97 |
| POND 5 HALO PIT 5A | 6/5/2001 | 4 | 5 | 1.13 | 3.55 | 1.49 |
| POND 5 HALO PIT 5B | 6/5/2001 | 0 | 3 | 1.04 | 7.58 | 0.91 |
| POND 5 HALO PIT 5B | 6/5/2001 | 1 | 2 | 0.48 | 1.38 | 0.83 |
| POND 5 HALO PIT 5B | 6/5/2001 | 2 | 3 | 0.38 | 0.4 | 1.78 |
| POND 5 HALO PIT 5B | 6/5/2001 | 3 | 4 | 0.47 | 4.81 | 2.26 |
| POND 5 HALO PIT 5B | 6/5/2001 | 4 | 5 | 0.46 | 1.11 | 1.14 |
| POND 5 HALO PIT 5C | 6/5/2001 | 0 | 1 | 7.45 | 365 | 5.98 |
| POND 5 HALO PIT 5C | 6/5/2001 | 1 | 2 | 0.79 | 3.56 | 1.41 |
| POND 5 HALO PIT 5C | 6/5/2001 | 2 | 3 | 0.79 | 2.08 | 2.78 |
| POND 5 HALO PIT 5C | 6/5/2001 | 3 | 4 | 0.48 | 0.58 | 5.18 |
| POND 5 HALO PIT 5C | 6/5/2001 | 4 | 5 | 0.3 | 0.35 | 3.11 |
| POND 5 HALO PIT 5D | 6/5/2001 | 0 | 1 | 6.19 | 65.9 | 2.58 |
| POND 5 HALO PIT 5D | 6/5/2001 | 1 | 2 | 8.12 | 371 | 7.85 |
| POND 5 HALO PIT 5D | 6/5/2001 | 2 | 3 | 1.3 | 17.7 | 1.22 |
| POND 5 HALO PIT 5D | 6/5/2001 | 3 | 4 | 1.17 | 1.62 | 1.16 |
| POND 5 HALO PIT 5D | 6/5/2001 | 4 | 5 | 1.03 | 1.13 | 1.29 |
| | | | | | | |
| Average | | | | 2 | 43 | 2 |
| Standard Deviation | | | | 2 | 112 | 2 |
| Count | | | | 20 | 20 | 20 |
| Upper 80% Confidence Level (two-tailed) | | | | 2 | 76 | 3 |
| % error of average at Upper 80% Confidence Level | | | | 42 | 78 | 27 |

**Table 2-6. Analytical Results of Soil Samples from Footprint of Evaporation Pond 5**

| Sample location | Sample date | Sample depth top (ft) | Sample depth bottom (ft) | Ra-226 (pCi/g) | Th-230 (pCi/g) | U-total (pCi/g) |
|---|---|---|---|---|---|---|
| POND 5-A | 4/18/1997 | 0 | 0.5 | 22 | 1660 | 7 |
| POND 5-A | 7/1/1997 | 0.5 | 1 | 14 | 612 | 2 |
| POND 5-A | 7/1/1997 | 1 | 1.5 | 29 | 1490 | 3 |
| POND 5-A | 7/1/1997 | 1.5 | 2 | 20 | 1050 | 3 |
| POND 5-A | 11/1/1998 | 3 | 3 | 52 | 1730 | 1 |
| POND 5-A | 11/1/1998 | 4 | 4 | 20 | 709 | 1 |
| POND 5-A | 11/1/1998 | 5 | 5 | 27 | 2330 | 24 |
| POND 5-B | 4/18/1997 | 0 | 0.5 | 28 | 1750 | 3 |
| POND 5-B | 7/1/1997 | 0.5 | 1 | 14 | 720 | 2 |
| POND 5-C | 4/18/1997 | 0 | 0.5 | 5 | 340 | 43 |
| POND 5-C | 7/1/1997 | 0.5 | 1 | 7 | 618 | 43 |
| POND 5-D | 4/18/1997 | 0 | 0.5 | 20 | 899 | 1 |
| POND 5-D | 7/1/1997 | 0.5 | 1 | 6 | 386 | 7 |
| POND 5-D | 7/1/1997 | 1 | 1.5 | 4 | 324 | 6 |
| POND 5-D | 7/1/1997 | 1.5 | 2 | 7 | 768 | 6 |
| POND 5-D | 11/1/1998 | 3 | 3 | 17 | 918 | 2 |
| POND 5-D | 11/1/1998 | 4 | 4 | 8 | 677 | 19 |
| POND 5-D | 11/1/1998 | 5 | 5 | 8 | 680 | 5 |
| POND 5-D | 11/1/1998 | 6 | 6 | 5 | 632 | 2 |
| POND 5-D | 11/1/1998 | 7 | 7 | 8 | 976 | 4 |
| POND 5-D | 11/1/1998 | 8 | 8 | 8 | 784 | 6 |
| POND 5-E | 4/18/1997 | 0 | 0.5 | 14 | 1200 | 6 |
| POND 5-E | 7/1/1997 | 0.5 | 1 | 20 | 2780 | 12 |
| Average | | | | 16 | 1045 | 9 |
| Standard Deviation | | | | 11 | 636 | 12 |
| Count | | | | 23 | 23 | 23 |
| Upper 80% Confidence Level (two-tailed) | | | | 19 | 1220 | 12 |
| % error of average at Upper 80% Confidence Level | | | | 19 | 17 | 37 |

**Table 2-7. Analytical Results of Soil Samples from Perimeter of Evaporation Pond 6.**

| Sample location | Sample date | Sample depth top (ft) | Sample depth bottom (ft) | Ra-226 (pCi/g) | Th-230 (pCi/g) | U-total (pCi/g) |
|---|---|---|---|---|---|---|
| POND 6 HALO PIT 6A | 6/5/2001 | 0 | 1 | 1.66 | 3.35 | 1.34 |
| POND 6 HALO PIT 6A | 6/5/2001 | 1 | 2 | 0.77 | 1.23 | 3.1 |
| POND 6 HALO PIT 6A | 6/5/2001 | 2 | 3 | 9.4 | 966 | 14.6 |
| POND 6 HALO PIT 6A | 6/5/2001 | 3 | 4 | 9.81 | 631 | 4.86 |
| POND 6 HALO PIT 6A | 6/5/2001 | 4 | 5 | 4.31 | 705 | 44.1 |
| POND 6 HALO PIT 6B | 6/5/2001 | 0 | 1 | 2.39 | 12.6 | 5.15 |
| POND 6 HALO PIT 6B | 6/5/2001 | 1 | 2 | 1.36 | 2.43 | 1.2 |
| POND 6 HALO PIT 6B | 6/5/2001 | 2 | 3 | 1.06 | 2.39 | 1.05 |
| POND 6 HALO PIT 6B | 6/5/2001 | 3 | 4 | 1.07 | 1.4 | 1.01 |
| POND 6 HALO PIT 6B | 6/5/2001 | 4 | 5 | 0.91 | 0.86 | 1.08 |
| POND 6 HALO PIT 6C | 6/5/2001 | 0 | 1 | 10.7 | 131 | 2.46 |
| POND 6 HALO PIT 6C | 6/5/2001 | 1 | 2 | 0.95 | 3.94 | 1.05 |
| POND 6 HALO PIT 6C | 6/5/2001 | 2 | 3 | 0.8 | 1.89 | 0.71 |
| POND 6 HALO PIT 6C | 6/5/2001 | 3 | 4 | 0.61 | 1.27 | 0.68 |
| POND 6 HALO PIT 6C | 6/5/2001 | 4 | 5 | 0.46 | 3.23 | 0.64 |
| Average | | | | 3 | 165 | 6 |
| Standard Deviation | | | | 4 | 321 | 11 |
| Count | | | | 15 | 15 | 15 |
| Upper 80% Confidence Level (two-tailed) | | | | 4 | 276 | 9 |
| % error of average at Upper 80% Confidence Level | | | | 42 | 68 | 71 |

**Table 2-8. Analytical Results of Soil Samples from Footprint of Evaporation Pond 6**

| Sample location | Sample date | Sample depth top (ft) | Sample depth bottom (ft) | Ra-226 (pCi/g) | Th-230 (pCi/g) | U-total (pCi/g) |
|---|---|---|---|---|---|---|
| POND 6 TEST HOLE #1 | 7/14/1999 | 0 | 0 | 17.1 | 1130 | 16.4 |
| POND 6 TEST HOLE #1 | 7/14/1999 | 0 | 6 | 4.55 | 279 | 13.5 |
| POND 6 TEST HOLE #1 | 7/14/1999 | 1 | 1 | 1.57 | 22.5 | 48.7 |
| POND 6 TEST HOLE #1 | 7/14/1999 | 2 | 2 | 1.61 | 2.44 | 1.67 |
| POND 6 TEST HOLE #1 | 7/14/1999 | 3 | 3 | 1.69 | 2.22 | 1.45 |
| POND 6 TEST HOLE #1 | 7/14/1999 | 4 | 4 | 1.67 | 0.93 | 1.25 |
| POND 6 TEST HOLE #1 | 7/14/1999 | 6 | 6 | 1.25 | 32.2 | 5.4 |
| POND 6 TEST HOLE #2 | 7/14/1999 | 0 | 0 | 27.1 | 1920 | 27.6 |
| POND 6 TEST HOLE #2 | 7/14/1999 | 0 | 6 | 10.3 | 959 | 21.1 |
| POND 6 TEST HOLE #2 | 7/14/1999 | 1 | 1 | 12.3 | 990 | 45.8 |
| POND 6 TEST HOLE #2 | 7/14/1999 | 2 | 2 | 13.3 | 457 | 27.8 |
| POND 6 TEST HOLE #2 | 7/14/1999 | 3 | 3 | 1.22 | 12.9 | 2.25 |
| POND 6 TEST HOLE #2 | 7/14/1999 | 4 | 4 | 0.98 | 0.92 | 1.38 |
| POND 6 TEST HOLE #3 | 7/14/1999 | 0 | 0 | 26.1 | 1640 | 10.7 |
| POND 6 TEST HOLE #3 | 7/14/1999 | 0 | 6 | 7.05 | 579 | 20.7 |
| POND 6 TEST HOLE #3 | 7/14/1999 | 1 | 1 | 11.7 | 853 | 8.2 |
| POND 6 TEST HOLE #3 | 7/14/1999 | 2 | 2 | 14.1 | 1040 | 25.3 |
| POND 6 TEST HOLE #3 | 7/14/1999 | 3 | 3 | 1.22 | 64 | 24.8 |
| POND 6 TEST HOLE #3 | 7/14/1999 | 4 | 4 | 0.81 | 1.7 | 50.9 |
| POND 6 TEST HOLE #3 | 7/14/1999 | 6 | 6 | 0.64 | 1.4 | 26.4 |
| Average | | | | 8 | 499 | 19 |
| Standard Deviation | | | | 8 | 607 | 16 |
| Count | | | | 20 | 20 | 20 |
| Upper 80% Confidence Level (two-tailed) | | | | 10 | 680 | 24 |
| % error of average at Upper 80% Confidence Level | | | | 32 | 36 | 25 |

### Table 2-9. Analytical Results of Soil Samples from Evaporation Pond 7.

| Sample location | Sample date | Sample depth top (ft) | Sample depth bottom (ft) | Ra-226 (pCi/g) | Th-230 (pCi/g) | U-total (pCi/g) |
|---|---|---|---|---|---|---|
| POND 7 TEST HOLE #1 | 6/1/1999 | 1 | 1 | 4.74 | 297 | 10.2 |
| POND 7 TEST HOLE #1 | 6/1/1999 | 2 | 2 | 5.03 | 366 | 8.84 |
| POND 7 TEST HOLE #1 | 6/1/1999 | 3 | 3 | 2.01 | 151 | 5.11 |
| POND 7 TEST HOLE #1 | 6/1/1999 | 4 | 4 | 4.63 | 366 | 4.76 |
| POND 7 TEST HOLE #1 | 6/1/1999 | 5 | 5 | 2.81 | 226 | 10.3 |
| POND 7 TEST HOLE #1 | 6/1/1999 | 6 | 6 | 0.83 | 7.32 | 3.67 |
| POND 7 TEST HOLE #1 | 6/1/1999 | 7 | 7 | 3.27 | 199 | 7.4 |
| POND 7 TEST HOLE #1 | 6/1/1999 | 8 | 8 | 0.86 | 9.88 | 10.2 |
| POND 7 TEST HOLE #2 | 6/1/1999 | 1 | 1 | 9.65 | 312 | 2.03 |
| POND 7 TEST HOLE #2 | 6/1/1999 | 3 | 3 | 1.14 | 22.8 | 8.73 |
| POND 7 TEST HOLE #2 | 6/1/1999 | 4 | 4 | 6.83 | 562 | 7.72 |
| POND 7 TEST HOLE #2 | 6/1/1999 | 5 | 5 | 1.16 | 54.9 | 10.4 |
| POND 7 TEST HOLE #2 | 6/1/1999 | 6 | 6 | 10.1 | 565 | 8.1 |
| POND 7 TEST HOLE #2 | 6/1/1999 | 7 | 7 | 1.27 | 158 | 4.34 |
| POND 7 TEST HOLE #3 | 6/1/1999 | 1 | 1 | 5.52 | 924 | 2.15 |
| POND 7 TEST HOLE #3 | 6/1/1999 | 2 | 2 | 11.6 | 1000 | 7.85 |
| POND 7 TEST HOLE #3 | 6/1/1999 | 3 | 3 | 9.13 | 685 | 3.28 |
| POND 7 TEST HOLE #3 | 6/1/1999 | 4 | 4 | 7.09 | 560 | 3.12 |
| POND 7 TEST HOLE #3 | 6/1/1999 | 5 | 5 | 2.63 | 34.8 | 0.87 |
| POND 7 TEST HOLE #3 | 6/1/1999 | 6 | 6 | 0.76 | 13 | 14.7 |
| POND 7 TEST HOLE #3 | 6/1/1999 | 7 | 7 | 2.8 | 141 | 2.64 |
| POND 7 TEST HOLE #3 | 6/1/1999 | 8 | 8 | 0.63 | 0.07 | 4.44 |
| POND 7 TEST HOLE #3 | 6/1/1999 | 10 | 10 | 2.15 | 95.1 | 4.66 |
| POND 7 TEST HOLE #4 | 6/1/1999 | 1 | 1 | 4.28 | 255 | 3.92 |
| POND 7 TEST HOLE #4 | 6/1/1999 | 2 | 2 | 0.65 | 72.8 | 1.87 |
| POND 7 TEST HOLE #4 | 6/1/1999 | 3 | 3 | 0.91 | 7.49 | 8.17 |
| POND 7 TEST HOLE #4 | 6/1/1999 | 4 | 4 | 0.5 | 10 | 4.08 |
| POND 7 TEST HOLE #4 | 6/1/1999 | 5 | 5 | 2.69 | 334 | 22.5 |
| POND 7 TEST HOLE #4 | 6/1/1999 | 6 | 6 | 1.25 | 21.2 | 17.2 |
| POND 7 TEST HOLE #5 | 6/1/1999 | 1 | 1 | 7.94 | 639 | 7.33 |
| POND 7 TEST HOLE #5 | 6/1/1999 | 2 | 2 | 2.34 | 37.1 | 1.03 |
| POND 7 TEST HOLE #5 | 6/1/1999 | 3 | 3 | 1.03 | 28.6 | 4.34 |
| POND 7 TEST HOLE #5 | 6/1/1999 | 4 | 4 | 14 | 292 | 3.44 |
| POND 7 TEST HOLE #5 | 6/1/1999 | 5 | 5 | 18.6 | 850 | 6.66 |
| POND 7 TEST HOLE #6 | 6/1/1999 | 1 | 1 | 1.75 | 24.9 | 0.87 |
| POND 7 TEST HOLE #6 | 6/1/1999 | 2 | 2 | 0.89 | 59.3 | 3.47 |
| POND 7 TEST HOLE #6 | 6/1/1999 | 3 | 3 | 0.53 | 10.1 | 3.7 |
| POND 7 TEST HOLE #6 | 6/1/1999 | 4 | 4 | 0.47 | 17.8 | 4.31 |
| POND 7 TEST HOLE #6 | 6/1/1999 | 5 | 5 | 11.5 | 1030 | 6.3 |

**Table 2-9. Analytical Results of Soil Samples from Evaporation Pond 7.**

| Sample location | Sample date | Sample depth top (ft) | Sample depth bottom (ft) | Ra-226 (pCi/g) | Th-230 (pCi/g) | U-total (pCi/g) |
|---|---|---|---|---|---|---|
| POND 7 TEST HOLE #6 | 6/1/1999 | 6 | 6 | 9.24 | 925 | 10.2 |
| POND 7 TEST HOLE #6 | 6/1/1999 | 7 | 7 | 0.56 | 9.54 | 14.6 |
| POND 7 TEST HOLE #6 | 6/1/1999 | 8 | 8 | 2.19 | 238 | 5.6 |
| POND 7 TEST HOLE #6 | 6/1/1999 | 10 | 10 | 5.1 | 448 | 14.8 |
| Average | | | | 4 | 280 | 7 |
| Standard Deviation | | | | 4 | 312 | 5 |
| Count | | | | 43 | 43 | 43 |
| Upper 80% Confidence Level (two-tailed) | | | | 5 | 343 | 8 |
| % error of average at Upper 80% Confidence Level | | | | 20 | 22 | 14 |

**Table 2-10. Analytical Results of Soil Samples from Evaporation Pond 8.**

| Sample location | Sample date | Sample depth top (ft) | Sample depth bottom (ft) | Ra-226 (pCi/g) | Th-230 (pCi/g) | U-total (pCi/g) |
|---|---|---|---|---|---|---|
| POND 8 PIT A | 6/1/2001 | 0 | 1 | 60.3 | 1160 | 2.16 |
| POND 8 PIT A | 6/1/2001 | 1 | 2 | 78.2 | 2070 | 2.58 |
| POND 8 PIT A | 6/1/2001 | 2 | 3 | 32.6 | 918 | 1.29 |
| POND 8 PIT A | 6/1/2001 | 3 | 4 | 28.3 | 1020 | 1.56 |
| POND 8 PIT A | 6/1/2001 | 4 | 5 | 20.8 | 580 | 1.56 |
| POND 8 PIT B | 6/1/2001 | 0 | 1 | 39.3 | 1450 | 1.06 |
| POND 8 PIT B | 6/1/2001 | 1 | 2 | 26.6 | 1040 | 1.76 |
| POND 8 PIT B | 6/1/2001 | 2 | 3 | 39 | 1720 | 3.6 |
| POND 8 PIT B | 6/1/2001 | 3 | 4 | 21.7 | 1010 | 3.11 |
| POND 8 PIT B | 6/1/2001 | 4 | 5 | 16.1 | 717 | 2.86 |
| POND 8 PIT C | 6/1/2001 | 0 | 1 | 12.2 | 613 | 7.04 |
| POND 8 PIT C | 6/1/2001 | 1 | 2 | 32.6 | 677 | 3.19 |
| POND 8 PIT C | 6/1/2001 | 2 | 3 | 25.4 | 441 | 2.29 |
| POND 8 PIT C | 6/1/2001 | 3 | 4 | 18 | 362 | 2.05 |
| POND 8 PIT C | 6/1/2001 | 4 | 5 | 34.7 | 628 | 2.84 |
| POND 8 PIT D | 6/1/2001 | 0 | 1 | 22.9 | 149 | 2.16 |
| POND 8 PIT D | 6/1/2001 | 1 | 2 | 27.1 | 822 | 3.04 |
| POND 8 PIT D | 6/1/2001 | 2 | 3 | 9.16 | 456 | 2.17 |
| POND 8 PIT D | 6/1/2001 | 3 | 4 | 10.8 | 832 | 5.08 |
| POND 8 PIT D | 6/1/2001 | 4 | 5 | 6.79 | 622 | 3.7 |
| POND 8 PIT E | 6/1/2001 | 0 | 1 | 25.6 | 353 | 2.59 |
| POND 8 PIT E | 6/1/2001 | 1 | 2 | 27 | 719 | 1.65 |
| POND 8 PIT E | 6/1/2001 | 2 | 3 | 29.4 | 1030 | 2.07 |
| POND 8 PIT E | 6/1/2001 | 3 | 4 | 14.2 | 603 | 2.68 |
| POND 8 PIT E | 6/1/2001 | 4 | 5 | 9.85 | 632 | 2.05 |
| Average | | | | 27 | 825 | 3 |
| Standard Deviation | | | | 16 | 434 | 1 |
| Count | | | | 25 | 25 | 25 |
| Upper 80% Confidence Level (two-tailed) | | | | 31 | 939 | 3 |
| % error of average at Upper 80% Confidence Level | | | | 16 | 14 | 13 |

**Table 2-11. February-March 1994 Pond 10 Soil Sampling Data**

| Date | Location | Depth (inches) | Radium (pCi/g) |
|---|---|---|---|
| 13-Jun-94 | D2-B3 | 0-6 | 10.7 |
| 17-Feb-94 | D3-C1 | 0-6 | 2.5 |
| 17-Feb-94 | D3-D3 | 0-6 | 14.9 |
| 11-Feb-94 | E1-C5 | 0-6 | 1.9 |
| 03-Mar-94 | E2-B4 | 0-6 | 6.7 |
| 11-Feb-94 | E2-E5 | 0-6 | 4.0 |
| 11-Feb-94 | E3-B2 | 0-6 | 6.8 |
| 14-Feb-94 | E3-C5 | 0-6 | 2.6 |
| 14-Feb-94 | F1-A3 | 0-6 | 4.7 |
| 11-Feb-94 | F1-D5 | 0-6 | 8.3 |
| 14-Feb-94 | F2-A2 | 0-6 | 9.5 |
| 11-Feb-94 | F2-D5 | 0-6 | 8.4 |
| 14-Feb-94 | F3-A3 | 0-6 | 4.1 |
| 11-Feb-94 | F3-D5 | 0-6 | 5.2 |
| 14-Feb-94 | G1-C3 | 0-6 | 13.6 |
| 11-Feb-94 | G1-E5 | 0-6 | 5.4 |
| 03-Mar-94 | G2-B3 | 0-6 | 6.1 |
| 11-Feb-94 | G2-E5 | 0-6 | 5.4 |
| 03-Mar-94 | G3-B3 | 0-6 | 2.8 |
| 11-Feb-94 | G4-D1 | 0-6 | 3.2 |
| 14-Feb-94 | H2-C2 | 0-6 | 6.8 |
| 14-Feb-94 | H3-C3 | 0-6 | 5.7 |
| 03-Mar-94 | H4-C1 | 0-6 | 4.5 |
| 11-Feb-94 | I1-A4 | 0-6 | 3.5 |
| 11-Feb-94 | I2-A5 | 0-6 | 15.7 |
| 03-Mar-94 | I2-E2 | 0-6 | 15.9 |
| 03-Mar-94 | I3-D3 | 0-6 | 5.3 |
| 11-Feb-94 | I4-A1 | 0-6 | 10.2 |
| 14-Feb-94 | J1-B4 | 0-6 | 10.5 |
| 11-Feb-94 | J2-A5 | 0-6 | 10.0 |
| 11-Feb-94 | J4-B1 | 0-6 | 18.7 |
| 13-Jun-94 | D2-B3 | 6-12 | 3.3 |
| 17-Feb-94 | D3-C1 | 6-12 | 4.5 |
| 17-Feb-94 | D3-D3 | 6-12 | 11.4 |
| 11-Feb-94 | E1-C5 | 6-12 | 3.2 |
| 11-Feb-94 | E2-E5 | 6-12 | 1.8 |
| 03-Mar-94 | E3-B2 | 6-12 | 8.4 |
| 14-Feb-94 | F1-A3 | 6-12 | 4.1 |
| 11-Feb-94 | F1-D5 | 6-12 | 3.6 |

**Table 2-11. February-March 1994 Pond 10 Soil Sampling Data**

| Date | Location | Depth (inches) | Radium (pCi/g) |
|---|---|---|---|
| 14-Feb-94 | F2-A2 | 6-12 | 17.0 |
| 11-Feb-94 | F2-D5 | 6-12 | 2.0 |
| 14-Feb-94 | F3-A3 | 6-12 | 0.8 |
| 11-Feb-94 | F3-D5 | 6-12 | 1.0 |
| 14-Feb-94 | C1-C3 | 6-12 | 3.5 |
| 11-Feb-94 | C1-E5 | 6-12 | 4.6 |
| 03-Mar-94 | G2-B3 | 6-12 | 2.4 |
| 11-Feb-94 | G2-E5 | 6-12 | 5.6 |
| 11-Feb-94 | G4-D1 | 6-12 | 1.9 |
| 14-Feb-94 | H2-C2 | 6-12 | 2.9 |
| 14-Feb-94 | H3-C3 | 6-12 | 2.5 |
| 03-Mar-94 | H4-C1 | 6-12 | 2.9 |
| 11-Feb-94 | I2-A5 | 6-12 | 12.1 |
| 03-Mar-94 | I3-D3 | 6-12 | 3.7 |
| 11-Feb-94 | I4-A1 | 6-12 | 5.1 |
| 14-Feb-94 | J1-B4 | 6-12 | 11.6 |
| 11-Feb-94 | J2-A5 | 6-12 | 10.6 |
| 14-Feb-94 | J4-B1 | 6-12 | 14.0 |

**Table 2-12. Results of Re-Analysis of 1994 Pond 10 Soil Samples by GEL Laboratories**

| Location | Depth (inches) | U-238 (pCi/g) | Th-230 (pCi/g) | Ra-226 (pCi/g) |
|---|---|---|---|---|
| E2-B4 | 0-6 | ND | 332 | 3.19 |
| E3-B2 | 0-6 | ND | 298 | 4.45 |
| F1-A3 | 0-6 | ND | 376 | 3.2 |
| F3-D5 | 0-6 | ND | 269 | 3.24 |
| G1-C3 | 0-6 | ND | 1230 | 17.2 |
| G2-B3 | 0-6 | ND | 325 | 3.58 |
| G2-E5 | 0-6 | ND | 244 | 3.98 |
| H4-C1 | 0-6 | 5.77 | 58.7 | 1.89 |
| I1-A4 | 0-6 | 110 | 232 | 3.4 |
| I2-A5 | 0-6 | ND | 1490 | 14.6 |
| I2-E2 | 0-6 | 2.74 | 1050 | 7.6 |
| I3-D3 | 0-6 | 2.72 | 210 | 3.71 |
| D3-D3 | 6-12 | 0.948 | 68.6 | 8.98 |
| E3-B2 | 6-12 | ND | 414 | 5.82 |
| F2-A2 | 6-12 | ND | 1570 | 17.8 |
| G2-E5 | 6-12 | ND | 621 | 4.78 |
| I2-A5 | 6-12 | ND | 5030 | 14 |
| J4-B1 | 6-12 | 1.82 | 773 | 11.8 |

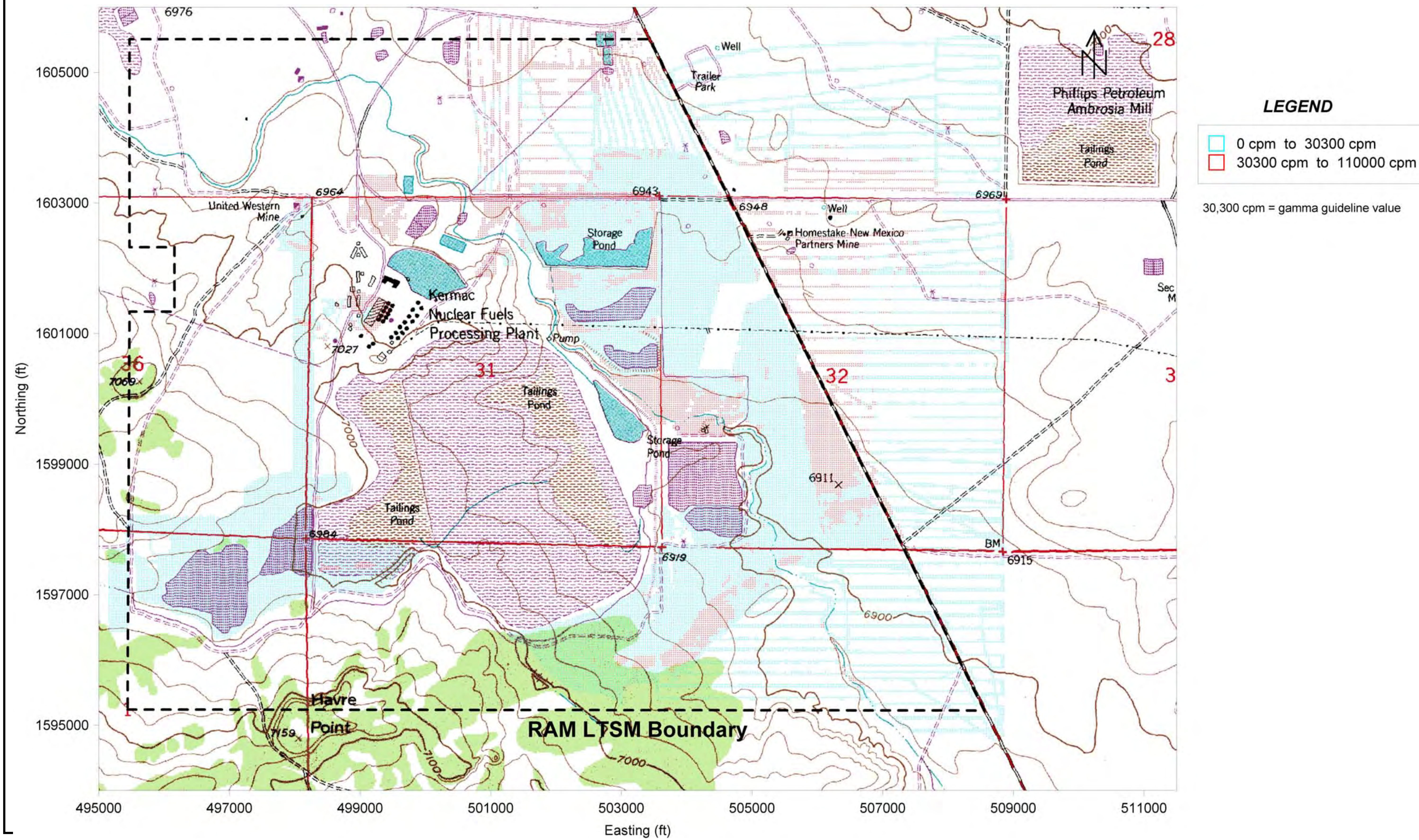


Figure 2-1. Gross Gamma Distribution (Walkover and ATV Driveover).

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Date: 11/09/2004

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FIGURE 2-1

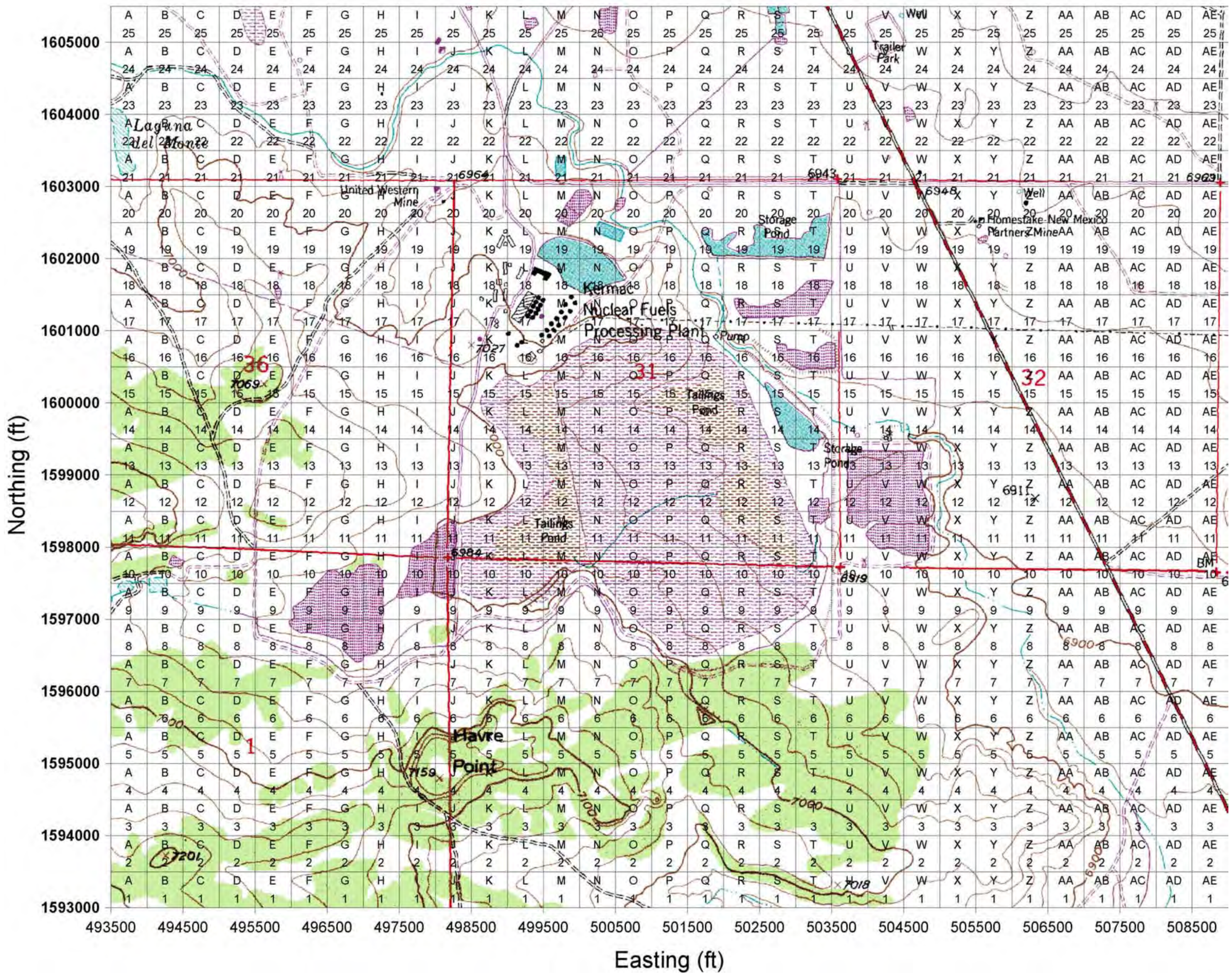


Figure 2-2. Site 500 x 500-foot sampling grid.

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FIGURE 2-2

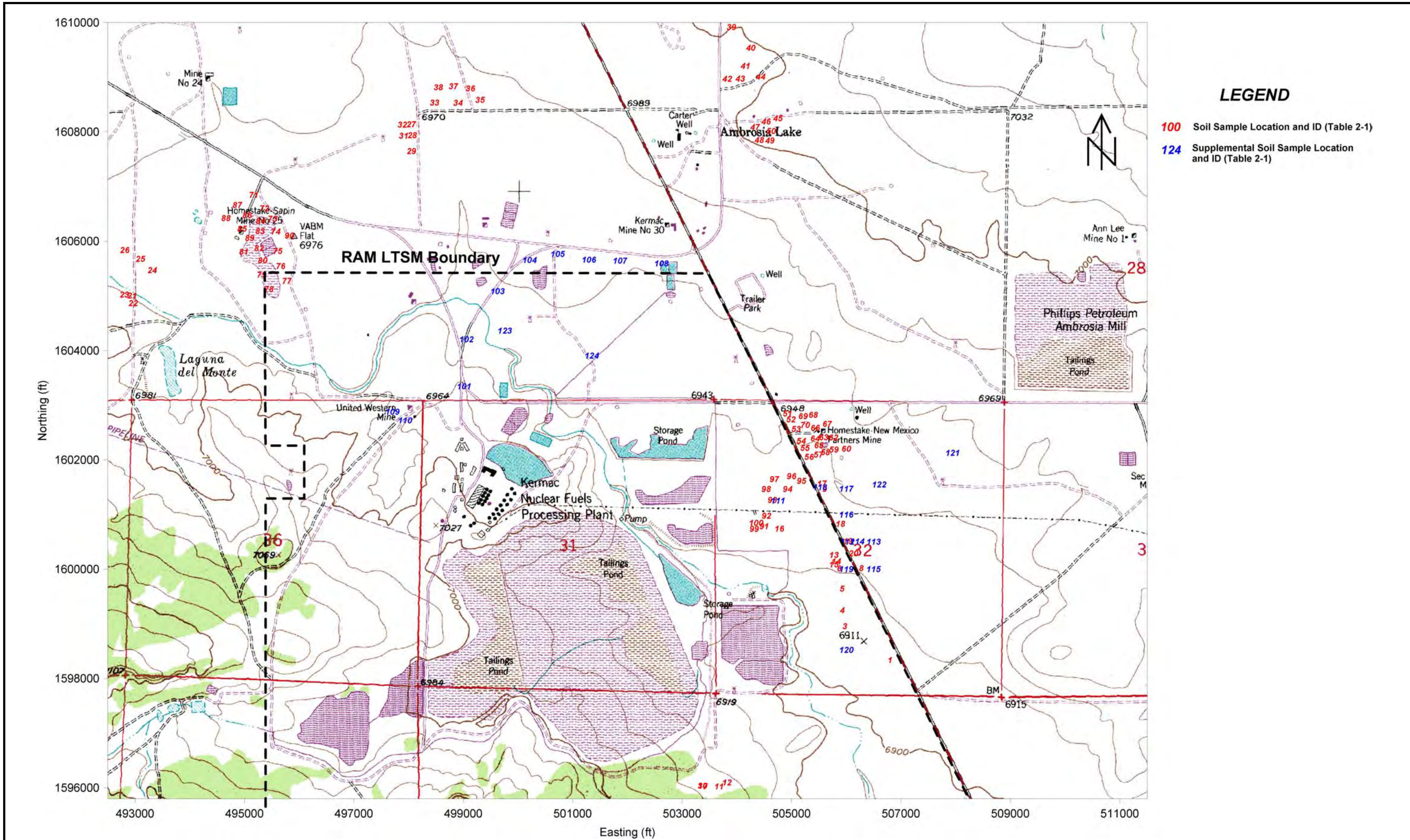


Figure 2-3. Location of Samples Used to Support Gamma Correlation and Background Development.

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Date: 11/09/2004

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FIGURE 2-3

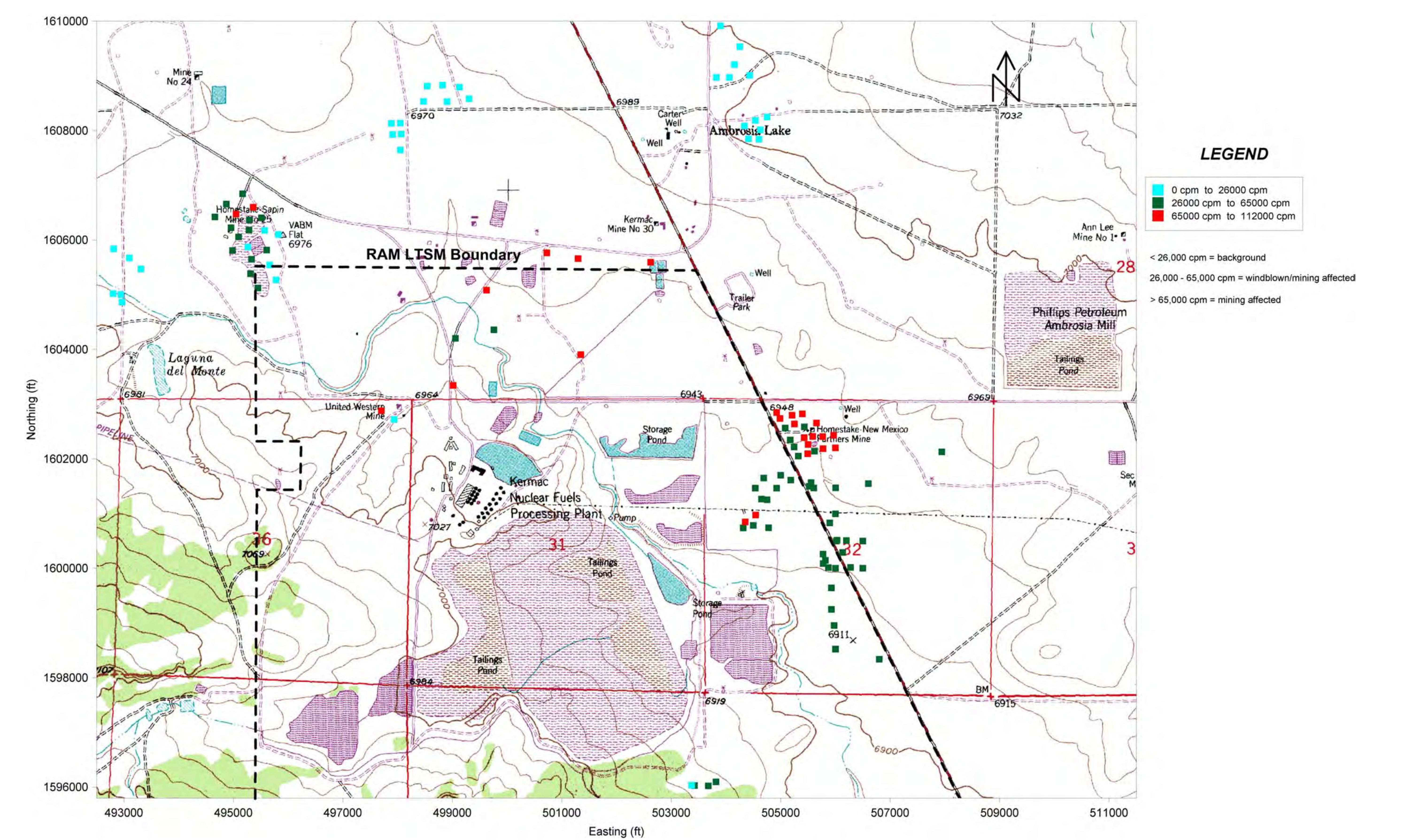


Figure 2-4. Gamma Distribution in Soil Samples Collected to Support Gamma Correlation and Background Development

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FIGURE 2-4

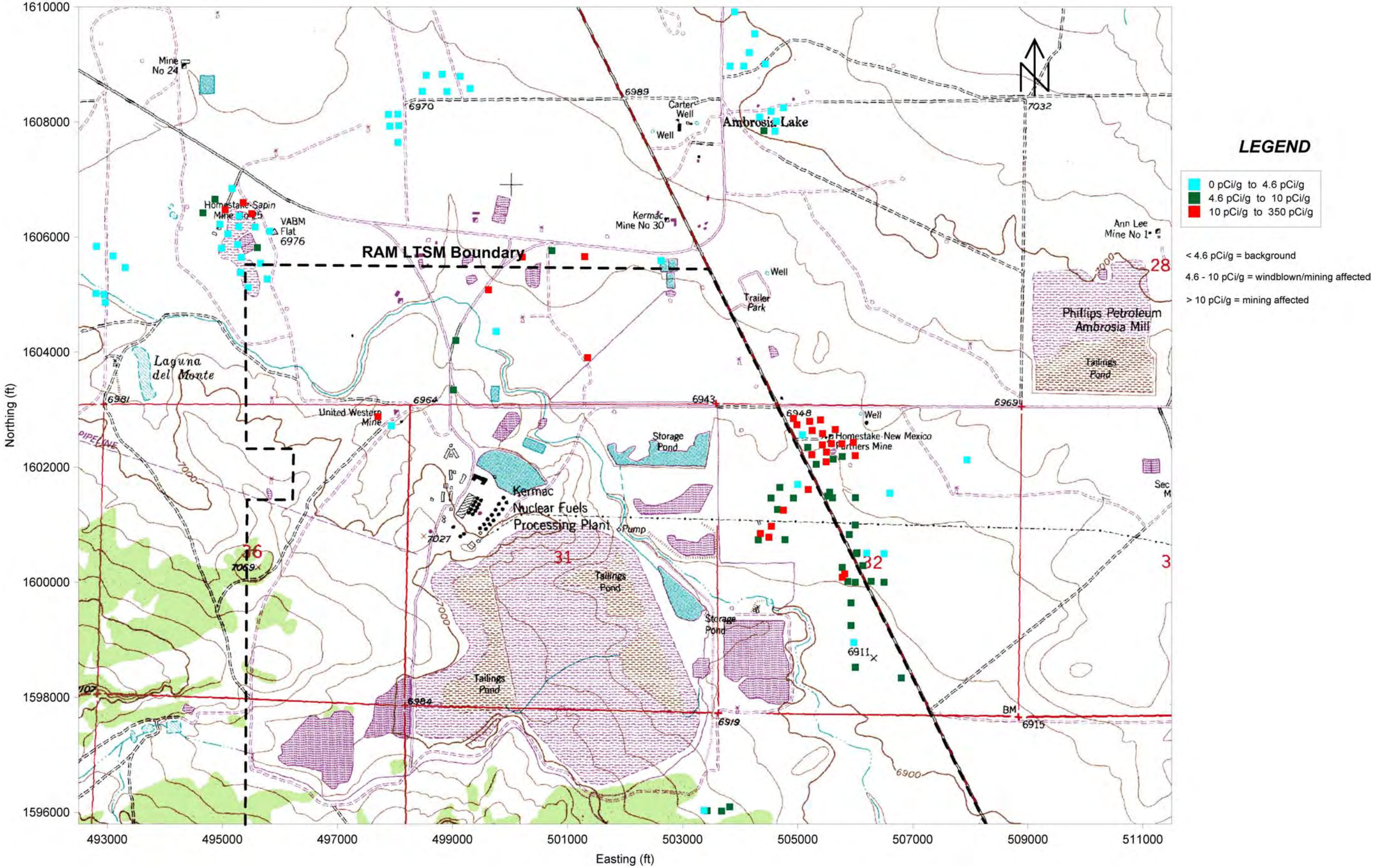


Figure 2-5. Radium-226 Distribution in Soil Samples Collected to Support Gamma Correlation and Background Development

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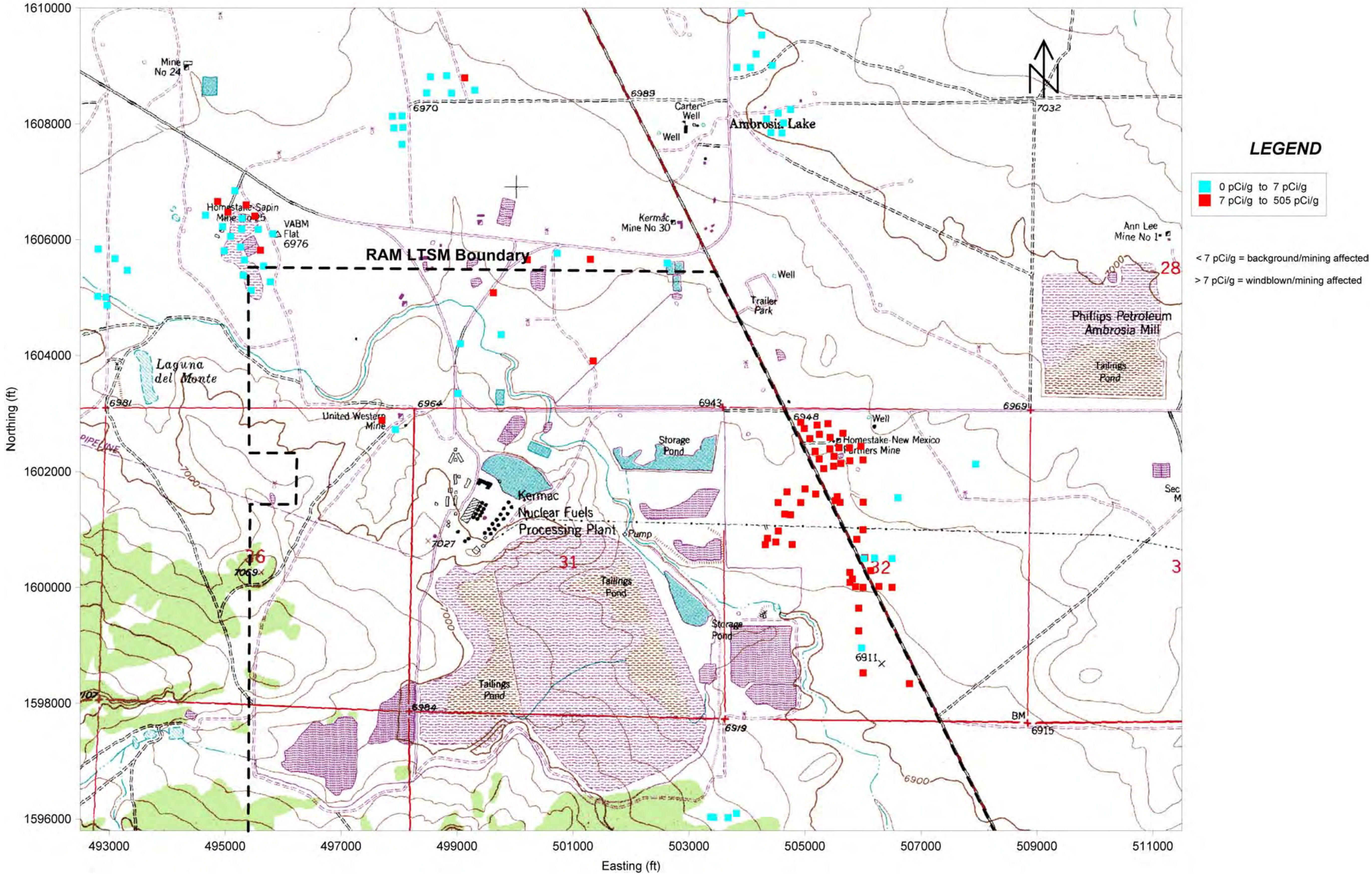
FIGURE 2-5




| Figure 2-6. Thorium-230 Distribution in Soil Samples Collected to Support Gamma Correlation and Background Development | Project No: D0295A<br>Date: 11/09/2004<br>File Name: P:\Ambrosia Soils\NRC Report\Figures\11 x 17.ppt | FIGURE 2-6 |
|---|---|---|

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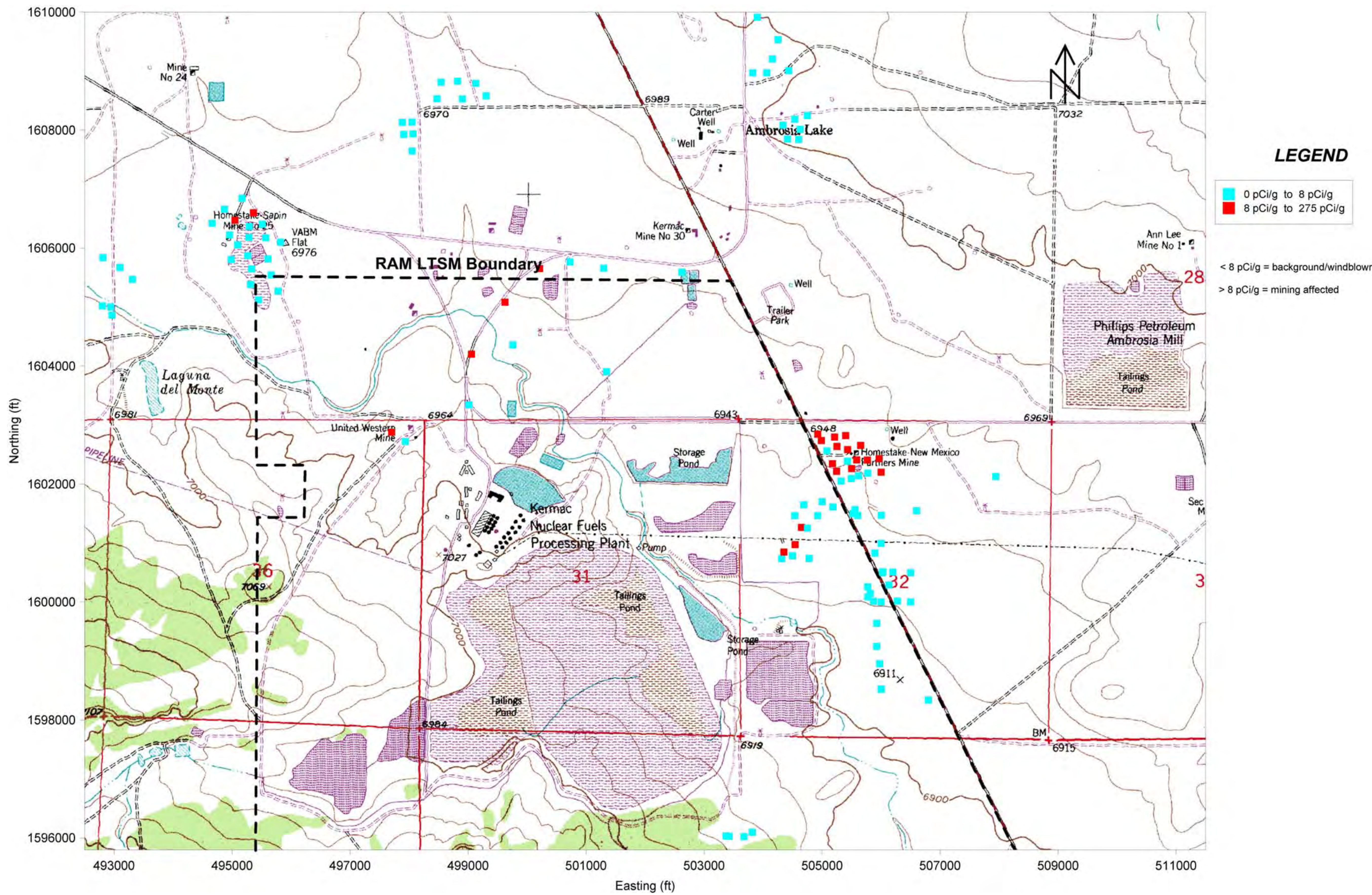


Figure 2-7. Natural Uranium Distribution in Soil Samples Collected to Support Gamma Correlation and Background Development

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Date: 11/09/2004

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FIGURE 2-7

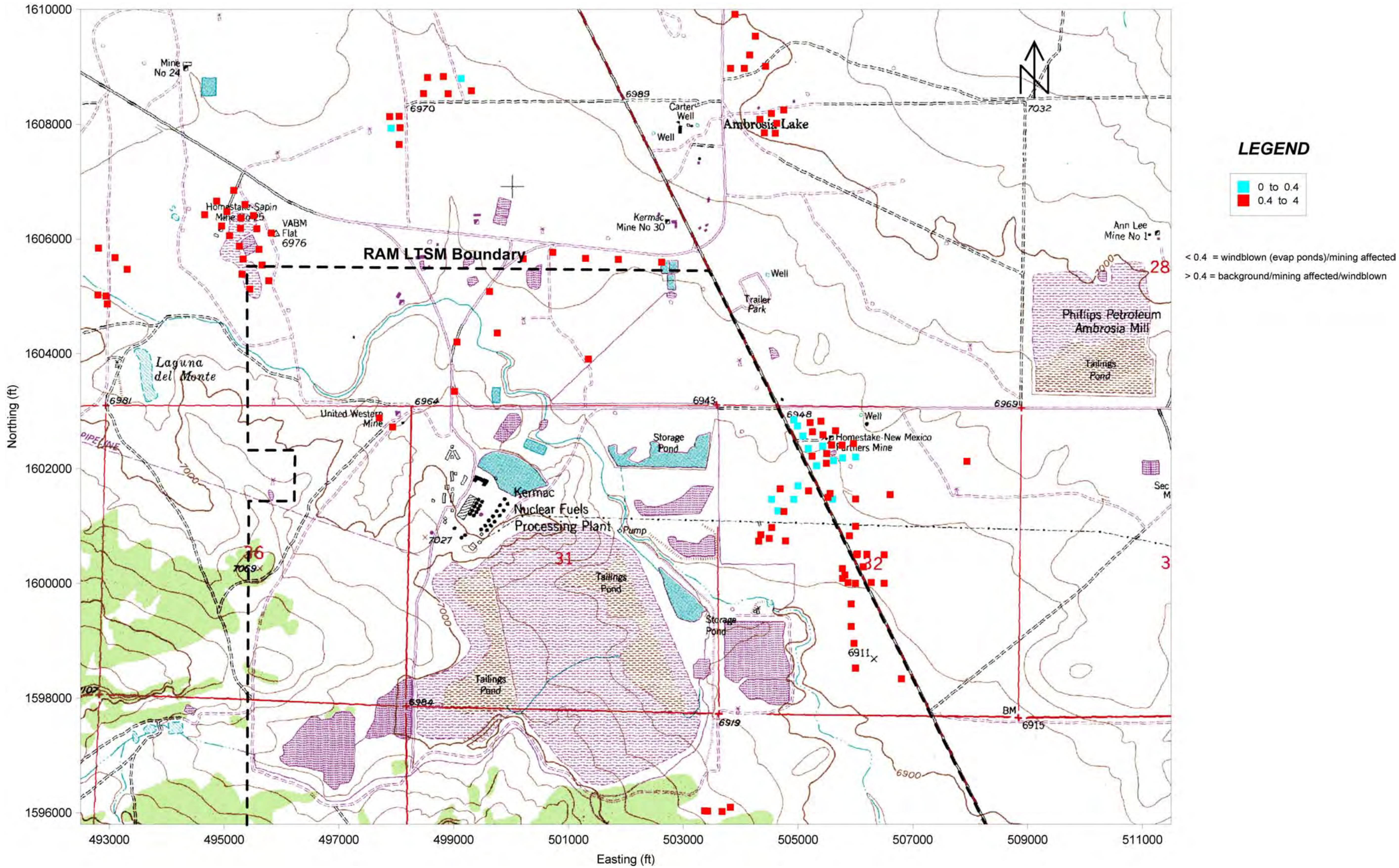


Figure 2-8. Ra-226/Th-230 Ratio in Soil Samples Collected to Support Gamma Correlation and Background Development

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FIGURE 2-8

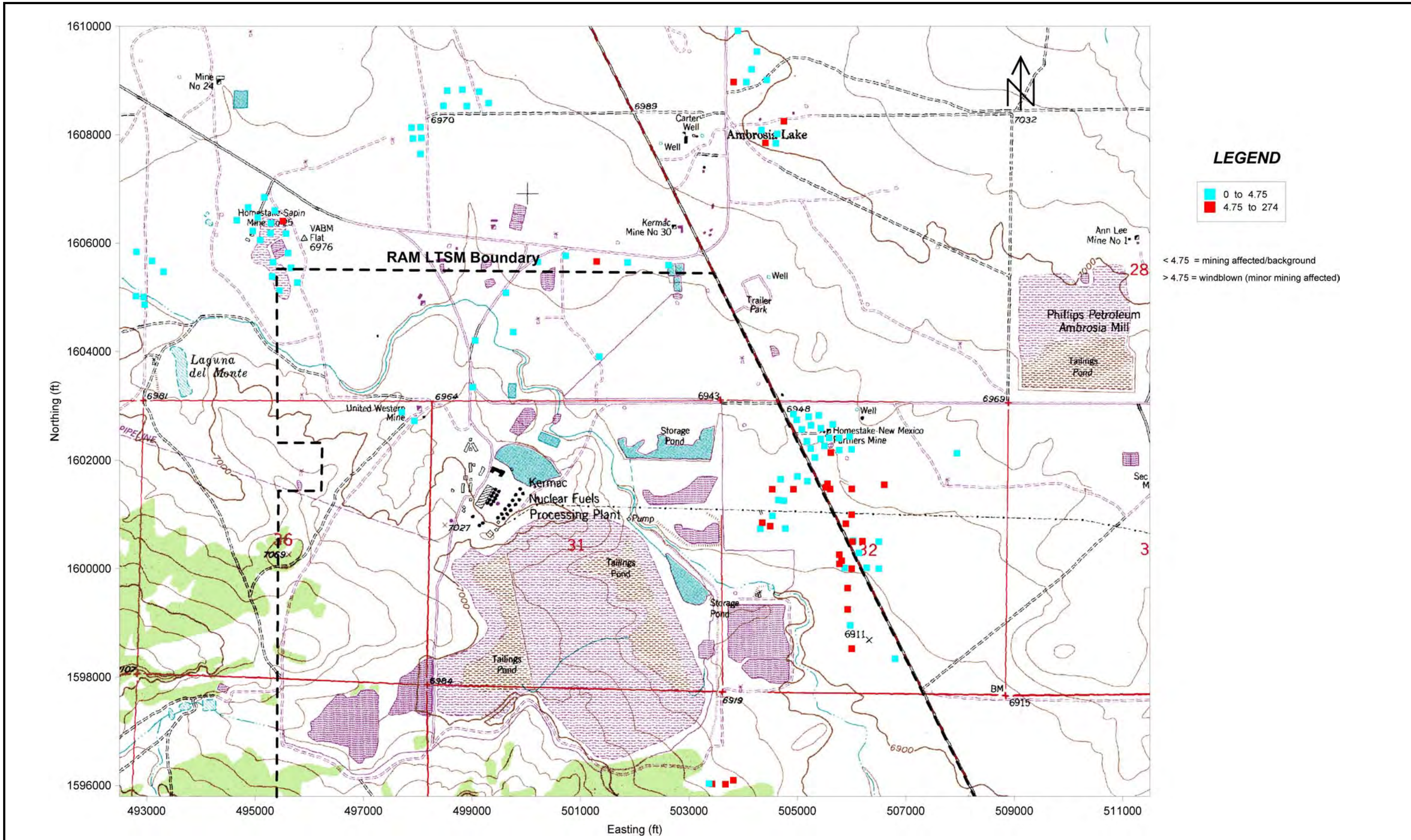


Figure 2-9. Ra-226/Unat Ratio in Soil Samples Collected to Support Gamma Correlation and Background Development

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Date: 11/09/2004

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FIGURE 2-9

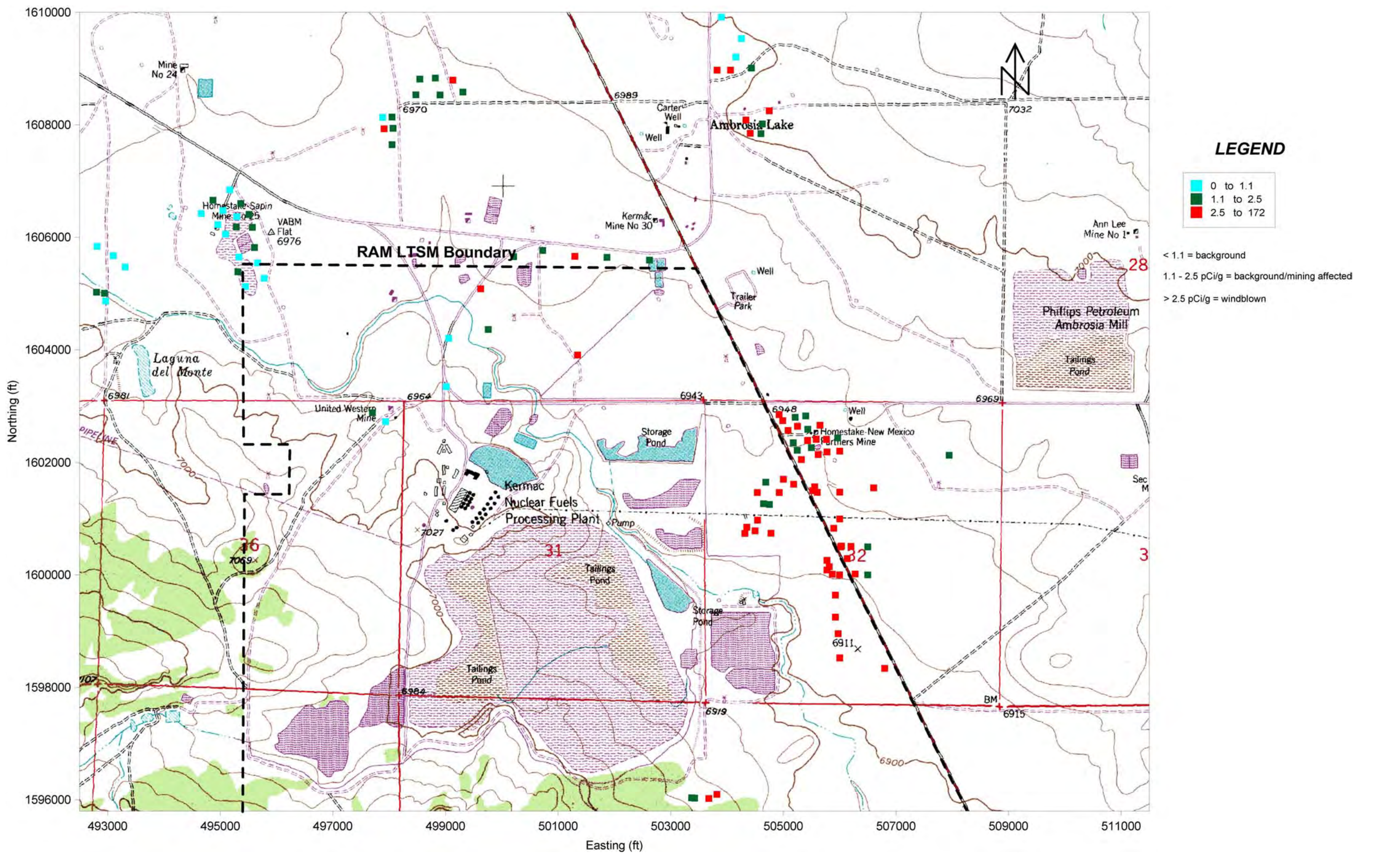


Figure 2-10. Th-230/Unat Ratio in Soil Samples Collected to Support Gamma Correlation and Background Development

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FIGURE 2-10

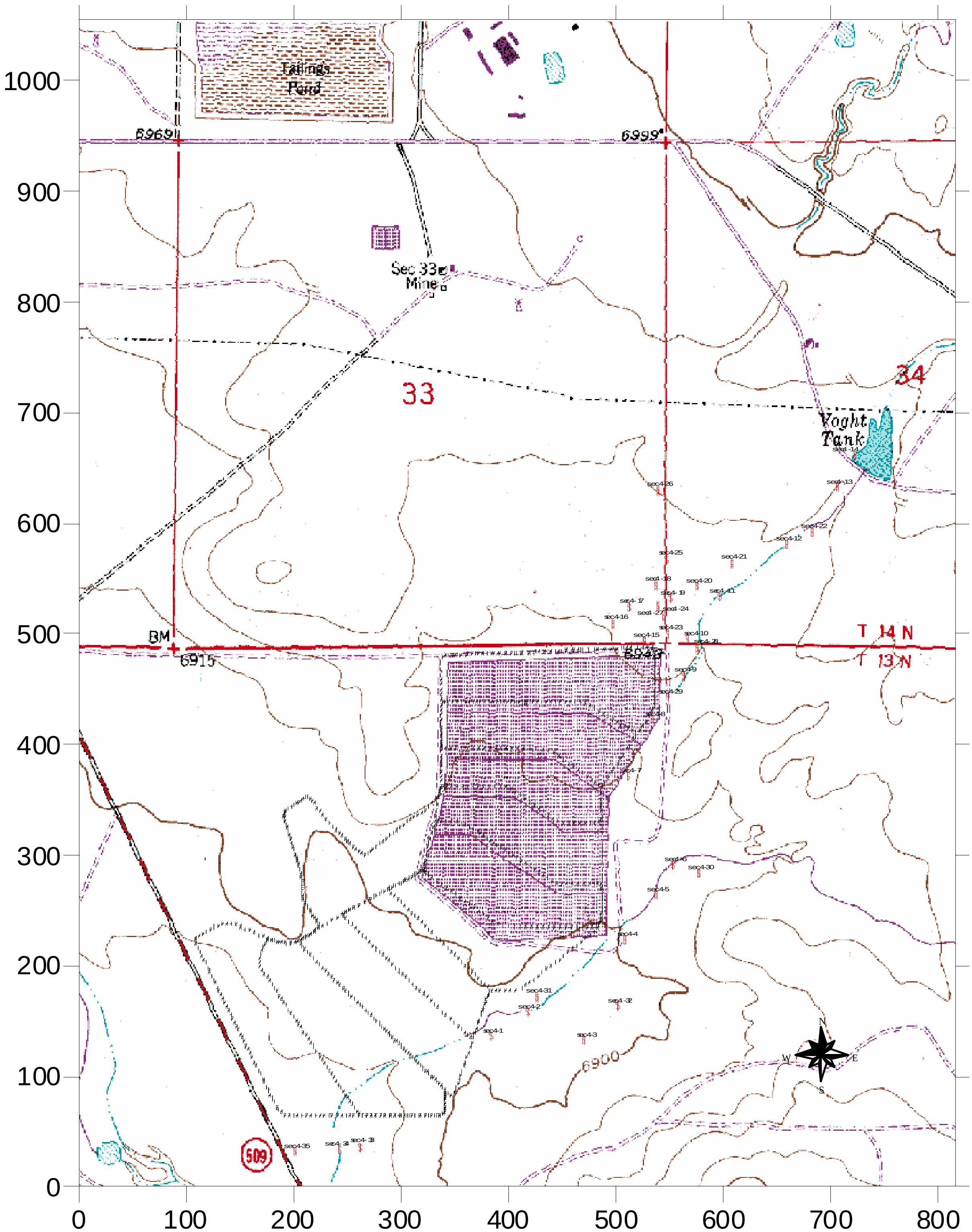


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Figure 2-11. Location of Surface Soil Samples
Section 4 Ponds Area

Project No. D0295A

Date: 11/09/2004

File Name: 8 x 11 Portrait

FIGURE
2-11

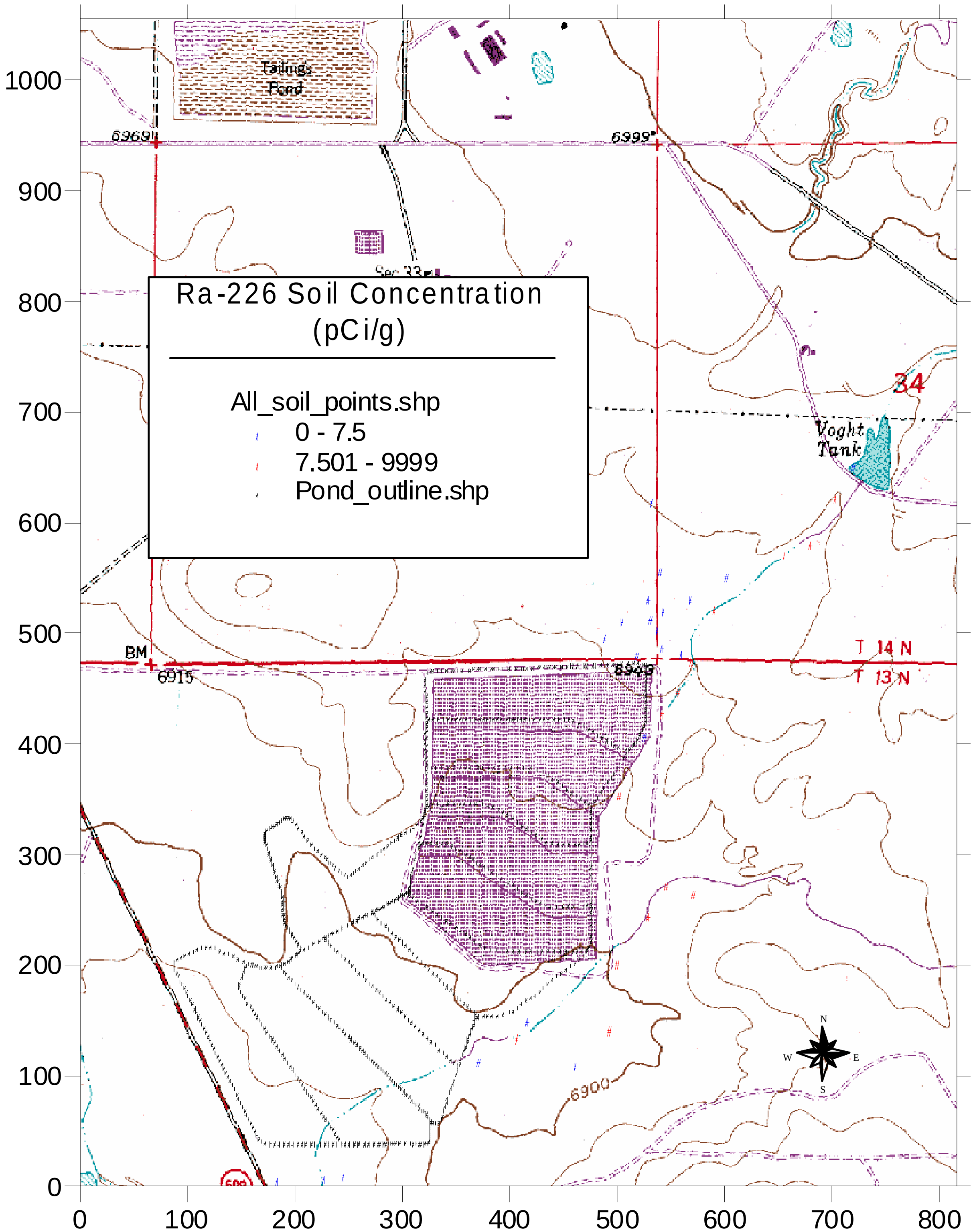


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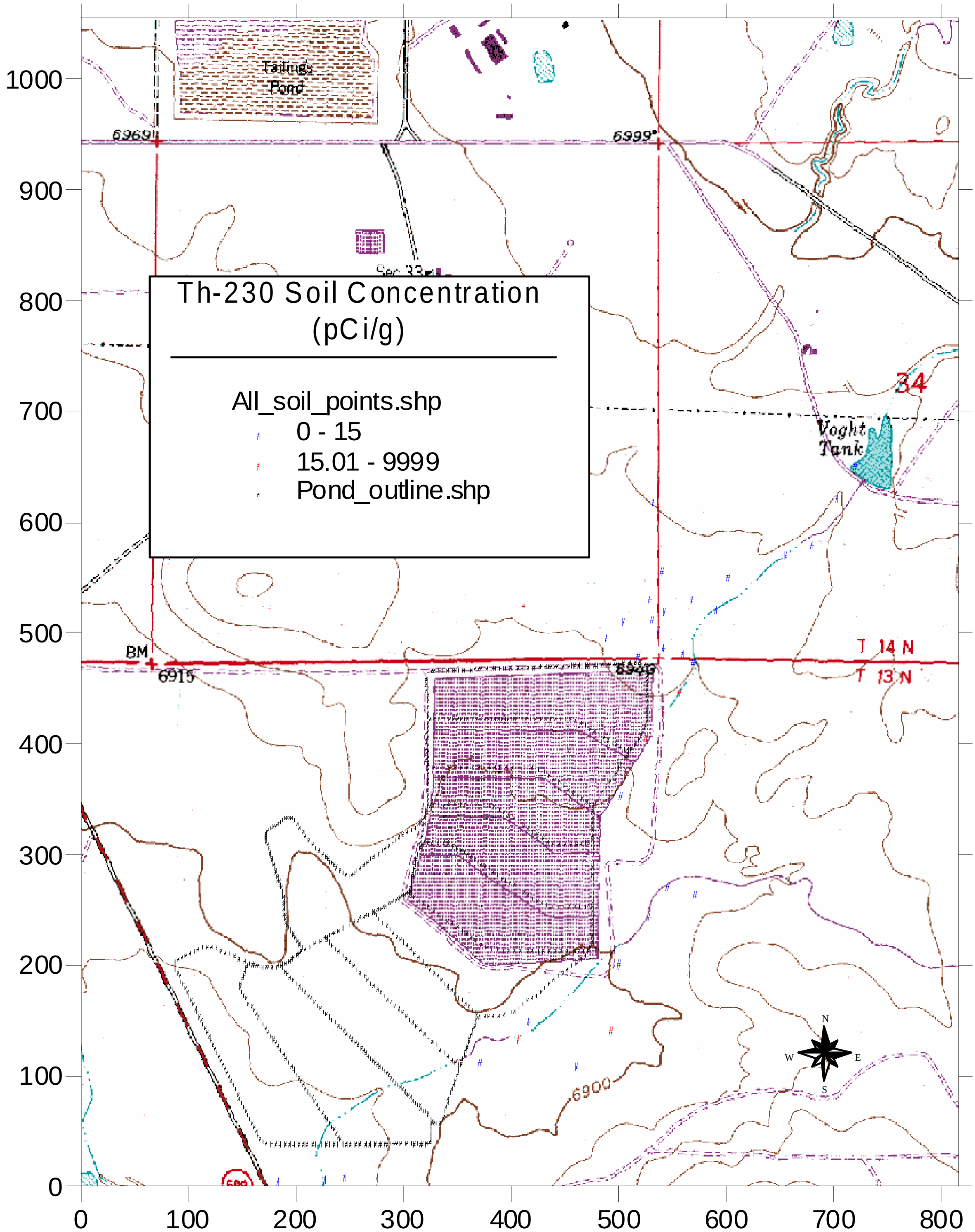
Figure 2-12. Radium-226 Concentration in Surface Soils
Section 4 Ponds Area

Project No. D0295A

Date: 11/09/2004

File Name: 8 x 11 Portrait

FIGURE 2-12




KOMEX

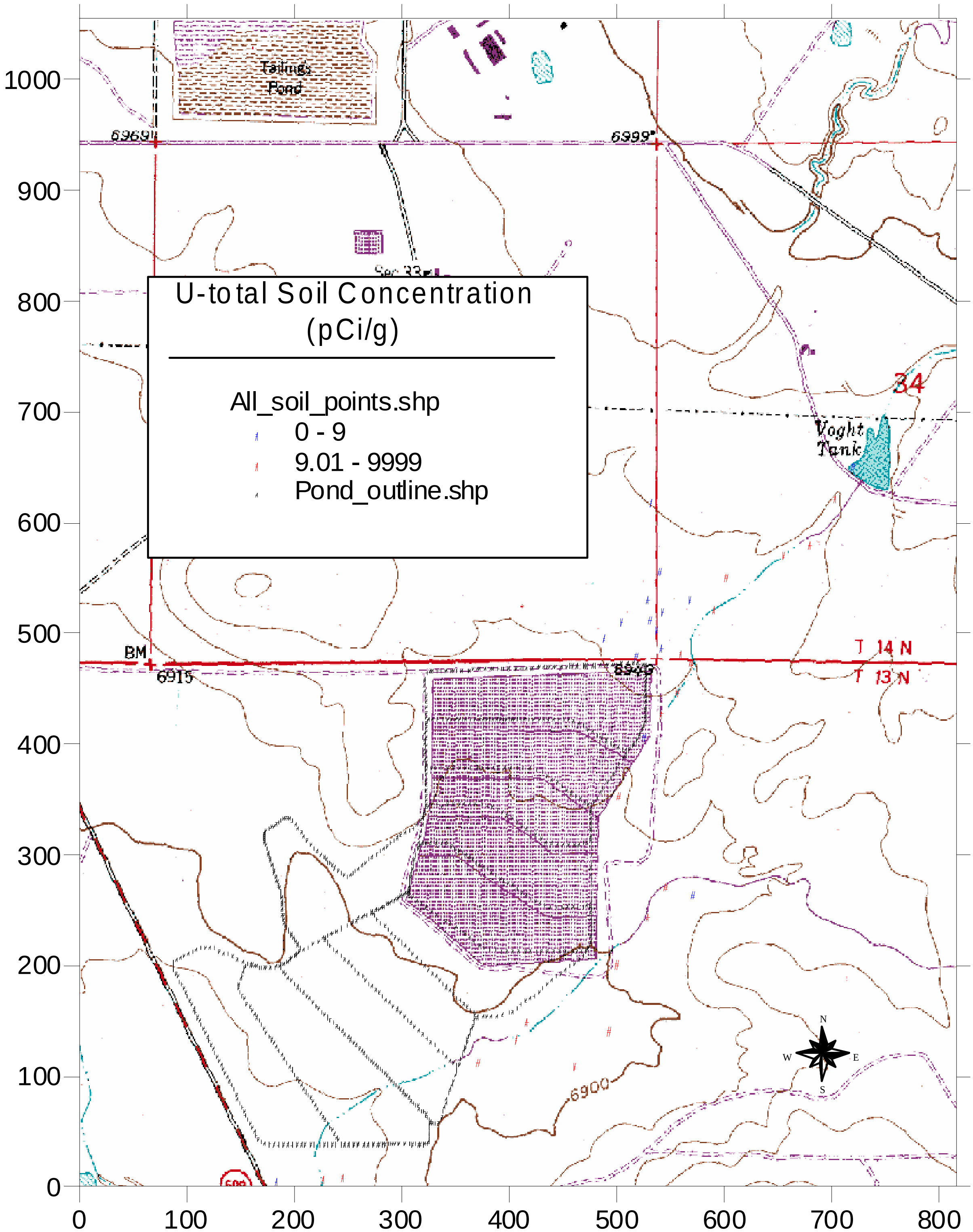
Figure 2-13. Thorium-230 Concentration in Surface Soils
Section 4 Ponds Area

Project No. D0295A

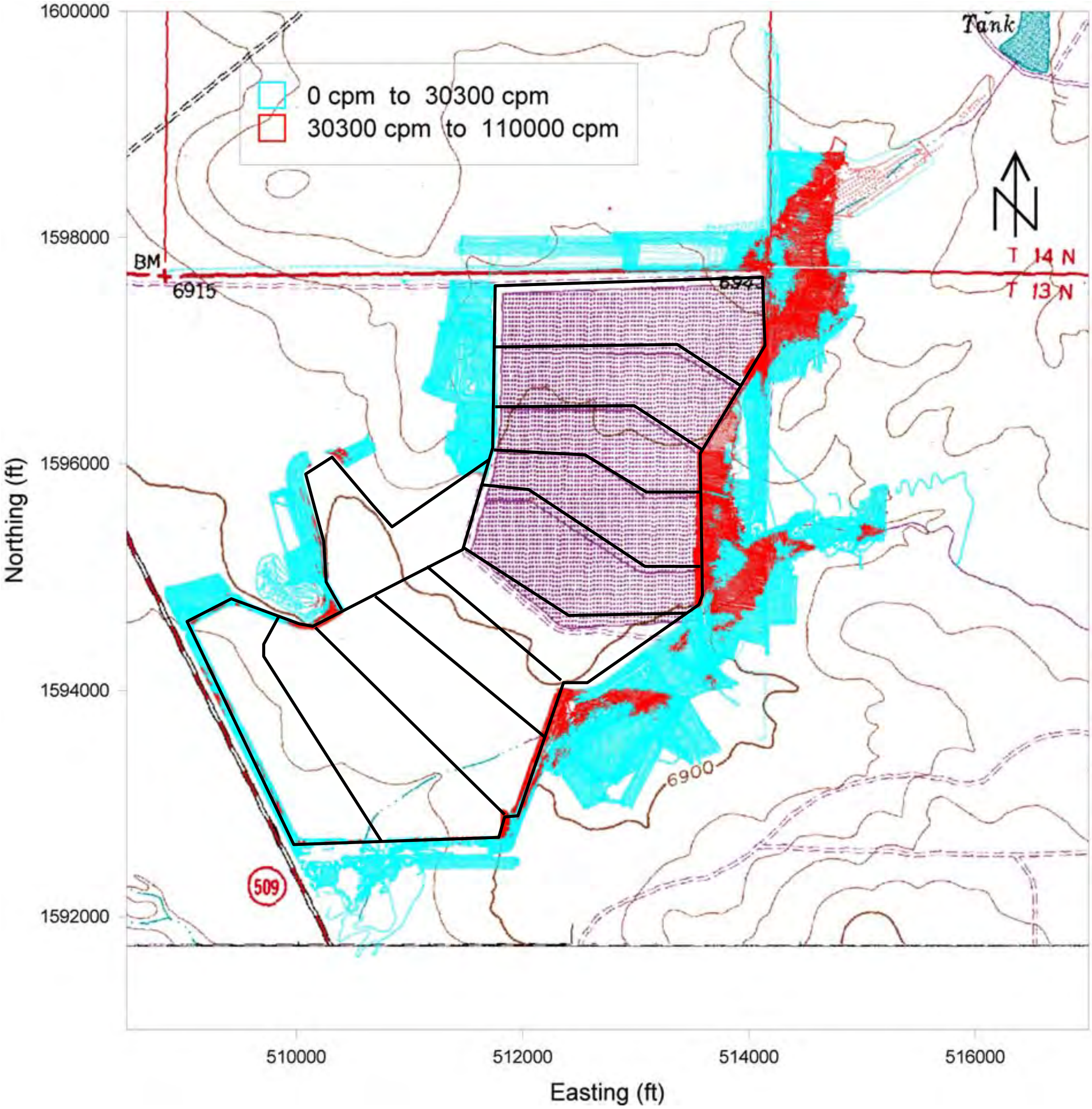
Date: 11/09/2004

File Name: 8 x 11 Portrait

FIGURE 2-13




| | | | |
|---|---|---|---|
| KOMEX | Figure 2-14. Uranium (nat) Concentration in Surface Soils<br>Section 4 Ponds Area | Project No. D0295A<br>Date: 11/09/2004<br>File Name: 8 x 11 Portrait | FIGURE<br>2-14 |




KOMEX

Figure 2-15. Gross Gamma Distribution
Section 4 Ponds Area

Project No. D0295A

Date: 11/09/2004

File Name: 8 x 11 Portrait

FIGURE
2-15

# 3.0 SOIL BACKGROUND RADIOACTIVITY

Background surface soil concentrations have been determined using representative soil samples from areas undisturbed by licensed site activities. The windblown-affected areas are characterized geologically as alluvial valley fill. Therefore, background soil samples were obtained in areas north and northwest of the site that are geologically and chemically similar to the contaminated areas (**Figure 2-3**). Upland areas south and southwest of the site are geologically and chemically dissimilar, and were therefore not included in the background samples. The background sample locations are within 2 miles (3.2 km) of the site boundary, in areas that are generally cross-gradient to the prevailing wind direction. The samples were obtained from locations far enough from the site to be outside potential areas of contamination based on the characterization of the extent of contamination at the site (Section 2.2).

Numerous uranium mines are located near the Ambrosia Lake site and mine wastes have affected surface soils in these areas. Area soils have also been affected by drainage from the uranium mines. The presence of mine waste and mine drainage has resulted in elevated concentrations of radium-226, thorium-230, and uranium-238 in surface soils. These sources are a component of the area background levels as defined within NRC Regulations at 10 CFR Part 20. Because of the mining-related soil contamination in the area, two sets of background values must be determined for the Ambrosia Lake site. These background values will be referred to as "natural" background, representing relatively undisturbed areas near the Ambrosia Lake site, and "mining-affected" background, representing areas near the site unaffected by milling-related activities but where soils have been affected by mining-related activities (non-11e.(2) material).

Samples were collected from 124 locations to support the site background investigation and gamma correlation development (**Table 2-1**). These samples and data were collected and analyzed using the procedures planned for the final status survey (Section 8.0). Thirty grids were sampled to characterize natural background soils (Komex-21 through Komex-50) and 20 samples were collected from areas that are affected by uranium mine waste to characterize mining-affected background soils (Komex-71 through Komex-90). Additional samples were collected to provide comparable characterization data for areas potentially affected by windblown tailings (Komex-1 through Komex-20 and Komex 112 through Komex-121), the Homestake Mining area northeast of the site (Komex-51 through Komex-70, Komex-91 through Komex-100, Komex-111, and Komex-122), and the mining area north of the impoundment within or just outside the LTSM (Komex-101 through Komex-110, Komex-123, and Komex-124).

The data were analyzed using probability distribution diagrams and histograms to identify characteristics of various populations of soil sample data. This evaluation was based on gamma measurements, radium-226 concentrations, thorium-230 concentrations, and uranium-238 concentrations. Different ratios of these parameters were also examined to determine the distinguishing characteristics of the data populations. Comparison of gamma measurements obtained using a hand-held detector and an ATV-mounted detector positioned with similar geometry indicated that there was no significant difference in the results obtained using the two methods (**Figure 3-1**). Because the majority of the gamma data will be collected using an ATV-mounted detector, only the ATV-mounted data are included in the following discussion.

## 3.1 NATURAL BACKGROUND AND MINING-AFFECTED BACKGROUND SOILS

Gamma measurements fell into three populations (**Figure 3-2**). Examination of the histogram and the probability distribution diagram (using log-transformed data) indicated that the thresholds between these populations were approximately 26,000 cpm and 65,000 cpm. The natural background samples had gamma measurements that fell within the lowest population (< 26,000 cpm). A few of the mining-affected background samples also had gamma measurements that fell in the lowest population (Komex-74, Komex-76, Komex-77, Komex-82, Komex-90, and Komex-110). These samples can be attributed to the surface reclamation (cover placement) performed at these former mining sites. The majority of the mining-affected background samples had higher gamma measurements consistent with the middle and highest populations.

Three populations of radium-226 data were observed on a log-transformed histogram (**Figure 3-3)** and probability plot. The thresholds between the three populations were found to be approximately 4.6 pCi/g (log value of 0.66) and 10 pCi/g (log value of 1.0). The natural background samples and many of the mining-affected background samples were consistent with the two lowest-concentration populations. However, three of the mining-affected background samples (Komex-72, Komex-73, and Komex-86) fell into the highest radium-226 population. These samples, with the exception of Komex-73, also had the highest uranium concentrations of the mining background samples.

Thorium-230 data for the samples fell into two populations on a log-transformed histogram and probability plot, with a threshold between these populations of approximately 7 pCi/g (log value of 0.85, **Figure 3-4**). All natural background samples were included in the lowest-concentration population. Many of the mining-affected background samples also were

included in the lowest-concentration population, but five mining-affected background samples (Komex-72, Komex-73, Komex-75, Komex-86, and Komex-87) had thorium-230 concentrations consistent with the highest-concentration population.

Two uranium-238 populations were observed on log-transformed histograms of the data (**Figure 3-5**), with a threshold between the two populations equal to about 8 pCi/g (log value of 0.9). All of the natural background samples were included in the lowest-concentration population. Mining-affected background samples were observed in both uranium populations.

Evaluation of radium-226/thorium-230 ratios for the samples indicated the presence of two populations on log-transformed probability distribution diagrams and histograms (**Figure 3-6**). The larger population occurred at higher radium-226/thorium-230 ratios, and included all of the natural background samples except Komex-31 and all mining-affected background samples. This population had a mean ratio of 0.8 (log value of -0.1).

The radium-226/uranium-238 ratio can sometimes be used to indicate soils contaminated with uranium-mining wastes. Evaluation of log-transformed probability distribution diagrams and histograms of this ratio for the sample data indicated the presence of two populations (**Figure 3-7**). However, both the natural background and mining-affected background samples fell within the lower population (ratios of less than 4.75 or log value of 0.6), making it unlikely that this ratio can be used to distinguish mining-affected background samples from natural background samples.

Thorium-230/uranium-238 ratios were also examined using log-transformed probability distribution diagrams and histograms and three populations were observed (**Figure 3-8**). Most of the natural background and mining-affected background samples fell within the lower two populations (below a ratio of 2.5 or log value of 0.4).

### 3.1.1 CHARACTERIZATION OF NATURAL BACKGROUND

The gamma measurement data and radium-226, thorium-230, and uranium-238 concentrations for the natural background samples were evaluated using histograms to identify obvious outliers among the data. The thorium-230 concentration reported for Komex-36 was 9.75 pCi/g, which was almost twice as high as the next-highest thorium-230 concentration reported for the other natural background samples (**Table 2-1**). This value was also inconsistent with the observation that radium-226 concentrations were approximately equal to thorium-230 concentrations in the other natural background samples. Therefore, the thorium-230 concentration reported for Komex-36 was not included in the statistical evaluation of the data.

The reported uranium-238 concentration for Komex-40 equaled 2.99 pCi/g. However, this value was approximately three times the concentration reported for a replicate sample (Komex-40R) collected at the same time from the same grid. Other natural background samples generally had uranium-238 concentrations equal to or slightly greater than their radium-226 or thorium-230 concentrations; however, the reported uranium-238 concentration for Komex-40 was approximately three times the radium-226 and thorium-230 concentrations. Therefore, sample Komex-40R was used instead of sample Komex-40 in the statistical evaluation.

The summary statistics calculated for gamma measurements and for radium-226, thorium-230, and uranium-238 are included in **Table 3-1**. Summary statistics for different ratios of gamma measurements and radionuclide concentrations for the natural background samples are included in **Table 3-2**. For natural background samples, the mean radium-226/thorium-230 ratio was slightly less than 1, the mean radium-226/uranium-238 was slightly higher than 2 and the mean thorium-230/uranium-238 ratio was approximately equal to 3 (**Table 3-2**).

### 3.1.2 CHARACTERIZATION OF MINING-AFFECTED BACKGROUND

The gamma measurement data and radium-226, thorium-230, and uranium-238 concentrations for the mining-affected background samples were evaluated using histograms to identify obvious outliers among the data. No outliers were identified, so all data for the mining-affected background samples were used to calculate summary statistics (**Table 3-1**). Summary statistics for different ratios of gamma measurements and radionuclide concentrations for the mining-affected background samples are included in **Table 3-2**. The mean radium-226/thorium-230 ratio was approximately equal to 1, and the mean radium-226/uranium-238 and thorium-230/uranium-238 ratios were slightly less than 2 (**Table 3-2**).

Mean and maximum gamma measurements and concentrations of radium-226, thorium-230, and uranium-238 were higher for the mining-affected background samples than for the natural background samples (**Table 3-1**). Different mean ratios were also observed for the natural background and mining-affected background samples (**Table 3-2**). However, the ranges of the concentrations and ratios overlap significantly for the two background data sets.

## 3.2 DISTINGUISHING BETWEEN TAILINGS-AFFECTED, NATURAL BACKGROUND, AND MINING-AFFECTED AREAS

In this section, areas potentially affected by windblown 11e.(2) material are evaluated and compared to background soils to determine their distinguishing characteristics. This

evaluation also considers soils characteristics for differentiating between the effects of windblown 11e.(2) materials and the effects of non-11(e).2 mining-related materials. Soil characterization data used in this analysis are summarized in **Table 2-1**.

### 3.2.1 SOURCE CHARACTERIZATION

Analytical data for a tailings sand sample from the RAM Ambrosia Lake mill are presented in **Table 3-3**. The data indicate that mill tailings have relatively high radium-226 and thorium-230 concentrations, high ratios of radium-226 and thorium-230 to uranium-238, and relatively high ratios of radium-226 to thorium-230. Consequently, these concentrations and ratios are likely to be elevated in windblown-contaminated soils relative to background soil samples.

Comparisons of the analysis results from the various soil samples and the tailings sample were carried out to determine the effects of windblown 11e.(2) material on soils, and to determine the distinguishing characteristics of soils affected by windblown tailings and non-11e.(2) mining waste. The soils data obtained from the various groups of samples were examined using both histograms and probability plots.

### 3.2.2 GAMMA MEASUREMENTS AND RADIUM-226 CONCENTRATIONS

Gamma survey measurements formed three populations, with thresholds between the populations at approximately 26,000 cpm and 65,000 cpm (**Figure 3-2**). All natural background sample locations were included in the lowest-gamma population, whereas in the absence of mining-related contamination, windblown-tailings affected soils were included in the intermediate gamma population (between approximately 26,000 and 65,000 cpm). Consequently, gamma measurements may be used to help distinguish between background and windblown-affected areas in the absence of mining-related soils contamination (Section 6.0).

Although a few mining-affected background sample locations were included in the lowest gamma population as a result of mine reclamation activities, most were in the two higher-gamma populations (greater than 26,000 cpm), and several of the mining-affected background sample locations had gamma measurements near the maximum value observed (i.e., Komex-72). All Homestake Mining Area and all mining-affected samples obtained near the northern LTSM boundary (except Komex-110) were included in the two highest-gamma populations. Based on these data and examination of site-wide gamma measurements (**Figure 2-1**), it is

apparent that gamma measurements alone cannot be used to distinguish between the effects of mining-related and windblown tailings contamination.

Radium-226 soils concentrations are a source of elevated gamma measurements; consequently, radium-226 concentrations formed three populations similar to the gamma measurement results (**Figure 3-3**). All natural background samples were included in the lowest-concentration population (**Figure 2-5**). Radium-226 concentrations in windblown-tailings-affected soils in the absence of mining-related contamination were mostly included in the intermediate-concentration population. Therefore, in the absence of mining-related contamination, elevated radium-226 concentrations indicate windblown tailings contamination.

Mining-affected background samples were included in all three radium-226 populations. As previously observed for the gamma measurements, some of the highest radium-226 concentrations were measured in mining-affected background samples (i.e., Komex-86). Homestake Mining Area samples and samples from the mining-affected area north of the impoundment were also included in all three radium-226 populations. Based on these data and examination of **Figure 2-5**, it is apparent that radium-226 concentrations alone cannot be used to distinguish between the effects of mining-related and 11e.(2)-related contamination.

### 3.2.3 THORIUM-230 AND URANIUM-238 CONCENTRATIONS

As a result of the acid leach process, the liquid fraction of the mill effluents contained the thorium-230 and was disposed in the evaporation pond system. Therefore, thorium-230 concentrations in the tailings sands were relatively low compared to radium-226 concentrations. Thorium-230 data formed two distinct populations, with the threshold between these populations at approximately 7 pCi/g (**Figure 3-4**). All natural background samples fell into the lowest-concentration thorium-230 population. Windblown-affected samples outside areas affected by mining-related waste were included only in the higher thorium-230 population (**Figure 2-6**). Therefore, in the absence of mining-related contamination, thorium-230 soil concentrations above approximately 7 pCi/g may indicate windblown-tailings contamination.

Mining-affected background samples were included in both populations of thorium-230 data, and some of the highest thorium-230 concentrations were observed in mining-affected background samples (i.e., Komex-86). In the Homestake Mining Area and the mining-affected area north of the impoundment, thorium-230 concentrations were included only in the higher-

concentration population. Because elevated thorium-230 concentrations are observed in both windblown tailings and mining-affected soils, thorium-230 concentrations cannot be used to distinguish between the effects of windblown tailings and mining-related contamination. This drainage exhibits elevated levels of predominantly uranium and radium resulting from the mine discharges. Alternatively, soil contamination attributable to seepage of the lined ponds and/or windblown pond materials would be expected to contain elevated thorium concentrations.

The uranium-238 data also formed two populations, with a threshold between the populations of approximately 8 pCi/g (**Figure 3-5**). Natural background samples and soil samples from windblown-tailings affected areas fell into the lowest-concentration uranium-238 population (**Figure 2-7**). Mining-affected background areas and mining areas potentially affected by windblown tailings material had concentrations that fell into both the lower and higher-concentration populations. The inclusion of samples from mining-affected areas in the lowest-concentration population indicates that some of these samples may indicate the effects of cover placement during remediation. Because of the relatively low uranium-238 in natural background soils and in the RAM Ambrosia Lake tailings (**Table 3-3**), uranium-238 concentrations provide an excellent indication of soils affected by uranium mining waste (**Figure 2-7**).

### 3.2.4 RADIONUCLIDE CONCENTRATION RATIOS

The radium-226/thorium-230 ratios for the samples formed two populations. The largest population had a mean value of 0.76, and included all natural background and mining background samples. The smaller population represented only about 10% of the samples. This population had lower ratios of radium-226 to thorium-230, with a threshold between the two populations of approximately 0.4. The radium-226/thorium-230 sample ratios are illustrated in **Figure 3-6**. With the exception of background samples Komex-31 and Komex-36, samples with a radium-226/thorium-230 ratio less than 0.4 were located only in a limited area (**Figure 2-8**). These samples were mostly located near Highway 509 and in drainages from the Homestake area. The source of the relatively low radium-226/thorium-230 ratio for background samples Komex-31 and Komex-36 is not known. Tailings material has a relative high radium-226/thorium-230 ratio (**Table 3-3**), so it is unlikely that the lower-ratio material in the vicinity of the Homestake Mining area is contaminated by windblown tailings. It is possible that the slightly reduced radium-226/thorium-230 ratios in these samples represent the effects of small amounts of windblown evaporation pond sediments, which are relatively enriched in thorium-230.

Radium-226/uranium-238 ratios formed two populations (**Figure 3-7**). All natural background samples were included in the population with the lowest radium-226/uranium-238 ratios. Because of the relatively high radium-226/uranium-238 ratio in the RAM Ambrosia Lake mill tailings (**Table 3-3**), windblown-tailings affected soils should have relatively high radium-226/uranium-238 ratios. As expected, most of the samples collected from the area affected by windblown tailings were included in the higher-ratio population, with ratios greater than approximately 4.75 (**Figure 3-7**). However, a number of samples with windblown tailings contamination fell into the lower radium-226/uranium-238 population **(Figure 2-9)**.

All except one (Komex-73) of the mining-affected background samples were included in the population with the lowest radium-226/uranium-238 ratios. The radium-226/uranium-238 ratios for mining-affected samples in potentially windblown tailings-affected areas indicates that most samples had a ratio below 4.75. Of the six mining-affected samples with ratios in excess of 4.75 (Komex-91, Komex-94, Komex-98, Komex-100, Komex-106, and Komex-122) all except Komex-106 were located in the Homestake Mine Drainage Area (**Figure 2-9**). Therefore, based on the radium-226/uranium-238 ratios in the samples, there is little evidence of windblown contamination in the Homestake Mining and Homestake Mine Drainage areas or in the mining-affected area north of the impoundment that can be distinguished from the effects of mine waste.

Thorium-230/uranium-238 ratios formed three populations, with thresholds between the populations at ratios of approximately 1.1 and 2.5 (**Figure 3-8**). Natural background and mining-affected background samples were included in the two lowest-ratio populations; the exceptions were natural background samples Komex-31, Komex-36, Komex-42, Komex-43, Komex-45, Komex-47, and Komex-48 (**Figure 2-10)**. All of the samples from the windblown-tailings-affected area were included in the two higher-ratio populations. Samples in the mining-affected area north of the impoundment and in the Homestake mining area generally had thorium-230/uranium-238 ratios greater than 1.1.

### 3.2.5 DIFFERENTIATING BETWEEN TAILINGS-AFFECTED AND MINING-AFFECTED AREAS

Records related to mining activities in the vicinity of the Ambrosia Lake site and visual inspection (soil color and texture) have been used to identify areas affected by non-11e.(2) uranium mining waste. Mine locations are provided in **Figure 1-2**. Both windblown-tailings-affected areas and mining-affected areas are characterized by relatively high gamma measurements, radium-226 concentrations, and thorium-230 concentrations. However,

mining-affected areas can typically be differentiated from windblown-tailings affected areas by uranium-238 concentrations: uranium-238 concentrations were always less than 4.5 pCi/g in the windblown-tailings affected samples, whereas the large majority of mining-affected samples had higher uranium-238 concentrations.

### 3.2.6 DIFFERENTIATING BETWEEN TAILINGS-AFFECTED AND NATURAL BACKGROUND AREAS

Comparison of the mill tailings sand sample data to mean values observed for windblown-tailings affected soils and natural background soils indicates that the radionuclide concentrations and ratios vary as expected for the different sample types (**Table 3-3**). In areas unaffected by mining-related waste, windblown tailings contamination of soils can be identified by relatively high gamma measurements, high radium-226 and thorium-230 concentrations, and high radium-226/uranium-238 and thorium-230/uranium-238 ratios when compared to natural background samples.

The ranges of gamma measurements, radionuclide concentrations, and ratios observed for the mining-affected background, Homestake Mining Area, and the mining-affected area north of the impoundment are summarized in **Table 3-4**. All ranges for the three types of locations overlap significantly. Higher gamma, radium-226, thorium-230 and uranium-238 concentrations in the Homestake Mining area and the area north of the impoundment compared to the mining-affected background areas probably reflect a greater amount of contamination by uranium mining waste (non-11e.(2)) in the Homestake Mining area and the mining area north of the impoundment.

The addition of significant quantities of windblown tailings to the mine waste in these areas could be expected to result in higher radium-226/uranium-238 ratios compared to the mining-affected background values, based on the composition of the tailings (**Table 3-2**). For the Homestake Mining Area, only samples Komex-57, Komex-91, Komex-94, Komex-98, Komex-100 and Komex-122 were above the range of radium-226/uranium-238 ratios observed for the mining-affected background samples. These sample locations are along the southern boundary of the Homestake Mining area, mostly in drainage areas, and except for Komex-100, these samples have uranium-238 concentrations that are below detection limits. Therefore, these samples may have windblown tailings contamination and may be only minimally affected by mine waste. For other samples from the Homestake mining area, the effects of windblown tailings appear to be indistinguishable from the effects of the mining waste.

Among the mining-affected samples obtained north of the impoundment, only Komex-106 had a radium-226/uranium-238 ratio greater than the range observed for the mining-affected background samples. Sample Komex-106 had a uranium-238 concentration less than the analytical detection limit, possibly indicating that this sample may have windblown tailings contamination and may be minimally affected by mine waste. For the other samples from the mining area north of the impoundment, the effects of windblown tailings appear to be indistinguishable from the effects of the mining waste.

**Table 3-1. Summary Statistics for Natural Background and Mining-Affected Background Soils Data.**

| Natural Background | | | | |
|---|---|---|---|---|
| | Gamma ATV (cpm) | Radium-226 (pCi/g) | Thorium-230 (pCi/g) | Uranium-238 (pCi/g) |
| Number of Samples | 30 | 30 | 29 | 30 |
| mean | 17,807 | 1.95 | 2.69 | 1.65 |
| Median | 18,221 | 1.63 | 2.70 | 1.57 |
| standard deviation | 2,481 | 1.09 | 1.20 | 1.22 |
| 95% UCL | 18,576 | 2.29 | 3.07 | 2.02 |
| Max | 22,543 | 4.89 | 5.18 | 4.88 |
| Min | 11,447 | 0.65 | 0.69 | < 0.41 |
| **Mining-Affected Background** | | | | |
| | Gamma ATV (cpm) | Radium-226 (pCi/g) | Thorium-230 (pCi/g) | Uranium-238 (pCi/g) |
| Number of Samples | 20 | 20 | 20 | 20 |
| mean | 37,756 | 6.71 | 5.68 | 4.40 |
| median | 31,425 | 2.58 | 2.44 | 2.35 |
| standard deviation | 20,860 | 10.6 | 7.78 | 6.57 |
| 95% UCL | 45,801 | 10.8 | 8.68 | 6.94 |
| max | 87,144 | 38.8 | 27.8 | 27.0 |
| min | 14,432 | 0.49 | 0.751 | 0.415 |

## Table 3-2. Summary Statistics for Natural Background and Mining-Affected Background Ratios

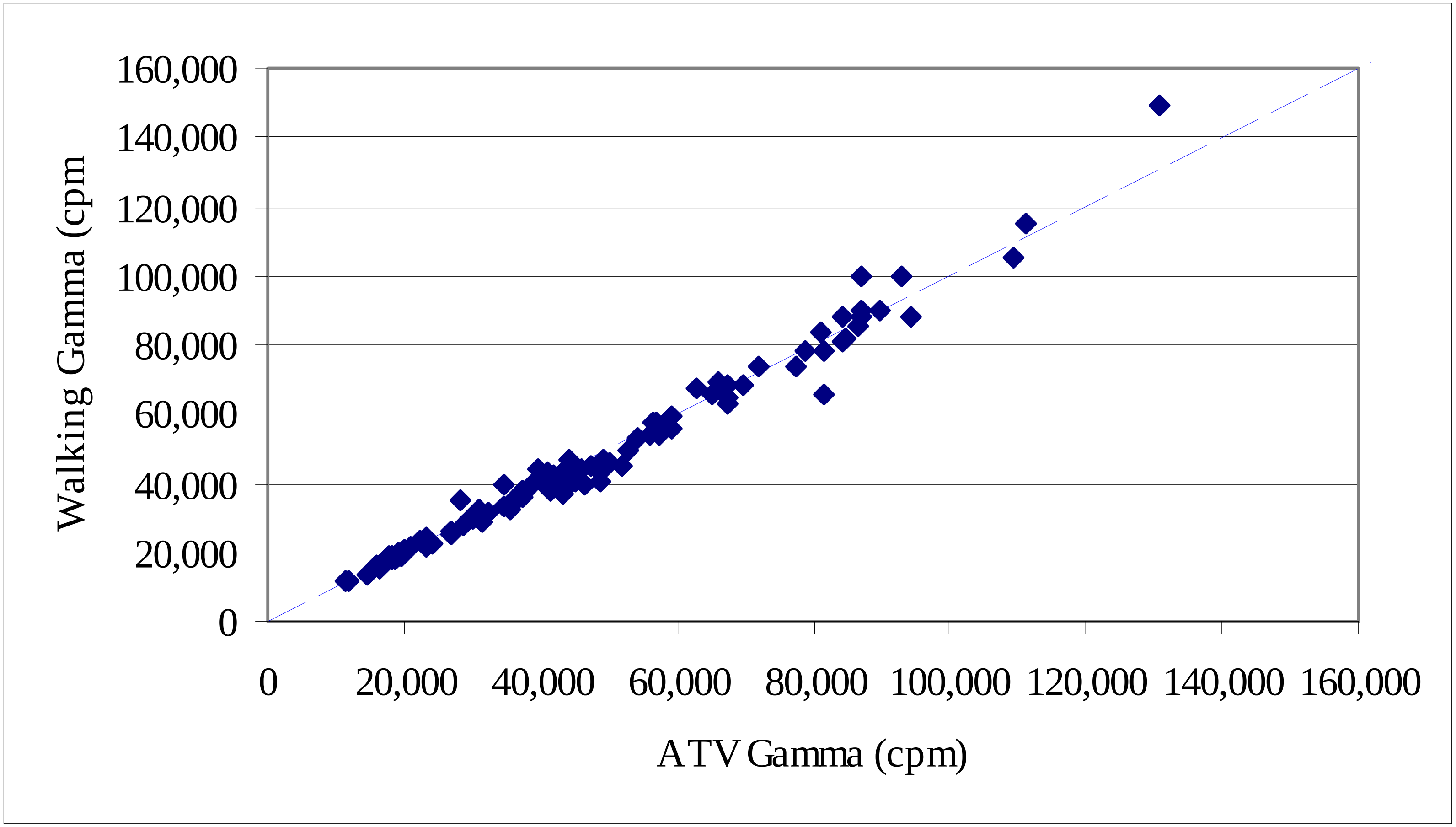
| Natural Background | | | |
|---|---|---|---|
| | Radium-226 /Thorium-230 | Radium-226 /Uranium-238 | Thorium-230 /Uranium-238 |
| Number of Samples | 29 | 30 | 29 |
| mean | 0.740 | 2.26 | 2.98 |
| median | 0.748 | 1.14 | 1.63 |
| standard deviation | 0.198 | 3.01 | 3.27 |
| 95% UCL | 0.803 | 3.19 | 4.01 |
| max | 1.11 | 13.87 | 14.9 |
| min | 0.338 | 0.305 | 0.492 |
| **Mining-Affected Background** | | | |
| | Radium-226 /Thorium-230 | Radium-226 /Uranium-238 | Thorium-230 /Uranium-238 |
| Number of Samples | 20 | 20 | 20 |
| mean | 1.15 | 1.59 | 1.57 |
| median | 0.888 | 1.29 | 1.34 |
| standard deviation | 0.851 | 1.14 | 1.09 |
| 95% UCL | 1.48 | 2.03 | 1.99 |
| max | 4.22 | 5.04 | 4.83 |
| min | 0.515 | 0.320 | 0.444 |

**Table 3-3. Ambrosia Lake Mill Tailings Sand Analysis and Mean Values for Windblown Soil Samples and Background Soil Samples**

| | Ambrosia Lake Mill Tailings Sands | Mean Windblown-Area Soils | Mean Natural Background Soils | Mean Mining-Affected Background Soils |
|---|---|---|---|---|
| Gamma ATV (cpm) | -- | 42,292 | 17,807 | 37,756 |
| Radium-226 (pCi/g) | 1,400 | 6.78 | 1.95 | 6.71 |
| Thorium-230 (pCi/g) | 240 | 9.72 | 2.69 | 5.68 |
| Uranium-238 (pCi/g) | 20.9 | 1.50 | 1.65 | 4.40 |
| ATV Gamma/Radium-226 | -- | 6,732 | 11.2 | 15,677 |
| Radium-226/Thorium-230 | 5.83 | 0.770 | 0.740 | 1.15 |
| Radium-226/Uranium-238 | 66.8 | 16.4 | 2.26 | 1.59 |
| Thorium-230/Uranium-238 | 11.5 | 11.6 | 2.98 | 1.57 |

**Table 3-4. Ranges of Mining-Affected Background Concentrations Compared to Homestake Mining Area and Mining-Affected Area North of the Impoundment**

| | Mining-Affected Background Locations | Homestake Mining Area Locations | Mining-Affected Locations North of Impoundment |
|---|---|---|---|
| Gamma ATV (cpm) | 14,432 – 87,144 | 28,188 – 111,381 | 23,175 – |
| Radium-226 (pCi/g) | 0.49 – 38.8 | 3.15 – 99.0 | 2.79 – 350 |
| Thorium-230 (pCi/g) | 0.751 – 27.8 | 5.50 - 149 | 2.46 – 505 |
| Uranium-238 (pCi/g) | < 0.83 – 27.0 | < 0.56 – 89.8 | <2.18 - 275 |
| ATV Gamma/Radium-226 | 2,170 – 46,813 | 704 - 15,339 | 1,362 – 20,050 |
| Radium-226/Thorium-230 | 0.515 – 4.22 | 0.104 - 1.88 | 0.645 - 1.43 |
| Radium-226/Uranium-238 | 0.320 – 5.0 | 0.425 – 45.6 | 0.523 - 13.1 |
| Thorium-230/Uranium-238 | 0.444 – 4.83 | 1.37 – 50.4 | 0.593 – 7.66 |




| | | | |
|---|---|---|---|
| KOMEX | Figure 3-1. Gamma Measurements Obtained Using Hand-Held (Walking) and ATV-Mounted Detectors | Project No: D0295A<br>Date: 11/09/2004<br>File Name: 8x11 Landscape.ppt | FIGURE<br>3-1 |

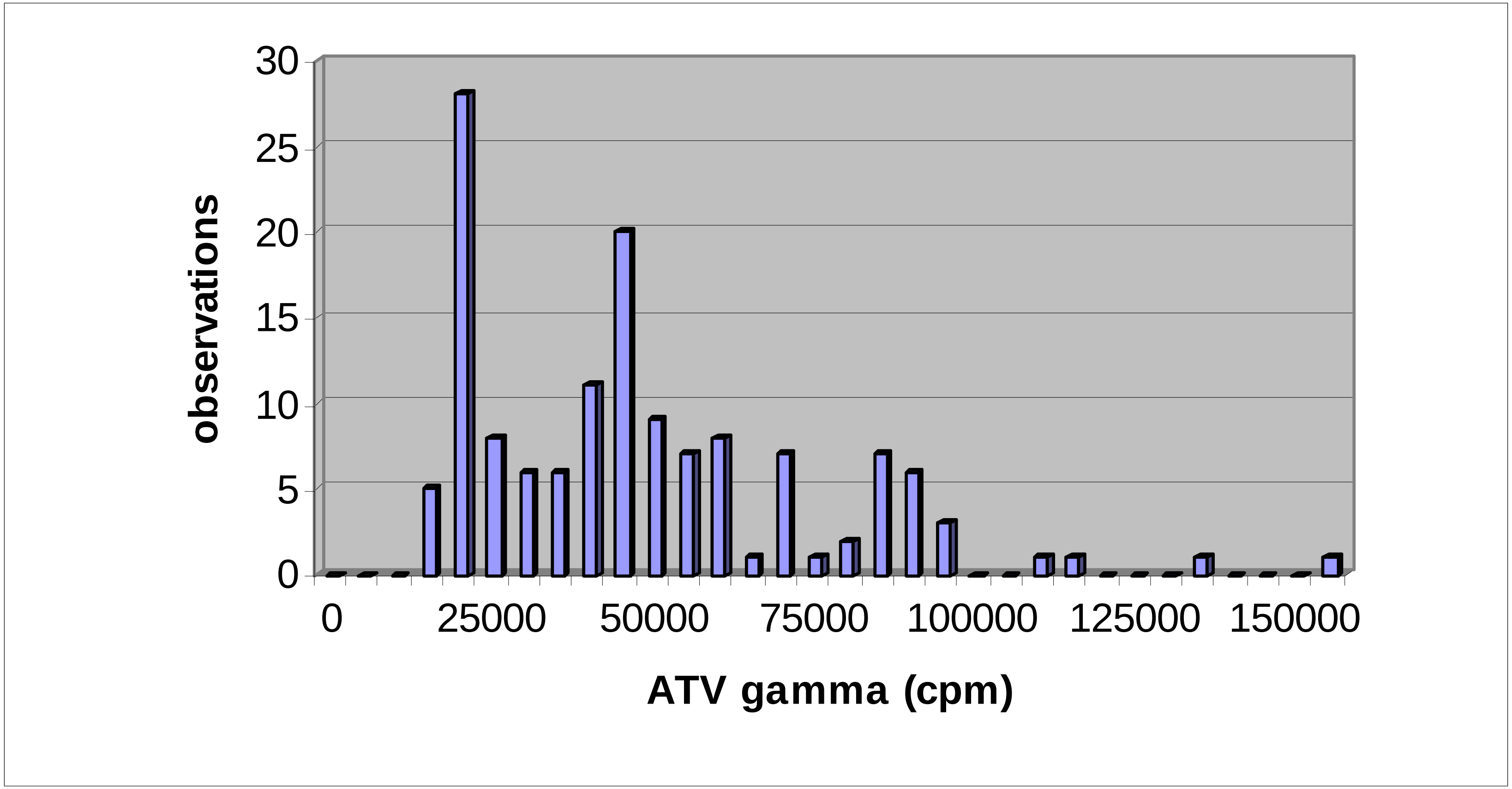


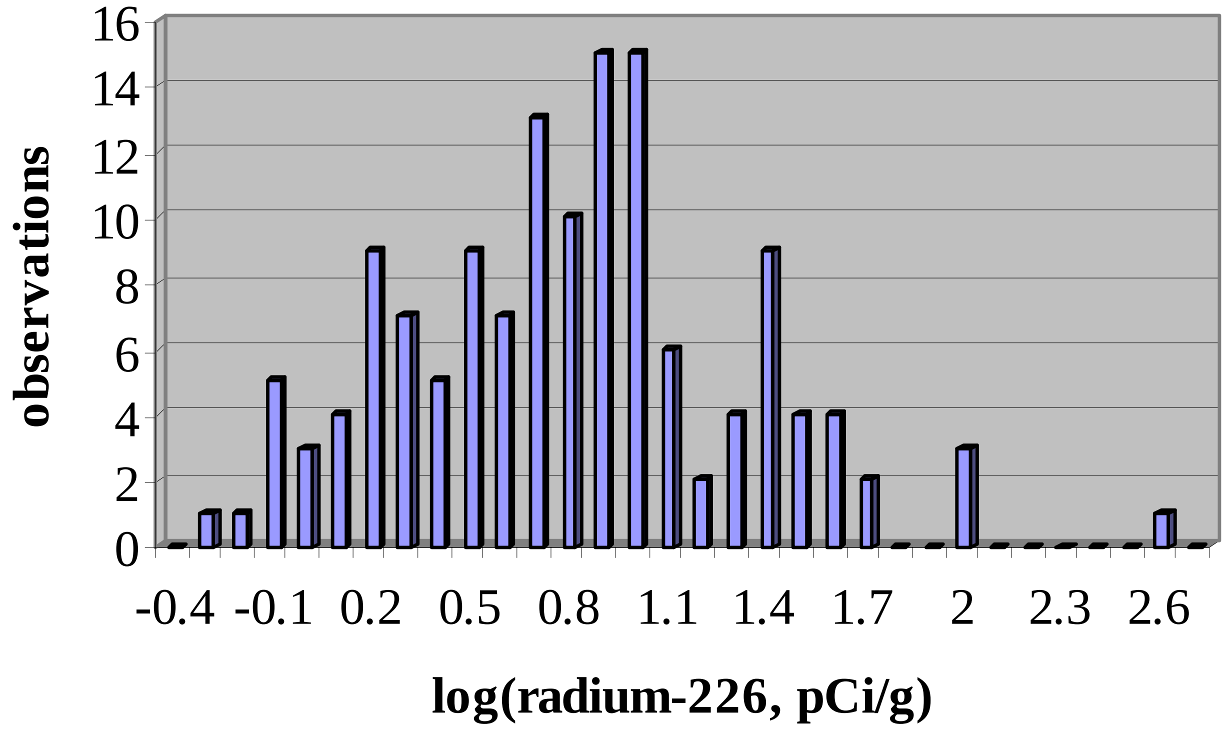

Figure 3-2. Histogram of ATV Gamma Measurements

Project No: D0295A

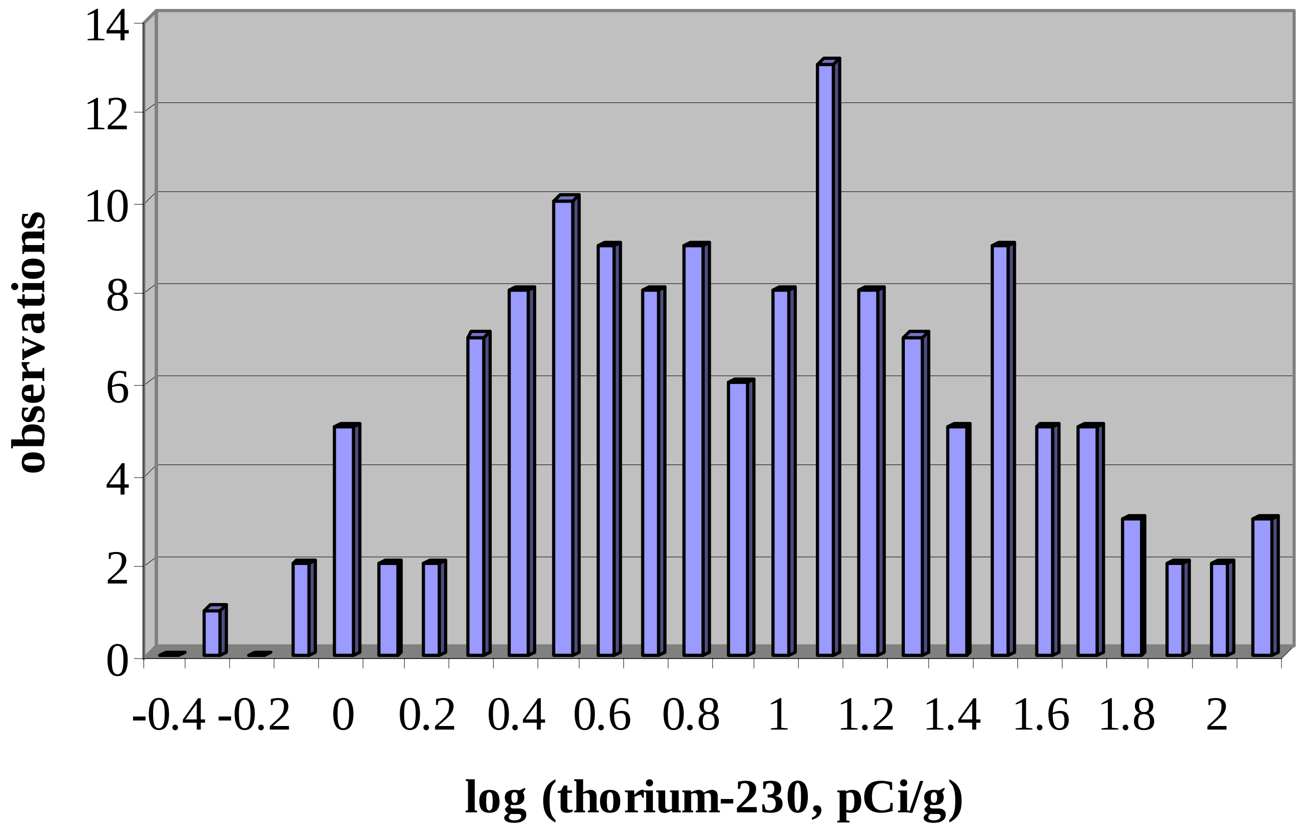
Date: 11/09/2004

File Name: 8x11 Landscape.ppt

FIGURE
3-2




| | | | |
|---|---|---|---|
| KOMEX | Figure 3-3. Log-transformed Histogram of Radium-226 Measurements | Project No: D0295A<br>Date: 11/09/2004<br>File Name: 8x11 Landscape.ppt | FIGURE<br>3-3 |




KOMEX

Figure 3-4. Log-transformed Histogram of Thorium-230 Measurements

Project No: D0295A

Date: 11/09/2004

File Name: 8x11 Landscape.ppt

FIGURE 3-4

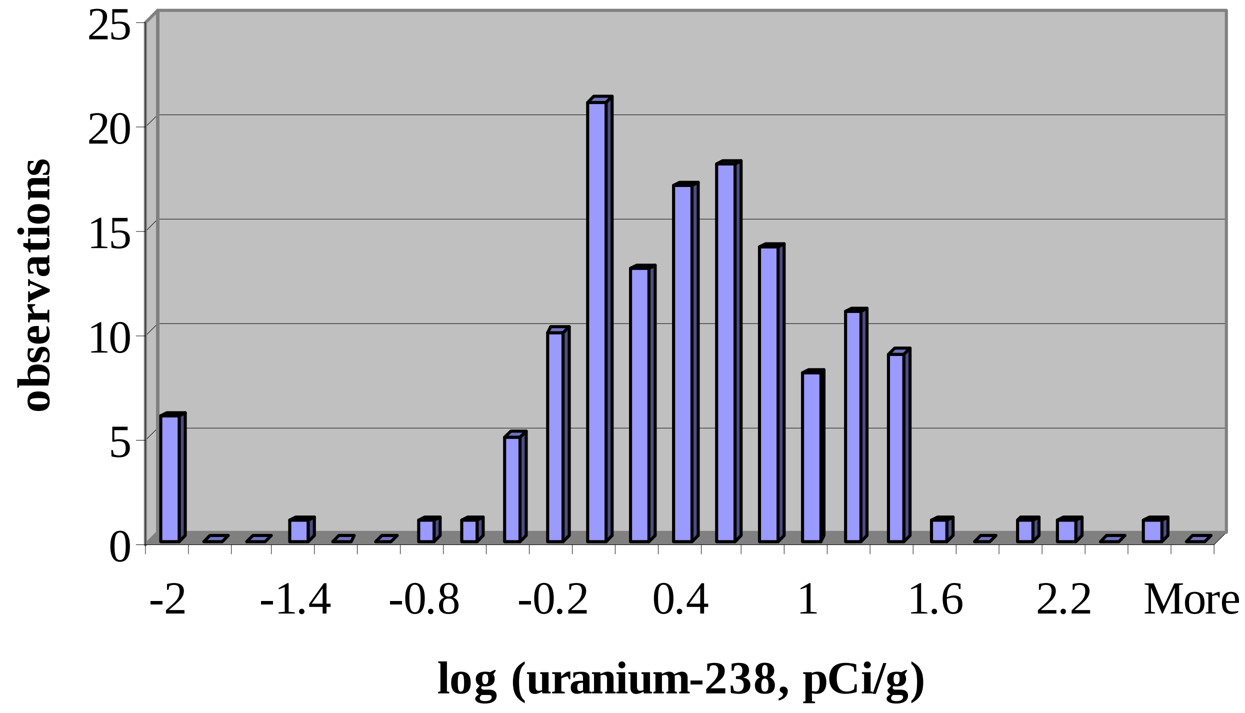


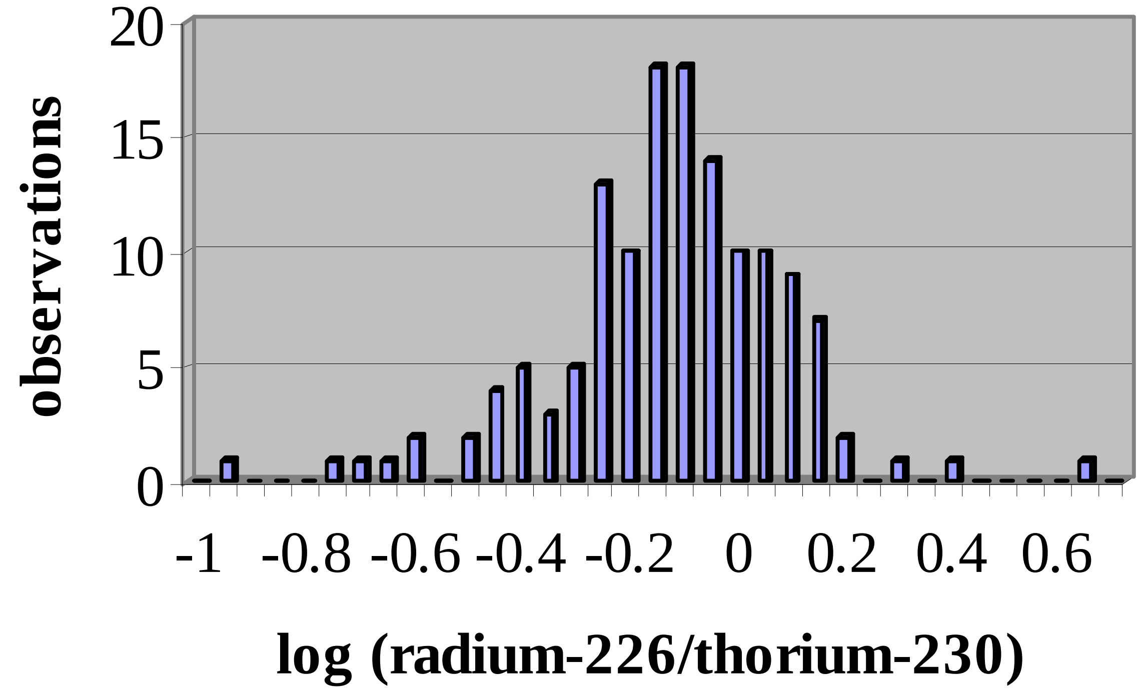

Figure 3-5. Log-transformed Histogram of Uranium(nat) Measurements

Project No: D0295A

Date: 11/09/2004

File Name: 8x11 Landscape.ppt

FIGURE 3-5




| | | | |
|---|---|---|---|
| KOMEX | Figure 3-6. Log-transformed Histogram of Ra-226/Th-230 Ratios | Project No: D0295A<br>Date: 11/09/2004<br>File Name: 8x11 Landscape.ppt | FIGURE 3-6 |

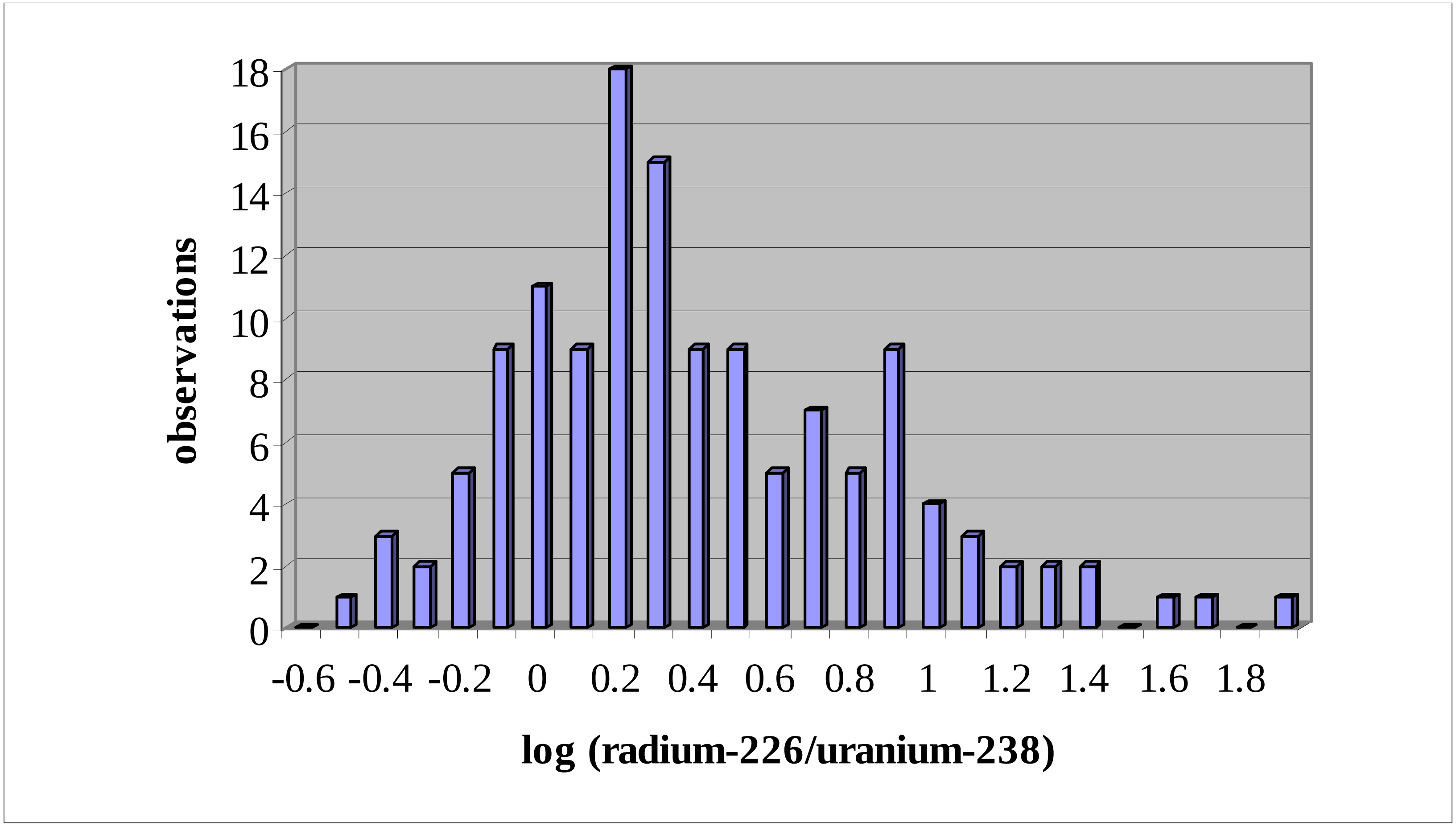



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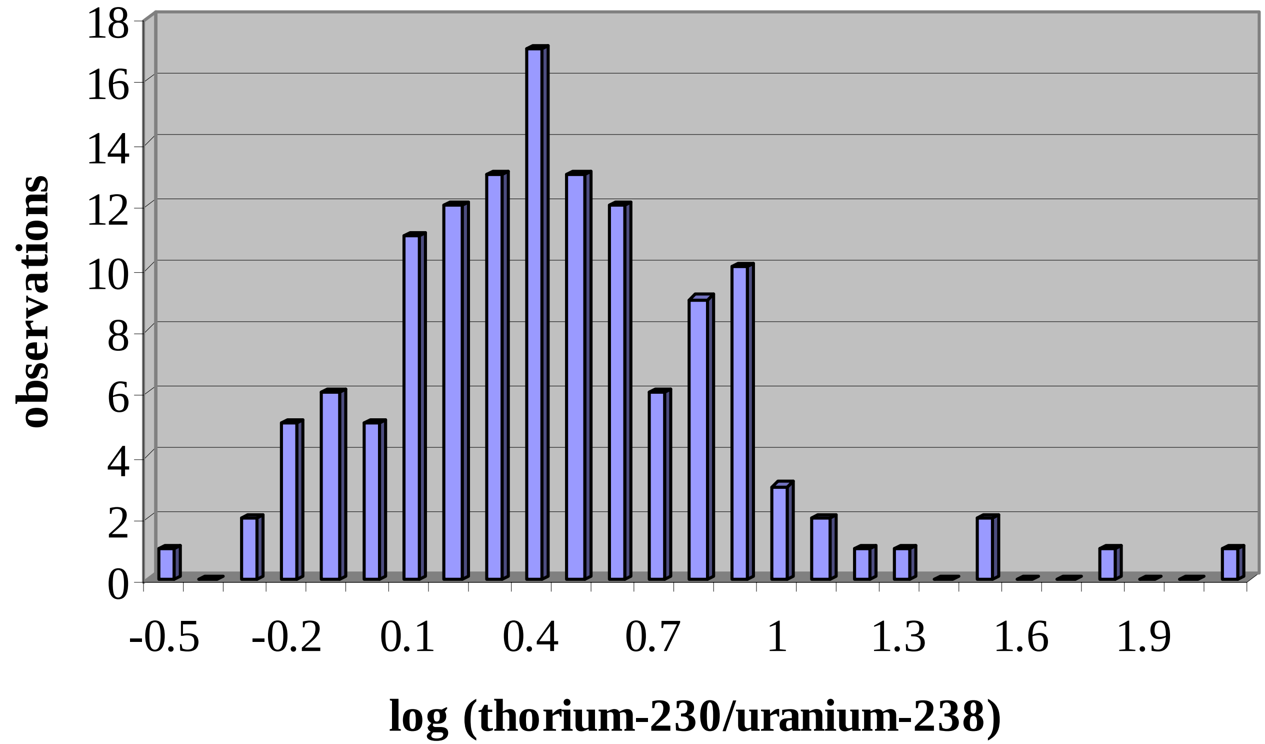
Figure 3-7. Log-transformed Histogram of Ra-226/U-238 Ratios

Project No: D0295A

Date: 11/09/2004

File Name: 8x11 Landscape.ppt

FIGURE 3-7




| | | | |
|---|---|---|---|
| KOMEX | Figure 3-8. Log-transformed Histogram of Th-230/U-238 Ratios | Project No: D0295A<br>Date: 11/09/2004<br>File Name: 8x11 Landscape.ppt | FIGURE 3-8 |

# 4.0 RADIUM BENCHMARK DOSE

Technical criteria[4] for termination of RAM's license include a limiting concentration of Ra-226 in soil, and limiting concentrations of other radionuclides in soil based on the equivalent dose to an average member of a group of individuals reasonably expected to receive the greatest exposure to residual radioactivity for any applicable set of circumstances. The equivalent dose is termed radium benchmark dose.

## 4.1 IDENTIFICATION OF CONSTITUENTS OF CONCERN

The constituents of concern for the radium benchmark dose are radium-226 and lead-210.[5]

## 4.2 EXPOSURE METHODOLOGY

The radium benchmark dose was assessed by constructing a source term and exposure scenario, and using a computer model to simulate the release and transport of radionuclides and radiation in the environment. The assessment was performed, to the extent possible, on a site-specific basis. The assessment reflected the site-specific characteristics of the residual radioactivity (i.e. type, extent, concentration) and of the environment (i.e. soil, water movement, plant growth) at the site. Exposure pathways relevant to the exposure scenario were chosen based on this information and regulatory guidance.

The radium benchmark dose was determined using version 6.21 of the RESRAD dose modeling software.[6]

## 4.3 AREAS OF SURFACE SOIL CONTAMINATION (WINDBLOWN)

Prior to the covering of former tailings impoundments, areas immediately downwind of the former tailings impoundments were subject to impacts by windblown tailings. A majority of the soils impacted by windblown tailings have either been previously excavated or have

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[4] 10 CFR 40, Appendix A, Criterion 6 (6)

[5] U.S. Nuclear Regulatory Commission (NRC), Final Report 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, NUREG-1620, Revision 1, June 2003. (sections H2.1.1 & H2.1.3(2)(b))

[6] 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.

minimal contamination present in the top six inches; i.e. residual radioactivity is limited to surface soil. A direct method of assessment of compliance with Criterion 6 will be used in these areas. Clean up requirements for other radionuclides in terms of soil concentration are derived in Section 5 from the radium benchmark dose. These clean-up requirements are then compared to measured or estimated concentrations in soil.

The development of the radium benchmark dose is described in Appendix B. The following sections summarize development of the benchmark dose.

### 4.3.1 SOURCE TERM

The radium benchmark dose was determined for a Ra-226 concentration in surface soil of 5 pCi/g with 5 pCi/g Pb-210.

### 4.3.2 EXPOSURE SCENARIO

A ranching exposure scenario was chosen for the site. The scenario and associated exposure pathways were established primarily from NRC guidance and evaluation.[7, 8] Values for exposure pathway parameters were chosen from either the same NRC guidance or evaluation, site specific or local information, or estimates from other applicable guidance.

## 4.4 RADIUM BENCHMARK DOSE (APPLICATION OF THE EXPOSURE SCENARIO)

The radium benchmark dose was determined as 18 mrem per year. A sensitivity analysis was completed for the radium benchmark dose and is described in Appendix B. The sensitivity analysis did not indicate that the radium benchmark dose is overly sensitive to any particular parameter.

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[7] U.S. Nuclear Regulatory Commission (NRC), Final Report 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, NUREG-1620, Revision 1, June 2003. (Appendix H)

[8] U.S. Nuclear Regulatory Commission, Commission Paper SECY 98 084, "Status of Efforts to Finalize Regulations for Radiological Criteria for License Termination: Uranium Recovery Facilities", April 15, 1998.

# 5.0 SOIL CLEAN-UP REQUIREMENTS

Criterion 6 of Appendix A of 10 CFR 40 sets concentration limits for radium-226 in soil at 5 pCi/g in the top six inches. The criterion also specifies that concentrations of radionuclides other than radium-226 in soil must not result in a Total Effective Dose Equivalent (TEDE) that exceeds the dose from radium-226-contaminated soil at specific concentration limits. This dose from Ra-226 is referred to as the radium benchmark dose. The criterion further specifies that if more than one residual radionuclide is present, the sum of the ratios for each radionuclide of concentration present to the concentration limit will not exceed unity.

NRC guidance[9] recognizes two different approaches to application of the radium benchmark dose. The conventional approach is to use the radium benchmark dose to derive soil concentration limits and, as discussed later in the SRP, apply the unity rule to determine compliance at the site. This approach is the direct method of compliance with Criterion 6.

The alternate approach is to model the current or planned future conditions at the site, calculate the dose from the residual contamination, and compare the results to the radium benchmark dose in order to demonstrate compliance. This approach incorporates the unity rule inherently as it limits the peak dose to the radium benchmark dose. This approach may allow higher initial total uranium, thorium-230, or radium-226 concentrations than the concentration limit approach, and as such does not expressly conform to the NRC guidance on limiting thorium-230 to a value that will not exceed the radium limit at the end of the planning period. This approach is an indirect method of compliance with Criterion 6.

## 5.1 SURFACE SOILS

Surface soil concentration limits (SCL) were developed from the radium benchmark dose (18 mrem/y) for total uranium and thorium-230 in accordance with NUREG-1620, Appendix H. The exposure scenario and associated inputs and model described for the radium benchmark dose were applied independently to concentrations of total uranium in soil and thorium-230 in soil. The radionuclide concentrations in soil for total uranium and thorium-230 that result in 18 mrem/y for the same exposure scenario are 440 pCi/g and 507 pCi/g, respectively.

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[9] U.S. Nuclear Regulatory Commission (NRC), Final Report 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, NUREG-1620, Revision 1, June 2003. (Section H2.2.1)

Conventional application of the technical criteria includes consideration of the ingrowth of radium-226 from thorium-230 over a 1000-year design period, which would limit the thorium-230 SCL to 14 pCi/g [10]. To ensure ALARA, RAM will utilize a Th-230 soil clean-up limit based on the Ra-226 concentration limit at 1000 years. A Th-230 concentration of 14 pCi/g will be used as the clean-up limit for the top 6 inches of soil. The Th-230 soil concentration limit of 43 pCi/g will be used in successive 6 inch layers below the surface. The uranium concentration in surface soils of the windblown area is much less than the SCL. In that regard it is reasonable to invoke ALARA by significantly lowering the SCL for total uranium. Current U-238 soils data (Table 2-1), indicate a total uranium SCL of 35 pCi/g is a reasonable remediation objective. The NRC has previously cited this concentration as a soil contamination level generally acceptable for unrestricted release[11].

The SCLs and applicable soil clean-up levels are listed in **Table 5-1**. The applicable soil clean-up levels are determined by adding respective background concentrations (**Table 3-1**) to the SCLs; i.e., 38 pCi/g uranium, 14 pCi/g Th-230, and 7.0 pCi/g Ra-226. In areas where uranium and thorium are not present above background, the radium-226 soil clean-up level will be used. In areas where uranium and thorium-230 are present, the soil clean-up level will be considered in combination to ensure that the applicable concentration objective is met; i.e. the sum of ratios of radionuclide concentration to respective soil clean-up level will not exceed one.

## 5.2 ALTERNATE RELEASE CRITERIA (ARC) FOR DEEPER CONTAMINATION

Areas of the site affected by mill operations or seepage from the evaporation ponds possess deep soil contamination. The concentrations of radionuclides in surface and subsurface soils exceed the soil concentration limits developed for the site. The Plan does not include remediation of these areas of deep contamination. These areas are targeted for cover placement and release without further clean-up. The alternate approach will be used to demonstrate compliance in each case. **Figure 1-3** depicts the areas of deep contamination at the RAM site.

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[10] NUREG-1620, Appendix H, Section H2.2.3, (3)

[11] Cunningham, R.E., USNRC: NMSS, Policy and Guidance Directive FC 83-23: Termination of Byproduct, Source, and Special Nuclear Licenses, November 4, 1983.

### 5.2.1 EVAPORATION PONDS

The facility utilized seven evaporation ponds immediately adjacent to the mill (Figures 1-2 and 1-3). Closure of these ponds is occurring pursuant to a plan approved by the NRC which will result in allowing for the land area associated with the Section 4 Lined Ponds to be released for unrestricted use. The unlined ponds 4 through 8, and lined ponds 9 and 10 are anticipated to be included within the area of institutional control to be transferred to the Department of Energy or the State of New Mexico upon license termination. Evaporation Ponds 4 through 8 were unlined ponds, while the remaining ponds were constructed with a synthetic liner. All unlined ponds were permanently removed from service in 1983.

Removal of the pond sediments was initiated and as excavation of the pond material progressed, delays were encountered as a result of intercepting the artificial shallow water table in the vicinity of the unlined ponds. Activities associated with the ongoing groundwater corrective actions are maintaining a groundwater mound near the tailings management area. These corrective actions can create conditions within the unlined pond area that are unsafe and unworkable for employees.

Analytical results from soil samples collected in trenches excavated within the unlined ponds indicates that up to ten feet of material may still require excavation from the ponds in order to eliminate the residual radioactive materials. Twenty five years of pond usage created a zone of residual radioactive material below the unlined ponds. Residual radioactive material that is present in these zones are radium-226, thorium-230, and uranium. The presence of this material at depth provides a significant challenge to closing these ponds in a safe, efficient, and cost-effective manner and has prompted RAM to seek ARC for the evaporation pond areas. Additionally, these areas will be included in the institutional control area for the Long-Term Surveillance Program, and unrestricted access will not be allowed. Therefore, RAM believes that exposures to the public will be minimized by covering the ponds in place and using institutional controls to restrict access to these areas by the public.

### 5.2.2 JUSTIFICATION FOR ARC – EVAPORATION PONDS

RAM believes that ARC is appropriate for the evaporation pond areas for the following reasons:

- Dose modeling completed for Ponds 7 and 8 is described in **Section 8.2.2.2** and **Appendix C**. The modeling indicates that placement of a soil cover over the evaporation pond areas without excavating the existing pond sediments will result in a radiation dose to the

average member of the critical group of 7 mrem/y. The present and future land use in the area is expected to remain as marginal ranching; and based on this limited land use, the predominant exposure pathways would be expected to be limited to external gamma and inhalation. As an ALARA consideration, modeling was performed assuming that additional exposure pathways would be present even though the likelihood is very remote. Additional pathways that were addressed in the evaluation included plant ingestion, meat ingestion, soil ingestion and drinking water. Consistent with NRC evaluation, only the aquatic, milk, and radon pathways were not included in the modeling.

- Excavation of the residual radioactive material in Ponds 7 and 8, which is present at depths down to ten feet, will neither be technologically or economically feasible considering the existence of a shallow groundwater mound in the area. Excavation will result in creating a depression within each pond that will fill with water thereby making removal of the residual radioactive material impractical. RAM estimates that approximately 370,000 $yd^3$ of contaminated soils will have to be excavated and placed onto the top of Pond 3 and replaced with clean borrow material for a cost of approximately $2,200,000. This cost includes only the soil handling, and it does not include additional costs associated with additional cover and erosion protection for Pond 3 as a result of the increased volume of material at closure. There is no estimate of additional exposure and safety issues that may result from the excavation.

- The same dose model, except without the soil cover, indicates that leaving Ponds 7 and 8 in their current condition may result in a radiation dose of 81 mrem/y. The net reduction in dose due to excavating Ponds 7 and 8 is 74 mrem/y. The cost per unit dose is then determined as $30,000 per person-rem. This is more than ten times greater than the value NRC concedes as ALARA. The same result is found for the other evaporation pond areas since the cost estimates are based on the same unit cost parameters, and the dose modeling, other than source term and area, is based on the same exposure pathway model.

- RAM intends to close Ponds 7 and 8 in place by grading the existing contaminated soils within the ponds to create a consistent base for placement of no less than one foot of clean soil cover onto the ponds. It is estimated that 9400 $yds^3$ of contaminated sediments will be redistributed within the ponds and 24,000 $yds^3$ of clean soil would be placed on the ponds and contoured for final closure. The estimated cost is $190,000 for this option. The anticipated radiation dose to the average member of the critical group resulting from this closure scenario is presented in **Section 8.2.2.2** and **Appendix C**. Compared to the option of excavating all of the contaminated soils and moving them to Pond 3, RAM's plan saves

approximately $2,000,000 and achieves an acceptable solution. Additional benefits not quantified here are reduced risk of injury and radiation dose to the construction worker.

- The same result is found for the other evaporation pond areas since the cost estimates are based on the same unit cost parameters and the dose modeling, other than source term and area, is based on the same exposure pathway model.
- Approval of Alternate Concentration Limits (ACLs) for the site provide additional protections that ARC at RAM's mill will not pose a threat to human health and the environment due to a mitigating combination of hydrological and geochemical conditions in alluvial aquifer materials including: 1) the alluvium will return to its pre-mining unsaturated state thereby eliminating the transport mechanism, and 2) natural attenuation processes including advection, dispersion, reduction and precipitation reduce constituent concentrations in groundwater over time and over distance from the source.
- Finally, the land area that encompasses the evaporation ponds will be included in the land transfer parcel to the U.S. Department of Energy upon license termination. Inclusion of this land area in the DOE transfer results in restricting public access to the area, thereby reducing or eliminating potential risks to public health and safety resulting from closure of the evaporation ponds.

### 5.2.3 OTHER AREAS OF POTENTIAL DEEP CONTAMINATION

There are other areas of potential deep soil contamination attributable to licensed activities. These areas include the areas adjacent to the unlined evaporation ponds, areas inaccessible due to on-going licensed activities, Pond 9 and the former Mill Area.

Remediation efforts that have occurred in some of these areas in the past have resulted in the excavation of over 500,000 cubic yards of contaminated soil, primarily resulting from windblown tailings. Although extensive reclamation efforts have been conducted in the affected area, there may still be a potential for some areas within the affected area to contain some residual radioactive materials.

RAM will re-evaluate the area at the time of final decommissioning of the site and ensure that any resultant exposure will be ALARA. This will be achieved by performing gamma surveys to delineate potentially contaminated areas, characterization of potentially contaminated areas to ascertain radiological concentrations via lab analysis, and revising dose modeling as necessary to determine potential exposure risk to individuals from site activities.

### 5.2.4 ARC METHODOLOGY

ARC will be used for areas of deeper soil contamination to demonstrate compliance with the regulatory criteria. A dose assessment will be completed for each area demonstrating that the contribution to the TEDE at the site is small. The dose assessment will be centered on the rancher scenario used to establish the radium benchmark dose. The exposure pathway modeling will be a deterministic analysis of the peak annual dose to the average member of the critical group for a rancher exposure scenario. The dose assessment will account 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 dose assessment will be developed in particular for the case of license termination. The dose assessment will be 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 dose assessment will be completed solely with respect to dose received due to pathways related to residual radioactive material in subsurface soil. Several pathways are anticipated to not be included in the dose assessment. Some pathways will not be included because they are not applicable; i.e. drinking water. Other pathways will not be included because they cannot be considered directly by the conceptual model applied; i.e. exposure rate from the disposal cell.

The results of the dose assessment will be will be compared to the radium benchmark dose to evaluate compliance status. Dose assessments have been completed for Ponds 4 through 8 and the results are presented in Section 8.2. As soil characterization data become available, dose assessments for the mill area, and Ponds 9 and 10 will be developed as addenda to this Plan. RAM will document the known depths and radiation levels of areas where the ARC are applied in the Final Status Survey.

**Table 5-1. Soil Concentration Limits and Clean up Levels for Radionuclides of Concern in Surface Soils**

| Radionuclide of Concern | Radium Benchmark Dose Soil Concentration pCi/g | Soil Concentration Limit pCi/g | Soil Cleanup Level[a] pCi/g |
|---|---|---|---|
| Total Uranium | 440 | 35 | 38 |
| Thorium-230 | 507 | 14 | 17 |
| Radium-226 | 5 | 5 | 7.0 |

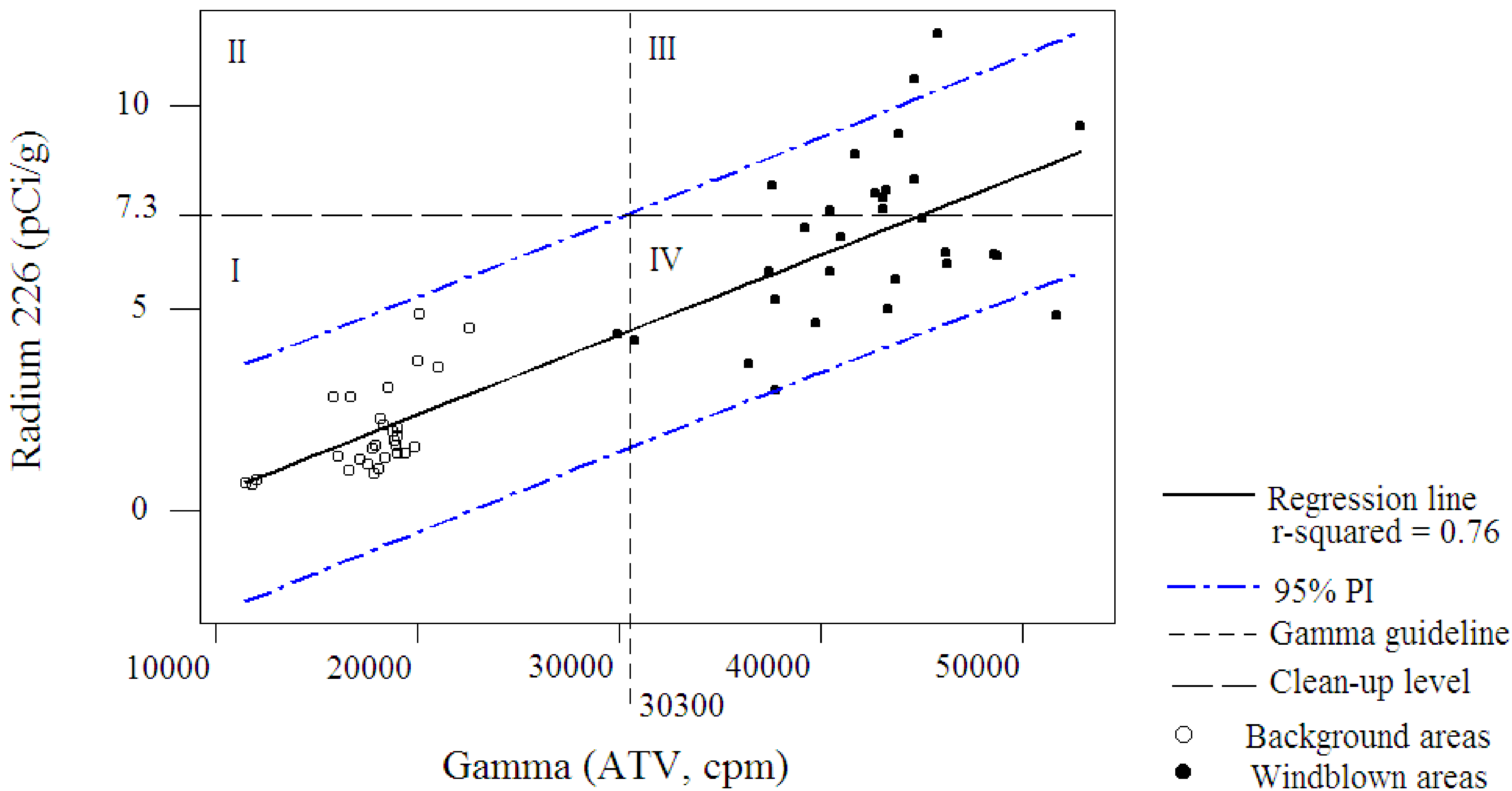
a – Soil Concentration Limit plus background concentration (Table 3-1).

# 6.0 GAMMA GUIDELINE VALUE

A correlation between gamma measurements and radium-226 concentrations was developed to identify areas requiring clean-up during the Final Status Survey at the Ambrosia Lake site. Data used in the correlation were collected in areas representative of natural background and areas believed to be affected by windblown 11e.(2) material near the site. Areas affected by non-11e.(2) uranium mining waste and drainage were not included in the gamma correlation, because these locations will be identified using other criteria.

The data used to develop the gamma correlation are included in **Table 2-1** and identified as windblown/undisturbed and background samples, i.e., samples Komex-1 through Komex-50 and Komex-112 through Komex-121. These data, which included only the primary samples and did not include split or replicate samples from the same grid, are plotted in **Figure 6-1**. The samples were collected and analyzed using the procedures planned for the final status survey (Section 8). Sixty samples were included in the correlation development. A linear regression was carried out on the data that produced an adjusted $r^2$ value of 0.76. The best-fit line and the 95% prediction interval about the line are illustrated in **Figure 6-1**.

The proposed gamma guideline value of 29,000 cpm is based on 7.0 pCi/g (5 pCi/g standard plus 2.0 pCi/g background). This gamma guideline value is conservative because it does not result in any false negative values (quadrant II in Figure 6-1), demonstrating that this guideline will result in the proper identification of grids that require clean-up. At low levels of contamination, samples from the windblown-affected area plot above the gamma guideline value (**Figure 6-1**). Thus, the gamma guideline value will result in contaminated grids being identified with confidence and conservatism, demonstrating that the soil clean-up will be consistent with levels that are ALARA.




| | | | |
|---|---|---|---|
| KOMEX | Figure 6-1. Ra-226/Gamma Correlation | Project No: D0295A<br>Date: 11/09/2004<br>File Name: 8x11 Landscape.ppt | FIGURE<br>6-1 |

# 7.0 REMEDIATION STRATEGY

The remediation strategy for any area at the site is dependent on the applicable soil clean-up requirements described in Section 5; i.e. surface soils or areas of deeper contamination. The remediation approach for surface soils will consist of removing (excavating) the contaminated soil. The remediation strategy for areas of deeper contamination will be to provide a physical cover for the area and applying institutional controls to restrict access.

## 7.1 SURFACE SOILS

Surface soils will be remediated by excavating contaminated soil and transporting it to the disposal cell. Excavation is expected to be limited to the top six inches of surface soil.

Excavation techniques for larger areas will include grading and/or scraping. The contaminated area may be graded to form windrows of surface soil that are subsequently picked up by scraper. Otherwise, the surface soil may be picked up directly by scraper. The excavated area will be contoured by grading as necessary after excavation to facilitate survey activities.

Excavation techniques for small areas will include grading and/or scraping. The surface soil of the contaminated area may be pushed into a pile that is subsequently picked up by bucket loader. Otherwise, the surface soil may be picked up directly by bucket loader. The excavated area will be contoured by grading or backfill with clean soil as necessary after excavation and successful surveys.

Pipelines that were used for transferring waste solutions that are outside of the footprint of the final disposal cell area will be excavated, surveyed to determine compliance with the clean-up criteria and backfilled in order to eliminate potential safety hazards.

### 7.1.2 SOIL MIXING

Based on discussions with NRC staff and RAM's reponses to NRC Requests for Additional Information, RAM will *not* utilize soil mixing as a remediation strategy.

## 7.2 AREAS OF DEEPER CONTAMINATION

Remediation of soils in areas of deep soil contamination will be accomplished by grading, covering, and restricting access. The area will be prepared by grading to provide a consistent

base and uniform contours. Subsequently, no less than one foot of clean soil cover will be placed onto the area and contoured. Additionally, institutional controls provided as a part of the long-term site maintenance will afford an additional level of protection.

The grading and placement of cover will be completed using standard construction equipment and practices. Institutional controls will include deed of property to Department of Energy, fencing, signage, and monuments.

# 8.0 FINAL STATUS SURVEY PLAN

This section describes the plan for conducting the Final Status Survey (FSS) at the site. The objective of the final status survey plan described here is to demonstrate that the final condition of the site satisfies the requirements of 10 CFR 40 Appendix A Criterion 6(6).

## 8.1 SURFACE SOILS

### 8.1.1 SURVEY DESIGN

#### 8.1.1.1 Identification of areas

The windblown area subject to the FSS is shown as the area of surface soil contamination in **Figure 1-3**. The rationale for the boundary of windblown areas within the scope of the FSS is provided in Section 2 and Section 3.

#### 8.1.1.2 Radionuclides of Concern (RoCs)

The RoCs in the surface soils are identified in Section 2 as natural uranium, thorium-230, and radium-226.

#### 8.1.1.3 Clean-up Requirements

Soil clean-up levels were determined in Section 5 to be 38 pCi/g natural uranium, 14 pCi/g thorium-230, and 7.0 pCi/g radium-226.

### 8.1.2 SURVEY TECHNIQUES (INSTRUMENTS AND PROCEDURES)

Instruments and procedures used to generate data during the surveys can be placed into two categories commonly known as scanning surveys and soil sampling. These survey techniques will be combined in an integrated survey design.

#### 8.1.2.1 Instrumentation

Instrumentation utilized for scanning and measurements will be calibrated and maintained in accordance with written procedures. These procedures utilize the manufacturers' guidance. Portable instruments are calibrated on an annual frequency or as required due to maintenance.

Specific requirements for instrumentation include traceability to NIST standards, daily checks for operability, daily performance checks of background and source, operation of instruments within established environmental bounds (i.e. temperature), training of individuals, calibration with radiations of energies similar to those to be measured, quality assurance tests, data review, and recordkeeping. Where applicable, activities of sources utilized for calibration are also corrected for decay. All calibration and source check records are completed, reviewed, and retained in accordance with quality assurance requirements.

##### *8.1.2.1.1 Scanning Surveys*

Land areas will be scanned for gross gamma radiations. The type of instrument used for scanning and typical performance characteristics are provided in **Table 8-1**.

##### *8.1.2.1.2 Soil Sampling*

Samples of soil will be collected and analyzed for the RoCs, as applicable. The analysis technique and typical detection limit for each radionuclide of concern is provided in **Table 8-2**.

#### 8.1.2.2 Procedures

RAM will conduct survey activities and tasks in accordance with approved written procedures. The written procedures have been or will be prepared, reviewed, revised, approved and implemented in accordance with the facility source material license condition #14 and #16.

##### *8.1.2.2.1 Scanning Survey*

The scanning survey will be completed using a NaI(Tl) radiation detector coupled to a handheld scaler/ratemeter. Measurements will be collected by keeping the detector approximately 18 inches of ground surface while walking or driving over the area at a rate comparable to a casual walk. The measurements will be made along straight line paths between opposite borders of the area being surveyed. The distance between the paths will be approximately six feet.

The scaler/ratemeter will be coupled to global positioning system (GPS) equipment and a data logger. A gamma measurement from the scaler/ratemeter and a location from the GPS will be recorded approximately every two seconds. The gamma measurement will be recorded as

counts per minute. The location will be recorded with respect to the reference coordinate system described in Section 8.1.3.

#### *8.1.2.2.2 Soil Sampling*

Soil samples will be collected in a known and consistent fashion, and with respect to the location reference system used for the scanning survey. Soil plugs will be collected from five evenly spaced locations across a 100m$^2$ grid. The soil plugs will be collected from the top six inches of soil. The five plugs from a six inch layer will be combined to create one composite soil sample.

Sample collection activities will also include documentation of sampling activities on a field log, decontamination of equipment between sample locations, and collection of replicate samples at a rate of one per 10.

The composite soil samples will be prepared in a known and consistent manner for laboratory analysis. The preparation will include removing rocks and vegetation, drying (if needed), crushing, and mixing/blending. The preparation concludes with placement of the prepared soil in a container and labeling the container. Sample preparation will include splitting the sample as necessary to support analysis by radiochemistry and/or gamma spectrometry.

Sample preparation will also include documentation of preparation activities in a laboratory log, decontamination of equipment between samples, and creation of duplicate samples at a rate of one per 10.

The prepared samples will be stored indoors. The manner of storage will include an inventory system and access to allow convenient retrieval according to the sample's unique identification.

Prepared samples requiring analysis for the RoCs will be shipped to an offsite laboratory. Verification soil samples will be stored at least until NRC approval of the FSS Report is obtained.

### 8.1.3 REFERENCE COORDINATE SYSTEM

A reference coordinate system will be used to facilitate identification of measurement and sampling locations, and to provide a mechanism for relocating a survey point. Land area scanning surveys and soil sample locations will be referenced to the New Mexico State Plane

(NAD 27 horizontal). Additionally, a site origin has been established as Easting 493500 and Northing 1593000 for the main facility area.

### 8.1.4 BACKGROUND RADIOACTIVITY

The site specific background concentrations in soil for the RoCs and the gamma scan are described in Section 3.2.

### 8.1.5 SURVEY DESCRIPTION AND MEASUREMENT EVALUATION

#### 8.1.5.1 Scanning Survey

A scanning survey will be completed for all of the windblown area. The scanning survey data will consist of historical survey data and scanning survey data collected following remediation of contaminated areas. Surveying of the area beyond the clean-up area (buffer zone) will conform to requirements of NUREG-1620, Section 5.2.2.(7). RAM will include a 30-meter buffer zone beyond the clean-up area that will be included as part of the final status survey.

##### *8.1.5.1.1 Scanning Survey Description*

The instrumentation and procedures for the scanning survey are described in Section 8.1.2.

##### *8.1.5.1.2 Scanning Survey Measurement Evaluation*

The scanning measurements will be averaged for each 100 $m^2$ grid. The scanning average value will be compared directly to the gamma guideline value. If the scanning average value is less than or equal to the gamma guideline value, no further scanning survey will be made of the grid. If the scanning average value is greater than the gamma guideline value, the failed grid will be remediated and another gamma scan performed.

Additionally, the number of individual survey readings in each grid will be determined. Grids not meeting the scanning density of 10 readings per grid will be subjected to additional scanning survey.

A tabular and graphic record will be compiled describing the scanning survey results relative to the gamma guideline value, remediation, and subsequent scanning survey results.

#### 8.1.5.2 Soil Sampling

Soil sampling will be completed after evaluation of the scanning survey.

##### *8.1.5.2.1 Soil Sampling Description*

Remediation control soil sampling may be conducted to support scanning survey evaluation.

Final status survey soil sampling will be completed for two percent of the 100 $m^2$ grids contained within the windblown area. The locations of the final status survey soil samples will be chosen from areas where the scanning survey results are nearest the gamma guideline value. Areas that were remediated based on evaluation of scanning survey results will also be considered preferentially.

The instrumentation and procedures for remediation control and final status survey soil sampling are described in Section 8.1.2.

##### *8.1.5.2.2 Soil Sampling Measurement Evaluation*

The soil sample result will be compared to clean-up levels such that the sum of the ratios for the concentration of each radionuclide of concern to the respective concentration limit will not exceed "1" (unity). If the sum of ratios is less than or equal to one, no further measurement or evaluation will be made of the 100 $m^2$ grid. If the sum of the ratios exceeds unity, the grid and every adjacent grid will be remediated and re-sampled.

A tabular and graphic record will be compiled describing the initial soil sample results, remediation, and subsequent soil sample results.

Results of characterization sampling and remediation control sampling of soils may be incorporated into to the final status survey data set.

If the number of failed 100 $m^2$ grids is greater than five per 100 the gamma guideline value will be re-evaluated and adjusted downward.

### 8.1.6 QUALITY ASSURANCE AND QUALITY CONTROL

RAM will implement a quality system to ensure that the final status survey decisions are supported by sufficient data of adequate quality and usability for their intended purpose, and

further ensure that such data are authentic, appropriately documented, and technically defensible.

#### 8.1.6.1 Quality assurance project procedure

A written quality assurance project procedure (QAPP) will be developed for the final status survey effort. The QAPP will be developed using a graded approach. The graded approach will base the level of control on the intended use of the results and the degree of confidence needed in their quality. The QAPP will describe the QA/QC requirements regarding survey planning, survey implementation, and results evaluation.

#### 8.1.6.2 Data assessment

Assessment of the final status survey data will be made to determine if the data meet the objectives of the surveys, and the whether the data are sufficient to determine compliance with the soil concentration limits. The assessment will consist of three phases: data verification, data validation, and data quality assessment.

##### *8.1.6.2.1 Data Verification*

Data verification efforts will be completed to ensure that requirements stated in planning documents are implemented as prescribed. Identified deficiencies or problems that occur during implementation will be documented and reported. Activities performed during the implementation phase will be assessed regularly with findings documented and reported to management. Corrective actions will be reviewed for adequacy and appropriateness and documented in response to the findings. Data verification activities are expected to include inspections, QC checks, surveillance, and audits.

##### *8.1.6.2.2 Data Validation*

Data validation activities will be performed to ensure that the results of data collection activities support the objectives of the surveys, or support a determination that these objectives should be modified. The data validation effort will include use of the following data descriptors:

- Reports to Decision Makers of data, changes to the survey plan, and results of verification.

- Review of documentation including field records, laboratory records, and data handling records.
- Selection and use of appropriate analytical methods and associated detection limits.
- Review of data to assess data quality in terms of completeness with respect to field and laboratory data quality requirements.
- Assessment will be made of data quality indicators to determine data usability. The data quality indicators to be assessed include precision, bias, accuracy, representativeness, comparability, and completeness.

##### *8.1.6.2.3 Data quality assessment*

An assessment of data quality will be performed to determine if the data are of the right type, quality, and quantity to support their intended use. The assessment will include review of relation between survey objectives and design; an evaluation of the data using basic statistical and graphical representations, and quality assurance reports; selection of statistical tests; verifying assumptions of statistical tests; and performing the statistical tests and drawing conclusions with respect to the survey plan objective.

## 8.2 AREAS OF DEEPER CONTAMINATION

Seepage from evaporation ponds and areas adjacent to the tailings area has resulted in deep soil contamination. These areas are targeted for cover placement and release without further clean-up by application of ARC. The adequacy of ARC for closure of the evaporation ponds (and other areas of deep soil contamination) will be demonstrated by comparing results of site specific dose modeling to the benchmark dose. Dose modeling completed for the unlined evaporation ponds is provided in this section. Dose modeling for other areas of potential deep soil contamination (the mill area, and Ponds 9 and 10) will be provided as additional soil characterization data becomes available.

### 8.2.1 CHARACTERIZATION REQUIREMENTS

An adequate characterization of existing or anticipated contamination for each area is necessary to provide a description of the source term for use in constructing a dose assessment relative to planned future conditions. Characterization data for the unlined evaporation ponds are described in Section 2.

Sampling is required to define the horizontal and vertical extent and concentration of contamination for each area to develop a radionuclide-specific source term for any given dose assessment. As a conservative measure to offset uncertainties related to site characterization, the maximum concentrations of RoCs from exiting sampling data have been utilized in the dose modeling for evaporation ponds 4 through 8 (Appendix C).

Existing characterization data may be used to develop the sampling requirements for areas of deep soil contamination. The net number of samples needed is the total sampling requirement less the existing number of samples already collected. In cases where no characterization data exists, the sampling requirements may be estimated from data for like areas or selected based on professional judgment. For purposes of the FSS, if no data are available, 30 samples will initially be collected for characterization purposes.

The sample locations may be chosen randomly or placed on a systematic grid with a random starting location. Professional judgment via visual and/or empirical examination of borehole logs will be used to identify the vertical extent of contamination. Subsequently, sample locations will be chosen randomly based on the depth of contamination and the areal boundary.

### 8.2.2 DOSE ASSESSMENTS

The strategy outlined above and expanded upon in Section 5.2 has been applied to two distinct geographic areas containing deep soil contamination: 1) Ponds 4, 5, & 6, and 2) Ponds 7 & 8 (**Figures 1-2 and 1-3**). The model used in the radium benchmark dose assessment was used as a starting point for the dose assessment of each area. Changes were made to the model to reflect the anticipated final condition of each area; i.e. cover placement. Finally, a dose assessment was completed for each area and the dose compared to the radium benchmark dose as a demonstration of compliance.

#### 8.2.2.1 Dose Assessment for Ponds 4, 5, and 6

As a conservative measure, the radionuclide source term was assumed to be the maximum concentration for Ra-226, Th-230, and U-238 from the characterization data presented in Section 2. The contaminated area was modeled as equivalent to the entire area of Ponds 4, 5, and 6. Also, a cover of one foot of clean soil was placed over the entire area of Ponds 4, 5, and 6. Otherwise the dose assessment included the same parameters and inputs as the radium

benchmark dose. A complete description of the dose assessment for Ponds 4, 5, and 6 is provided in Appendix C.

The dose assessment was performed to compare the residual radioactivity in subsurface soils of evaporation Ponds 4, 5, and 6 to the radium benchmark dose limit of 18 mrem per year. The result of the dose assessment was 11 mrem per year. This value is less than the radium benchmark dose; i.e. from application of the site specific soil concentration limits.

The top few feet of contaminated soil has previously been removed from the footprint of each of ponds 4, 5, and 6. Analytical results from soil samples collected in trenches excavated within the unlined ponds indicate that more than six feet of material may still require excavation from the footprints of these ponds in order to eliminate the remaining residual radioactive materials. The presence of this material at depth provides a significant challenge to closing these ponds in a safe, efficient, and cost effective manner.

Following discussions with NRC staff regarding possible options for these areas, which centered on the ARC approach, the footprints were subsequently covered with clean soil. Section 5.2 and Appendix C and D demonstrate that the remediation strategy completed in these areas is appropriate and no further investigation or soil remediation is planned within pond footprints.

An evaluation of the long-term erosion potential at the RAM site is provided in Attachment B. The purpose of the evaluation was to predict soil loss in reclaimed areas beyond the existing reclaimed tailing ponds that could be affected by runoff and run-on from periodic and long term storm events. In addition, the erosion potential of the land surface of reclaimed evaporation ponds 4, 5, and 6 were evaluated both for short term periodic storm events and from a PMP event. In general, the evaluation found that slopes less than one percent would experience an acceptable erosion rate over a 1000 year period.

The report recommends that a gravel mulch be placed over the reclaimed surface of Ponds 4, 5 and 6. RAM will also apply the gravel mulch to the perimeter surrounding Ponds 4, 5 and 6 as an additional protective measure if deep impacts due to pond seepage are encountered in these areas.

The rock to be used for these areas will consist of a minimum $D_{50}$ 0.5 inch rock and will be placed in a minimum of 2 inch thickness. It is anticipated that belly dump trucks will be used to place the rock and a grader will spread the rock to the desired thickness. The perimeter of

ponds 4, 5, and 6 will be contoured to reduce erosion. RAM will then place a gravel mulch over the total area to further stabilize the cover.

The gradation specification for the $D_{50}$ 0.5 inch rock is provided in Table 8-3 below. RAM will perform a minimum of 4 gradation tests during placement activities.

#### 8.2.2.2 Dose Assessment for Ponds 7 and 8

As a conservative measure, the radionuclide source term was assumed to be the maximum concentration for Ra-226, Th-230, and U-238 from the characterization data presented in Section 2. The contaminated area was modeled equivalent to the entire area of Ponds 7 & 8. Also, a cover of one foot of clean soil was placed over the entire area of Ponds 7 & 8. Otherwise the dose assessment included the same parameters and inputs as the radium benchmark dose. A complete description of the dose assessment for Ponds 7 & 8 is provided in Appendix D.

The dose assessment was performed to compare the residual radioactivity in subsurface soils of evaporation Ponds 7 & 8 to the radium benchmark dose limit of 18 mrem per year. The result of the dose assessment was 11 mrem per year. This value is less than the radium benchmark dose; i.e. from application of the site specific soil concentration limits.

Ponds 7 and 8 have been stabilized in place by excavating and grading the remaining contaminated soils within the ponds to create a consistent base, followed by placement of no less than one foot of clean soil cover onto the ponds. Section 5.2 and Appendix D demonstrate that the remediation strategy completed in these areas is appropriate. Moderate native vegetation has been established over the whole area. No further remediation is planned within pond footprints other than placement of a rock mulch layer over the area as described below.

An evaluation of the long-term erosion potential at the RAM site is provided in Attachment B. In general, the evaluation found that slopes less than one percent would experience an acceptable erosion rate over a 1000 year period.

The report recommends that a gravel mulch be placed over slopes at Ponds 7 and 8 that exceed one percent. The rock to be used for these areas will consist of a minimum $D_{50}$ 0.5 inch rock and will be placed in a minimum of 2 inch thickness. It is anticipated that belly dump trucks will be used to place the rock and a grader will spread the rock to the desired thickness. The gradation specification for the $D_{50}$ 0.5 inch rock is provided in Table **8-**3. RAM will perform a minimum of one (1) gradation test during placement.

### 8.2.2.3 Dose Assessment for Ponds 9 and 10

In a letter dated August 27, 2015 (ML15223A957), NRC approved a supplement to the Plan that included a dose assessment for Ponds 9 and 10 and the Mill area. In this letter the NRC concluded "NRC staff reviewed the RESRAD analyses and the process for correlating the gamma scan data to existing soil data and confirmed that the appropriate information was provided in the submittal and that the individual steps of the processes were performed correctly. The NRC staff concludes that the Report is appropriate and should be included in the approved Plan".

A set of soil sample data is available for Pond 9. These samples were collected after the remediation in the pond area was completed by removing the soil in areas where the gamma scan results were below 27,000 cpm following the protocol discussed the KOMEX report. This data is expected to representative of data for areas that have the soil removed to similar levels such as the Mill Area. This data was compared to the background soil sampling data contained in Section 3. The comparison data is contained in Table 8-4 on the following pages. The data in Table 8-4 shows that the area sampled in Pond 9 were lower in the ROC's than the background area.

There is some limited soil sampling data available for Pond 10. Two composite soil samples were collected from previously collected soil samples from that area, one from soil from the top 0" to 6" and another from 6" to 12" from the surface. The 0' to 6" inch composite contained that contained 6.41, 444, 41.8 pCi/g for Ra-226, Th-230, and U-total, respectively. The 6"-12" composite sample had 1.12, 66, and 19.9 pCi/g for Ra-226, Th-230, and U-total, respectively.

The modeling result for Ponds 9 and 10 and the Mill Area were determined using the same parameters used in the dose assessments for other ponds after verifying that the later version of RESRAD would give the same results. The data used is provided in Appendix E includes maximum concentration of soil samples found in areas outside the area of Ponds 9 and 10 modeled in this report but are values that are not expected to be exceeded in Ponds 9 and 10 based on the information available. The modeling for the Mill Area is based on scan information and the results are projected to a level that is above any measured soil samples found at the site. The results indicate that the dose guideline limit of 18 mrem/yr will not be exceeded if the alternate remediation criteria (ARC) procedures are followed. The removal of all soil with gamma scan values >27,000 cpm will also assure that the dose levels will be extremely low in all the area modeled in this report. The parameters used in the modeling include a cover of one foot of soil (0.3 meters) which is a primary parameter for the ARC.

### 8.2.3 SUMMARY AND ARC COMPLIANCE DEMONSTRATION

Based on the results of dose modeling presented above, closure of the unlined evaporation ponds via cover placement and release without further clean-up is appropriate and protective of human health and the environment. Results of this dose modeling, in conjunction with practical and ALARA considerations described in Section 5.2, demonstrate that the application of ARC for areas of deep soil contamination is justified and appropriate.

## 8.3 PIPELINES

There is approximately 15,000 feet of buried pipeline at the site. Approximately 13,000 feet runs from Pond 9 to the Section 4 ponds. The other 2000 feet is in the mill area. The buried pipeline ranges from four to eight feet below surface. The spoils from the pipeline excavation will be removed to the disposal cell. The excavation will be backfilled with clean material.

The survey techniques for excavated pipelines will include scanning and soil sampling. The scanning will be performed as described in Section 8.1.2 of the Soil Decommissioning Plan. The scanning will be completed along the length of the pipeline as access permits; i.e. if the trench is too deep or the sidewalls unstable, a scan will not be attempted. The scanning results will be evaluated qualitatively, and locations of significant increase in count rate will be identified for biased sampling described below.

The soil sampling will contain both systematic and biased components. The systematic soil samples will be collected as follows:

- The length of the excavation will be divided into 100 meter segments.
- A composite sample will be collected from every other 100 meter segment.
- The composite sample will be comprised of five-plugs evenly-spaced across the bottom of the excavation for the respective 100 meter segment.

Biased soil samples will be collected from soils where the scanning result and/or visual observation of the soils beneath the pipeline are indicative of elevated levels. Biased soil samples will consist of discrete single plugs. Other aspects of soil sampling (i.e. methods, QA/QC) will be consistent with Section 8.1 of the Soil Decommissioning Plan.

All pipeline trenches outside of the mill yard area will be cleaned to meet soil concentration limits appropriate for subsurface soils below 6 inches (15cm). The soil concentration limits

applicable for subsurface soils will be provided with the revised Soil Decommissioning Plan (included in **Table 5-1**) to be submitted upon approval of RAI responses.

In the mill yard area, pipelines may be located on shallow bedrock. In areas where pipelines are in bedrock, impacted material will remain and ARC will be applied as described in Section 5.2 of the Soil Decommissioning Plan.

**Table 8-1. Identification Of Radiation Detection Instruments For The Final Status Survey**

| Measurement | Instrumentation Detector Meter | | Background[a] (cpm) | Detection Sensitivity |
|---|---|---|---|---|
| Scanning Survey | 2" x 2" NaI(Tl) Ludlum Meas., Inc., Model 44-10 | Scaler/ratemeter, Ludlum Meas., Inc., Model 2221. | 18000 | 21000 cpm[b], 2.6 pCi/g, Ra-226[c] |

[a] An average value derived from gamma scans of background soil sample locations: see Section 3.

[b] Minimum detectable count rate determined in accordance with NUREG-1575 at page 6-40.

[c] Refer to Figure 6-1 (gamma correlation) for Ra-226 concentration at minimum detectable count rate of 21000 cpm.

**Table 8-2. Identification Of Radioanalytical Methods For Final Status Survey**

| Radionuclide Of Concern | Analytical Method | Detection Limit[a], (pCi/g) |
|---|---|---|
| Total Uranium | gamma spectrometry via Th-234 and Pa-234$^m$<br><br>Total uranium activity will be determined from U-238 activity by assuming activity ratios of U-238/U-235/U-234 = 0.489 /0.022 /0.489 | 15 |
| Thorium-230 | alpha spectrometry | 1 |
| Radium-226 | gamma spectrometry via in-growth of radon | 0.5 |

[a] Maximum values

**Table 8-3. $D_{50}$ 0.5 Inch Rock Gradation**

| Sieve Size | Percent Passing | Percent Retained |
|---|---|---|
| 1 inch | 100% | 0% |
| ¾ inch | 89% | 11% |
| ½ inch | 42% | 58% |
| 3/8 inch | 20% | 80% |
| No. 4 | 2% | 98% |
| No. 8 | 1% | 99% |

**Table 8-4. Comparison Between Pond 9 Surface Soil Samples and Background Surface Soil Samples**

Table 1 Comparison Between Pond 9 Surface Soil Samples and Background Surface Soil Samples

| Pond 9 Surface Soil Samples | | | | Background Surface Soil Samples | | | |
|---|---|---|---|---|---|---|---|
| | Th-230 | Ra-226 | U-238 | | Th-230 | Ra-226 | U-Total |
| Label | pCi/g | pCi/g | pCi/g | Location | pCi/g | pCi/g | pCi/g |
| P-9 #-101 | 1.6 | 0.5 | 0 | W-17 | 4.5 | 6.49 | 4.95 |
| P-9 #-102 | 3.3 | 1.8 | 0 | W-18 | 22.5 | 7.06 | 6.21 |
| P-9 #-103 | 1.1 | 1.1 | 0 | W-19 | 9.03 | 1.47 | 1.09 |
| P-9 #01 | 1.3 | 1.2 | 0 | W-21 | 13.2 | 5.1 | 5.24 |
| P-9 #02 | 0.9 | 1.1 | 0 | W-8 | 1.62 | 1.82 | 0.39 |
| P-9 #04 | 1 | 0 | 0 | W-9 | 2.13 | 2.47 | 0.74 |
| P-9 #05 | 9.9 | 4 | 0 | X-11 | 0.65 | 1.02 | 1.03 |
| P-9 #08 | 16.5 | 3 | 0 | X-12 | 3.63 | 3.61 | 1.54 |
| P-9 #09 | 1.7 | 0.8 | 0 | X-12-SE | 1.23 | 1.66 | 1.23 |
| P-9 #10 | 1 | 0.8 | 0 | X-13 | 0.48 | 0.62 | 0.61 |
| P-9 #100 | 0.6 | 0.6 | 0 | X-13-SE | 0.83 | 1.07 | 0.77 |
| P-9 #11 | 0.9 | 0.5 | 0 | X-14 | 0.51 | 0.78 | 0.64 |
| P-9 #12 | 0.7 | 0.6 | 0 | X-14-SE | 0.79 | 0.88 | 0.43 |
| P-9 #13 | 0.4 | 2.5 | 0 | X-15 | 0.71 | 0.54 | 0.42 |
| P-9 #14 | 0.5 | 1.6 | 0 | X-15-SE | 1.48 | 1.72 | 1.22 |
| P-9 #15 | 0.9 | 1.1 | 0.56 | X-16 | 1.43 | 0.77 | 1.09 |
| P-9 #16 | 2 | 1.7 | 0 | X-16-SE | 2.28 | 1.82 | 1 |
| P-9 #17 | 0 | 1.2 | 0 | X-17 | 0.81 | 0.69 | 0.61 |
| P-9 #18 | 0.9 | 1.4 | 0 | X-17-SE | 2.27 | 2.01 | 1.48 |
| P-9 #19 | 13.3 | 1.9 | 0 | X-18-SE | 17.8 | 7.5 | 2.99 |
| P-9 #20 | 5.2 | 1 | 0 | X-19 | 15.1 | 8.7 | 22.8 |
| P-9 #21 | 7.1 | 1.6 | 0 | X-9 | 2.11 | 2.72 | 0.64 |
| P-9 #22 | 3 | 2.1 | 0 | Y-10 | 2.1 | 2.21 | 1.38 |
| P-9 #23 | 6.9 | 1.8 | 0 | Y-11 | 1.67 | 1.84 | 0.74 |
| P-9 #24 | 3.9 | 1.2 | 0 | Y-11-SE | 0.75 | 1.12 | 0.87 |
| P-9 #27 | 1.7 | 1.3 | 0 | Y-12 | 2.73 | 3.12 | 1.26 |
| P-9 #28 | 1.3 | 1.1 | 0 | Y-12 | | 1.86 | |
| P-9 #29 | 1.4 | 1.1 | 0 | Y-12-SE | 5.79 | 6.03 | 1.53 |
| P-9 #30 | 5.7 | 2 | 0 | Y-13 | 0.43 | 0.63 | 0.35 |
| P-9 #33 | 13.5 | 1.5 | 0 | Y-13-SE | 3.19 | 3.66 | 0.84 |
| P-9 #34 | 2 | 1.8 | 0 | Y-14 | 2.62 | 1.95 | 0.87 |
| P-9 #35 | 1.5 | 1.6 | 2.2 | Y-14-SE | 3.51 | 3.11 | 0.81 |
| P-9 #36 | 1.3 | 1.2 | 0 | Y-15 | 5.63 | 3.85 | 1.32 |
| P-9 #37 | 3.5 | 1.5 | 0 | Y-15-SE | 8.85 | 7.14 | 2.3 |
| P-9 #38 | 0.6 | 1.4 | 0 | Y-16-SE | 14.4 | 11.2 | 0.19 |
| P-9 #39 | 0.5 | 2.3 | 0 | Y-17 | 4.38 | 2.14 | 1.35 |
| P-9 #40 | 1.2 | 1.3 | 0 | Y-17-SE | 12.8 | 8.33 | 0.01 |
| P-9 #41 | 2.1 | 0.4 | 0 | Y-18-SE | 13.5 | 6.21 | 2.22 |
| P-9 #42 | 1.4 | 0.9 | 0 | Z-10 | 2.42 | 2.43 | 0.84 |
| P-9 #43 | 0.9 | 1.5 | 0 | Z-11 | 1.91 | 1.87 | 0.96 |
| P-9 #44 | 14.7 | 2.1 | 0 | Z-11-SE | 3.19 | 3.55 | 1.38 |
| P-9 #45 | 14.2 | 1.2 | 0.38 | Z-12 | 3.47 | 3.14 | 1.12 |
| P-9 #46 | 9.1 | 1.9 | 0 | Z-12-SE | 4.65 | 4.66 | 1.32 |
| P-9 #47 | 3.4 | 1.2 | 0 | Z-13-SE | 2.11 | 2.11 | 0.72 |
| P-9 #48 | 7.8 | 2.5 | 0 | Z-14-SE | 12.2 | 12.8 | 4.96 |

## Table 8-4. Continued

| Pond 9 Surface Soil Samples | | | |
|---|---|---|---|
| Label | Th-230 pCi/g | Ra-226 pCi/g | U-238 pCi/g |
| P-9 #45 | 14.2 | 1.2 | 0.38 |
| P-9 #46 | 9.1 | 1.9 | 0 |
| P-9 #47 | 3.4 | 1.2 | 0 |
| P-9 #48 | 7.8 | 2.5 | 0 |
| P-9 #49 | 3.6 | 1 | 0 |
| P-9 #50 | 1.4 | 0.8 | 0 |
| P-9 #53 | 5.5 | 3.1 | 0 |
| P-9 #54 | 12.9 | 1.8 | 0 |
| P-9 #56 | 12.7 | 1.8 | 0 |
| P-9 #57 | 10.5 | 1.6 | 0 |
| P-9 #58 | 10.4 | 1.2 | 0 |
| P-9 #59 | 0.8 | 1.9 | 0 |
| P-9 #60 | 4.3 | 3 | 0 |
| P-9 #61 | 6.1 | 1.5 | 0 |
| P-9 #62 | 3.8 | 2.5 | 0 |
| P-9 #63 | 13.1 | 1 | 0 |
| P-9 #64 | 0.8 | 1.8 | 0 |
| P-9 #67 | 4.4 | 1.4 | 0 |
| P-9 #70 | 10.4 | 1.2 | 0 |
| P-9 #71 | 4.2 | 2 | 0 |
| P-9 #72 | 12.8 | 3.9 | 0 |
| P-9 #73 | 11.8 | 1 | 0 |
| P-9 #74 | 6.2 | 6.2 | 0 |
| P-9 #75 | 15 | 1.4 | 2.98 |
| P-9 #76 | 15 | 1.7 | 0 |
| P-9 #77 | 2.5 | 2.1 | 0 |
| P-9 #78 | 4 | 3.1 | 0 |
| P-9 #79 | 7 | 2.5 | 0 |
| P-9 #80 | 2.9 | 1.3 | 0 |
| P-9 #81 | 7.3 | 2.5 | 0 |
| P-9 #82 | 1.3 | 0.8 | 0 |
| P-9 #83 | 10.1 | 1.1 | 0 |
| P-9 #86 | 1.5 | 1.2 | 1.74 |
| P-9 #88 | 5.4 | 0.9 | 0 |
| P-9 #93 | 14 | 0.6 | 0 |
| P-9 #94 | 2.7 | 1.8 | 0 |
| P-9 #95 | 5.7 | 1.5 | 0.63 |
| P-9 #97 | 2.1 | 1.3 | 0 |
| P-9 #98 | 1.4 | 1.3 | 0 |
| Average | 5.1 | 1.6 | 0.1 |
| ST DEV | 4.7 | 0.9 | 0.5 |
| 95th Conf | 14.4 | 3.4 | 1.0 |

| Background Surface Soil Samples | | | |
|---|---|---|---|
| Location | Th-230 pCi/g | Ra-226 pCi/g | U-Total pCi/g |
| Z-12 | 3.47 | 3.14 | 1.12 |
| Z-12-SE | 4.65 | 4.66 | 1.32 |
| Z-13-SE | 2.11 | 2.11 | 0.72 |
| Z-14-SE | 12.2 | 12.8 | 4.96 |
| Z-15 | 7.05 | 5.96 | 2.35 |
| Z-15-SE | 11.5 | 7.56 | 2.44 |
| Z-16-SE | | | |
| Z-17-SE | 7.3 | 5.18 | 1.48 |
| Z-9 | 1.71 | 2.33 | 0.87 |
| Average | 5.1 | 3.6 | 1.9 |
| ST DEV | 5.3 | 2.9 | 3.4 |
| 95th Conf | 15.5 | 9.3 | 8.5 |


| | | | |
|---|---|---|---|
| Average | 5.1 | 3.6 | 1.9 |
| ST DEV | 5.3 | 2.9 | 3.4 |
| 95th Conf | 15.5 | 9.3 | 8.5 |

# 9.0 NON-RADIOLOGICAL HAZARDOUS CONSTITUENTS

Based on historical site operations and the available data, significant concentrations of non-radiological hazardous constituents are not expected to exist at the site. A small quantity of organic contaminated soils may be present within the mill area as a result of the solvent extraction circuit operation. This material is classified as byproduct material and will be disposed within the disposal area prior to construction of the radon attenuation barrier.

Completing the majority of the mill demolition in early 2004 allowed RAM to access the areas that were used as part of the solvent extraction circuit. A June 2005 characterization study identified the extent of the organic contamination present within the mill site. The investigation involved drilling and trench work throughout the mill yard and analysis of the materials suspected of containing organic materials. A total of 50 sampling points were investigated with samples collected for outside analysis in all holes indicating the presence of hydrocarbons through field measurements.

Based on the analytical results, soils estimated to be impacted in the mill SX area totaled approximately 6,500 cubic yards. The mill yard containment channel indicated hydrocarbon impacts and Rio estimates an additional 4000 cubic yards of soils may be impacted in this area. No impacts were observed in the maintenance and fueling areas. Site wide, RAM estimates that approximately 10,000 to 15,000 yards of soils will require excavation and treatment to reduce the organic levels in the soils.

RAM will utilize a combination of bioremediation processes and land farming/soil tilling on soils requiring remediation. Numerous products are commercially available to perform this bioremediation process. RAM will introduce microbes and/or nutrients to the soil and allow the microbial agents to convert or degrade the organic compounds into non-toxic substances such as carbon dioxide and water. The process will be monitored until organic concentrations fall below clean-up criteria.

RAM recognizes that organic contaminated soil may contain elevated concentrations of radionuclides. RAM will use in-situ soil characterization data (i.e. borehole sampling) from the mill site characterization study to determine whether soil contaminated by organics should be classified as byproduct material (i.e. soils will not be classified based on radionuclide concentrations after land-farming is completed, which would be less conservative). Soils classified as containing by-product material will be disposed of on-site. Based on the location

of organic contaminated soils, Rio anticipates that all soils will be categorized as byproduct material.

The distribution of heavy metals in soils at the facility is directly correlated to the distribution of radiological constituents. To ensure that heavy metals are being adequately remediated, RAM will collect four composite verification samples per pond to be analyzed for heavy metal concentrations. RAM will also collect additional discrete soil samples in areas where visual evidence of contamination exists (i.e. damp or stained areas), which will be analyzed for heavy metal concentrations.

Nonetheless, various control measures are in place to ensure that such hazards are addressed. For example, RAM has submitted applications for Alternate Concentration Limits (ACLs) to the NRC that address non-radiological constituents in groundwater. RAM also possesses EPA NPDES discharge permits designed to minimize the impacts of non-radiological constituents to surface water. Finally, the area of the site transferred to the U.S. Department of Energy and subject to long–term monitoring and surveillance will possess controls (i.e. fencing, signage) designed to limit public access and prevent exposure to any non-radiological constituent.

# 10.0 DECOMMISSIONING COST ESTIMATE AND SURETY FUND

The following decommissioning cost estimate and surety fund information is based primarily upon RAM's surety renewal estimate provided to the NRC in June 2004. RAM will be revising this cost estimate as requested by the NRC in their July 28, 2004 RAI. A summary of the estimated soil decommissioning cost is provided in Table 10-1.

## 10.1 EVAPORATION PONDS

This section describes the current status and costs associated with all of the lined and unlined evaporation ponds at the site. Soil decommissioning costs for the evaporation ponds are summarized in Table 10-1.

### 10.1.1 UNLINED EVAPORATION PONDS

These ponds operated from 1957 until the early 1980's as the primary liquid effluent disposal areas for the mill. After dewatering, these ponds were excavated to remove the primary Ra-226 contamination. Characterization data indicate that there is deeper contamination of Th-230 that exceed safe excavation depth. These ponds have been closed and backfilled to grade to prevent any windblown contamination from the pond bottoms. The intent is to close these ponds using alternate release criteria within the site LTSM boundary. The status and soil decommissioning costs for the unlined ponds are summarized below:

- Pond 4 – Four to five feet of pond soils have been excavated and disposed into the Pond 3 disposal area. The pond has been backfilled to grade with soils obtained from the borrow area. The work unit cost estimates remaining are the labor and equipment costs, radiation safety, and revegetation expenses to complete the final contour and stabilize the surface.

- Pond 5 – Four to five feet of pond soils have been excavated and disposed into the Pond 3 disposal area. The pond has been backfilled to grade with soils obtained from the borrow area. The work unit cost estimates remaining are the labor and equipment costs, radiation safety, and revegetation expenses to complete the final contour and stabilize the surface.

- Pond 6 – Four to five feet of pond soils have been excavated and disposed into the Pond 3 disposal area. The pond has been backfilled to grade with soils obtained from the borrow

area. The work unit cost estimates remaining are the labor and equipment costs, radiation safety, and revegetation expenses to complete the final contour and stabilize the surface.

- Pond 7 – Excavation has been completed, and the surface has been re-contoured to grade, mulched and seeded. The work unit cost remaining covers any future reseeding and radiation surveys for final characterization.
- Pond 8 - Excavation has been completed, and the surface has been re-contoured to grade, mulched and seeded. The work unit cost remaining covers any future re-seeding and radiation surveys for final characterization
- Reclamation of Soil Borrow Areas – The locations of the borrow sites will be reclaimed, top-soil placed, and re-vegetated. There are two principle soil borrow areas. One to the north on Section 30 and one to the east of Pond 8.

### 10.1.2 LINED EVAPORATION PONDS

This section covers the lined evaporation ponds that are located near the tailings disposal areas, Pond 9, and the former Pond 10. Also included are the costs associated with the closure of the interceptor trench system associated with the groundwater corrective action program. The status and soil decommissioning costs of these items are summarized below:

- Pond 9 – This active disposal area was used almost exclusively for handling groundwater captured through the interceptor trench system. The plan for closure of Pond 9 includes the dewatering of the sediments, removal of the liner and sediments, and placement of these materials at the base of the main intercept trench. Costs associated with this work include the clean-up of contaminated soils, contouring of the former pond area, radiation safety, soil sampling, QA/QC, and revegetation.
- Pond 10 – This former lined evaporation pond has been reclaimed, and the work unit costs are associated with the characterization of the soils, additional cleanup of hot spots, contouring, radiation safety, and revegetation.

## 10.2 WINDBLOWN AND TAILINGS-CONTAMINATED MATERIAL

This section describes the current status and costs associated with windblown and tailings-contaminated materials at the site. These areas are located north, south and east of the tailings areas and the areas adjacent to the unlined and lined evaporation ponds (**Figure 1-3**). The

status and soil decommissioning costs associated with these areas are summarized below and in Table 10-1:

- Section 30 area – Complete.
- Section 5 area – Complete.
- Section 32 and area north of Pond 9 – Complete.
- Windblown areas – Re-surveys of previously released areas and areas re-contaminated by recent activities (i.e. windblown sediments from unlined ponds). This also includes the work for the development of background conditions and release levels. Cost includes labor and equipment, radiation safety, surveys, sampling, and QA/QC.
- Areas immediately north and east of Impoundment 1 – These areas are currently too wet to cleanup as a result of ongoing licensed activities (i.e. groundwater CAP surface discharges). The costs associated with this work include labor and equipment, radiation surveys, disposal, re contouring to grade.
- Soil verification – Gamma surveys and confirmatory soil sampling of prior cleanup. Costs include labor and equipment to conduct gamma surveys, sampling, and QA/QC.
- Revegetation of disturbed areas – Upon completion of the cleanup and verification, the disturbed areas will be re-vegetated. Costs include labor and equipment, mulch, seed and verification.

## 10.3 MILL DECOMMISSIONING

This work includes the cost to demolish the mill and associated buildings and dispose of the residual material into the designated disposal areas. Costs are based on contractor quotes obtained in 2005 to conduct the work. The initial soil decommissioning costs associated with the mill are summarized in Table 10-1 and do not include any salvage value. Annual updates to cost estimates for remaining elements of the site decommissioning requirements are provided to the NRC as required by License Condition 22 of SUA-1473.

## 10.4 OTHER COSTS

Other costs associated with soil decommissioning include site management, overhead and profit, and contingency margin. These costs are summarized in Table 10-1 and include the following:

- Site management – Estimated cost for the administration of the reclamation program at the site. Based on actual costs for the site.
- Overhead and profit – Contractor overhead and profit estimated at 10% of labor and expenses.
- Contingency – Estimated at 15% of all costs.

As discussed above, the cost estimates provided in Table 10-1 are the initial estimates for site decommissioning. Annual updates to cost estimates for remaining elements of the site decommissioning requirements, including other costs, are provided to the NRC as required by License Condition 22 of SUA-1473.

## Table 10-1. Soil Decommissioning Cost Estimate.

| | | | WORK UNIT | Estimated Cost ($000) |
|---|---|---|---|---|
| | | | | |
| A | | | **EVAPORATION PONDS** | |
| | 1 | | **Contour and/or Cover Unlined Ponds** | |
| | | a | Pond 4 (final contour and re-seeding) | 67 |
| | | b | Pond 5 (final contour and re-seeding) | 66 |
| | | c | Pond 6 (final contour and re-seeding) | 66 |
| | | d | Pond 7 (re-seeding) | 12 |
| | | e | Pond 8 (re-seeding) | 13 |
| | | f | Reclamation of Soil Borrow Sites | 140 |
| | | | Un-Lined Evaporation Ponds Sub-Total | 364 |
| | 2 | | **Lined Ponds** | |
| | | a | Pond 9 | 585 |
| | | b | Pond 10 | 40 |
| | | | Lined Evaporation Ponds Closure | 625 |
| | | | | |
| | 3 | | **Section 4 Ponds (Lined Evaporation Ponds 11-21)** | |
| | | c | Contaminated Soil Cleanup | 902 |
| | | f | Placement and contouring | 104 |
| | | g | Revegetation | 236 |
| | | | Section 4 Ponds Sub-Total | 1,242 |
| | | | | |
| | | | **SUB-TOTAL (Evaporation Ponds)** | **2,231** |
| | | | | |
| B | | | **Clean Up Tailings Contaminated and Windblown Material** | |
| | 1 | | Section 30 Area | Complete |
| | 2 | | Section 5 Area | Complete |
| | 3 | | Sec. 32 & Area N. of Pond 9 | Complete |
| | 4 | | Additional Survey | 100 |
| | 5 | | Area N. and E of Pond 1 | 100 |
| | 6 | | Soils verification | 115 |
| | 7 | | Re-vegetation of disturbed areas | 150 |
| | | | **SUB-TOTAL (Windblown)** | **465** |
| | | | | |
| C | | | **Mill Decommissioning** | |
| | 1 | | Soils Cleanup and verification | 100 |
| | 2 | | Contouring and vegetation | 200 |
| | | | **SUB-TOTAL (Mill Decommissioning)** | **300** |

**Table 10-1. Soil Decommissioning Cost Estimate.**

| | | | WORK UNIT | Estimated Cost ($000) |
|---|---|---|---|---|
| D | | | **Site Management** | **1,352** |
| | | | | |
| | | | **Subtotal Direct Costs - Soil Decommissioning** | **4,348** |
| | | | | |
| E | | | **Overhead and Profit at 10%** | **300** |
| F | | | **Contingency at 15%** | **697** |
| | | | **Total Closure Costs** | **5,345** |

# APPENDIX A

# COMPACT DISK CONTAINING SITE SOILS DATABASE

## APPENDIX B

# RADIUM BENCHMARK DOSE AND SENSITIVITY ANALYSIS

# DEVELOPMENT OF RADIUM BENCHMARK DOSE

Radioactive materials have been processed, used, and/or stored at RAM Ambrosia Lake facility ("the site") since 1958. Some soils on site are contaminated with radioactive material. The technical criteria for clean-up of contaminated soil are provided in 10 CFR 40[12]. The technical criteria may be summarized as: 1) the concentration of radium-226 in surface soil does not exceed the background concentration by more than 5 pCi/g; and 2) concentrations of radionuclides other than radium-226 in soil must not result in a total effective dose equivalent (TEDE) exceeding the dose from clean-up 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 radium benchmark dose. Exposure pathway modeling is an analysis of various exposure pathways of a given exposure scenario used to convert concentration of radioactive material in the source media into dose to a receptor.

The exposure pathway modeling completed here was a deterministic analysis of the peak annual dose to the average member of the critical group for a rancher exposure scenario. The radium benchmark dose 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.

## SCOPE OF RADIUM BENCHMARK DOSE

The radium benchmark dose was developed in particular for the case of license termination. The radium benchmark dose was developed without consideration of any institutional controls. Therefore, 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 radium benchmark dose was completed solely with respect to dose received due to pathways related to residual radioactive material in surface soil. There were several pathways not included in the development of the radium benchmark dose. Some

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

pathways were not included because they are not applicable; i.e. drinking water. Other pathways were not included because they cannot be considered directly by the conceptual model applied to develop the radium benchmark dose; i.e., exposure rate from the disposal cell. These and other pathway exceptions are discussed in a following section of this Appendix.

**Figure 1-3** of the Soil Decommissioning Plan shows the area to which the radium benchmark dose is applicable (surface soil contamination).

## 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 benchmark dose. The CoCs were determined to be radium-226 and lead-210.[13]

The source term is assumed to be uncovered contaminated soil of cylindrical shape. **Figure B-1** depicts the soil zones. The contaminated soil is modeled as a 0.15-meter thick zone of unconsolidated soil. The contaminated soil is underlain by one uncontaminated unsaturated soil zone; this zone is modeled as an 8-meter thick zone of alluvium (unconsolidated soil). The next zone is an uncontaminated saturated zone; this zone is modeled as the uppermost bedrock and is independent of thickness.

### RESIDUAL RADIOACTIVITY

The CoCs are assumed homogenously distributed within the contaminated soil at concentrations of 5 pCi/g for each of Ra-226 and Pb-210.

[13] 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. Revision 1. NUREG-1620. June 2003. (sections H2.1.1 & H2.1.3(2)(b))

### CHEMICAL FORM

In an effort to quantify the mobility of the CoCs in soil at the site, a distribution coefficient ($K_d$) was selected for each of the soil units in the model. Description of the selection and application of each $K_d$ is provided Attachment 1 of this Appendix.

## CRITICAL GROUP, SCENARIO, AND PATHWAYS IDENTIFICATION AND SELECTION

### SCENARIO IDENTIFICATION

The exposure scenario applied here may be described as representing a local rancher. The rancher scenario accounts for exposure involving residual radioactivity that is initially in the surface soil. A rancher periodically is present on the site and retrieves some of his diet from the site. The scenario assumes no disturbance of the disposal cell (this qualification is discussed later). The scenario is based on reasonable assumptions that tend to underestimate potential dose.

### CRITICAL GROUP DETERMINATION

The average member of the critical group is the rancher. 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
- Ingestion of animal products grown onsite using feed and surface water from potentially contaminated sources.

The exposure pathways selected for evaluation are listed in **Table B-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

Potential utilization of groundwater in the Ambrosia Lake area can be divided into two categories: (1) irrigation and (2) domestic/stock watering. Neither irrigation nor domestic stock watering wells in the vicinity of the site are completed in the uppermost bedrock units. The uppermost bedrock units in the vicinity of the tailings impoundment are not capable of providing sufficient water for use because these bedrock units have been essentially dewatered downgradient of the Facility due to drainage by the numerous vent holes and mine shafts, and reduced seepage from tailings following reclamation. Historically, groundwater supply wells were not completed in the uppermost bedrock hydrogeologic units in the vicinity of the Facility because these units were only partially saturated in this location near the outcrop.[14]

Neither irrigation nor domestic stock watering wells in the vicinity of the site are competed in the Alluvium. The Alluvium is not capable of providing sufficient water for use because it is not saturated anywhere except in the vicinity of the site and the U.S. DOE tailings impoundment. Groundwater corrective action compliance and license termination was obtained by the DOE at the Ambrosia Lake site through the application of Supplemental Standards, demonstrating that the Alluvium is not, and never was, an aquifer because of limited yield.[15]

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[14] "Corrective Action Program and Alternate Concentration Limits Petition for Uppermost Bedrock Units, Ambrosia Lake Uranium Mill Facility Near Grants, New Mexico", prepared for Quivera Mining Company by AVM Environmental Services, Inc. and Applied Hydrology Associates Inc., February 15, 2000.

[15] "Application for Alternate Concentration Limits in the Alluvial Materials at the Quivera Mill Facility Ambrosia Lake, New Mexico", prepared for Quivera Mining Company by MAXIM Technologies Inc., May 2001.

Localized areas of groundwater at the Site have been created by recharge from existing surface sources or man-made subsurface reservoirs such as utility trenches and foundation backfill areas. Once these features are removed during reclamation, these groundwater sources will disappear, thereby precluding any water pathways.

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

### *Cell Intrusion*

Development of the radium benchmark dose did not consider failure of the cell's engineered cover system. Inadvertent intrusion into the cell is very unlikely. Because the outermost layer of the cover system is rip-rap (i.e. not a vegetative cover), it is not reasonable to assume it a surface conducive to placement of a structure. 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.[16]

Deliberate intrusion into the cell was not considered during development of the radium benchmark dose. 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.[17]

### *Radon*

The radon pathway was not considered because it is specifically excluded from the scope of the technical criteria.[18]

## CONCEPTUAL MODEL

The conceptual model used to evaluate the previously described exposure scenario and pathways was the RESRAD[19] computer code version 6.21. RESRAD was developed, in part, to

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

[17] NUREG-0945, page 4-13

[18] 10 CFR 40, Appendix A, Criterion 6 (6)

[19] 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.

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.[20]

RESRAD models external exposure from volume sources when the individual is outside, using volume dose rate factors. 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 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

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

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 rancher spends 45% of the time indoors on site, 20% of the time outdoors on site, and 35% of the time away from the site.[21] Food production is assumed to occur in the contaminated area: 5% of the resident's vegetable, grain, and fruit diet assumed produced from the contaminated area; 5% of the resident's meat diet is assumed produced from the contaminated area.[8] Neither milk nor aquatic food is included in the rancher's diet.[8] Dust levels represent ambient suspension of soil particles in air.

Vegetables, fruits, and grains are not irrigated with water from the contaminated area. Some contaminated water is used for watering livestock on site. The rancher's drinking water is assumed from an uncontaminated potable water system or uncontaminated surface water.

The walls, foundation, and floor of the resident's house reduce external exposure by 21%.[22] Indoor dust level in air is assumed to be 56% of the outdoor dust level.[23]

The parameters, associated inputs, and rationale for value, are included in **Table B-2**. Attachment 1 of this Appendix provides description of the rationale for the value of each parameter.

## SENSITIVITY ANALYSIS

The results of the sensitivity analysis of the benchmark dose are provided in Attachment 2 of this Appendix. The radium benchmark dose was not found to be significantly sensitive to any exposure pathway parameters.

## RADIUM BENCHMARK DOSE (APPLICATION OF THE EXPOSURE SCENARIO)

The exposure scenario with associated model and inputs described above were applied to a soil concentration of 5.0 pCi/g radium-226 with 5 pCi/g lead-210.[24] The resulting dose, i.e. the radium benchmark dose, to the rancher was 18 millirem per year (mrem/y).

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

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[21] SECY 98 084, Attachment 3, Table 2.

[22] NUREG-6697, Attachment C, Table 7.10-1

[23] NUREG-6697, Attachment C, Table 7.1-2

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

**Table B-1: Rancher Scenario Exposure Pathway Selections[1]**

| PATHWAY[2] | USER SELECTION |
|---|---|
| External Gamma | Active |
| Inhalation (w/o radon) | Active |
| Plant Ingestion | Active |
| Meat Ingestion | Active |
| Milk Ingestion | Suppressed |
| Aquatic Foods | Suppressed |
| Drinking Water | Suppressed |
| Soil Ingestion | Active |
| Radon | Suppressed |

1 NUREG-1620, Section H2.1.3(2)(a)

2 These pathways match those available from the conceptual model used in the dose assessment; i.e. RESRAD version 6.21.

## Table B-2: Rancher Scenario Model Selected Values

| Parameter | Input | Background Information |
|---|---|---|
| **Source** | | |
| 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) | 1 | Site-specific estimate: see Attachment 1. |
| Unsaturated zone 1 (cm**3/g) | 1 | Site-specific estimate: see Attachment 1. |
| Saturated zone (cm**3/g) | 90 | Site-specific estimate: see Attachment 1. |
| Time since material placement (yr) | 0 | RESRAD default |
| Groundwater concentration (pCi/L) | -- | Not available; reflects use 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) | 1 | Site-specific estimate: see Attachment 1. |
| Unsaturated zone 1 (cm**3/g) | 1 | Site-specific estimate: see Attachment 1. |
| Saturated zone (cm**3/g) | 90 | Site-specific estimate: see Attachment 1. |
| Time since material placement (yr) | 0 | RESRAD default |
| Groundwater concentration (pCi/L) | -- | Not available; reflects use 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) | 25 | RESRAD default |
| Times for Calculations (years) | 0 | 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) | 1214040 | Estimate from NRC evaluation[3] (consistent with site specific estimate). |
| Thickness of contaminated zone (m) | 0.15 | Site-specific estimate: see Attachment 1. |
| Length parallel to aquifer flow (m) | 622 | Diameter of circle of area equal contaminated zone. |
| **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) | 1.5 | Site-specific estimate: see Attachment 1. |
| Contaminated zone erosion rate (m/yr) | 1 E-05 | Estimate from NRC evaluation.[3] |

| Parameter | Input | Background Information |
|---|---|---|
| Contaminated zone total porosity | 0.20 | Site-specific estimate: see Attachment 1. |
| Contaminated zone field capacity | 0.05 | Site-specific estimate: see Attachment 1. |
| Contaminated zone hydraulic conductivity (m/yr) | 2002 | Site-specific estimate: see Attachment 1. |
| Contaminated zone b parameter | 1 | Estimate for sand from RESRAD guidance.[2] |
| | | |
| Humidity in air (g/cm**3) | -- | Not available; reflects absence of radon pathway.[1] |
| Evapotranspiration coefficient | 0.9 | Estimate from NRC evaluation.[3] |
| Wind Speed (m/sec) | 3.9 | Site-specific estimate: see Attachment 1. |
| Precipitation (m/yr) | 0.266 | Site-specific estimate: see Attachment 1. |
| Irrigation (m/yr) | 0 | Assumed site condition. |
| 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) | 1.56 E+08 | Site-specific estimate: see Attachment 2. |
| Accuracy for water/soil computations | 0.001 | RESRAD default |
| | | |
| **Saturated Zone Hydrological Data** | | |
| Density of saturated zone (g/cm**3) | 2.4 | Site-specific estimate: see Attachment 1. |
| Saturated zone total porosity | 0.08 | Site-specific estimate: see Attachment 1. |
| Saturated zone effective porosity | 0.04 | Site-specific estimate: see Attachment 1. |
| Saturated zone field capacity | 0.04 | Site-specific estimate: see Attachment 1. |
| Saturated zone hydraulic conductivity (m/yr) | 67 | Site-specific estimate: see Attachment 1. |
| Saturated zone hydraulic gradient | 0.04 | Site-specific estimate: see Attachment 1. |
| Saturated zone b parameter | 1 | Estimate sand from RESRAD guidance.[2] |
| Water table drop rate (m/yr) | 1 | Assume recharge from mine water stops after reclamation. |
| 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 | 1 | Site-specific condition. |
| Unsaturated Zone 1, Thickness (m) | 8 | Site-specific estimate; see Attachment 1. |
| Unsaturated Zone 1, Density (g/cm**3) | 1.5 | Site-specific estimate; see Attachment 1. |
| Unsaturated Zone 1, Total Porosity | 0.20 | Site-specific estimate; see Attachment 1. |
| Unsaturated Zone 1, Effective Porosity | 0.15 | Site-specific estimate; see Attachment 1. |
| Unsaturated Zone 1, Field Capacity | 0.05 | Site-specific estimate; see Attachment 1. |
| Unsaturated Zone 1, Hydraulic Conductivity (m/yr) | 2002 | Site-specific estimate; see Attachment 1. |
| Unsaturated Zone 1, b Parameter | 1 | Estimate for sand from RESRAD guidance.[2] |
| | | |

| Parameter | 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) | 0.0001 | RESRAD default. |
| 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 | 0.45 | Estimate from NRC evaluation.[3] |
| Outdoor time fraction | 0.20 | Estimate from NRC evaluation.[3] |
| 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) | -- | Not available; reflects absence of milk pathway.[1] |
| Meat and poultry consumption (kg/yr) | 63 | RESRAD default. |
| Fish consumption (kg/yr) | -- | Not available; reflects absence of aquatic pathway.[1] |
| Other seafood consumption | -- | Not available; reflects absence of aquatic pathway.[1] |
| Soil ingestion (g/yr) | 36.5 | RESRAD default. |
| 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 surface water. |
| Contaminated fraction Aquatic food | -- | Not available; reflects absence of aquatic pathway.[1] |
| Contaminated fraction Plant food | 0.05 | Estimate from NRC evaluation.[3] |
| Contaminated fraction Meat | 0.05 | Estimate from NRC evaluation.[3] |
| Contaminated fraction Milk | -- | Not available; reflects absence of milk pathway.[1] |
| | | |
| **Ingestion Pathway, Nondietary Data** | | |
| Livestock fodder intake for meat (kg/day) | 68 | RESRAD default |
| Livestock fodder intake for milk (kg/day) | -- | Not available; reflects absence of milk pathway.[1] |
| Livestock water intake for meat (L/day) | 50 | RESRAD default |
| Livestock water intake for milk (L/day) | -- | Not available; reflects absence of milk pathway.[1] |
| Livestock soil intake (kg/day) | 0.5 | RESRAD default |
| | | |
| Mass loading for foliar deposition (g/m**3) | 1 E-04 | RESRAD default |
| Depth of soil mixing layer (m) | 0.15 | RESRAD default |
| Depth of roots (m) | 0.3 | Estimate from NRC evaluation.[3] |
| | | |
| 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] |

| Parameter | Input | Background Information |
|---|---|---|
| Groundwater Fractional Usage Livestock water | 0 | Reflects the absence of groundwater usage; i.e. *well pumping rate* equal zero. |
| Groundwater Fractional Usage Irrigation water | 0 | Reflects the absence of groundwater usage; i.e. *well pumping rate* equal zero. |
| | | |
| **Plant Factors** | | |
| Wet weight crop yield for Non-Leafy (kg/m**2) | 0.7 | RESRAD default |
| 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 | 20 | RESRAD default |
| Wet foliar interception fraction for Non-Leafy | 0.25 | RESRAD default |
| Wet foliar interception fraction for leafy | 0.25 | RESRAD default |
| 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 |
| 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 U.S. Nuclear Regulatory Commission, Commission Paper SECY 98 084, "Status of Efforts to Finalize Regulations for Radiological Criteria for License Termination: Uranium Recovery Facilities", April 15, 1998.

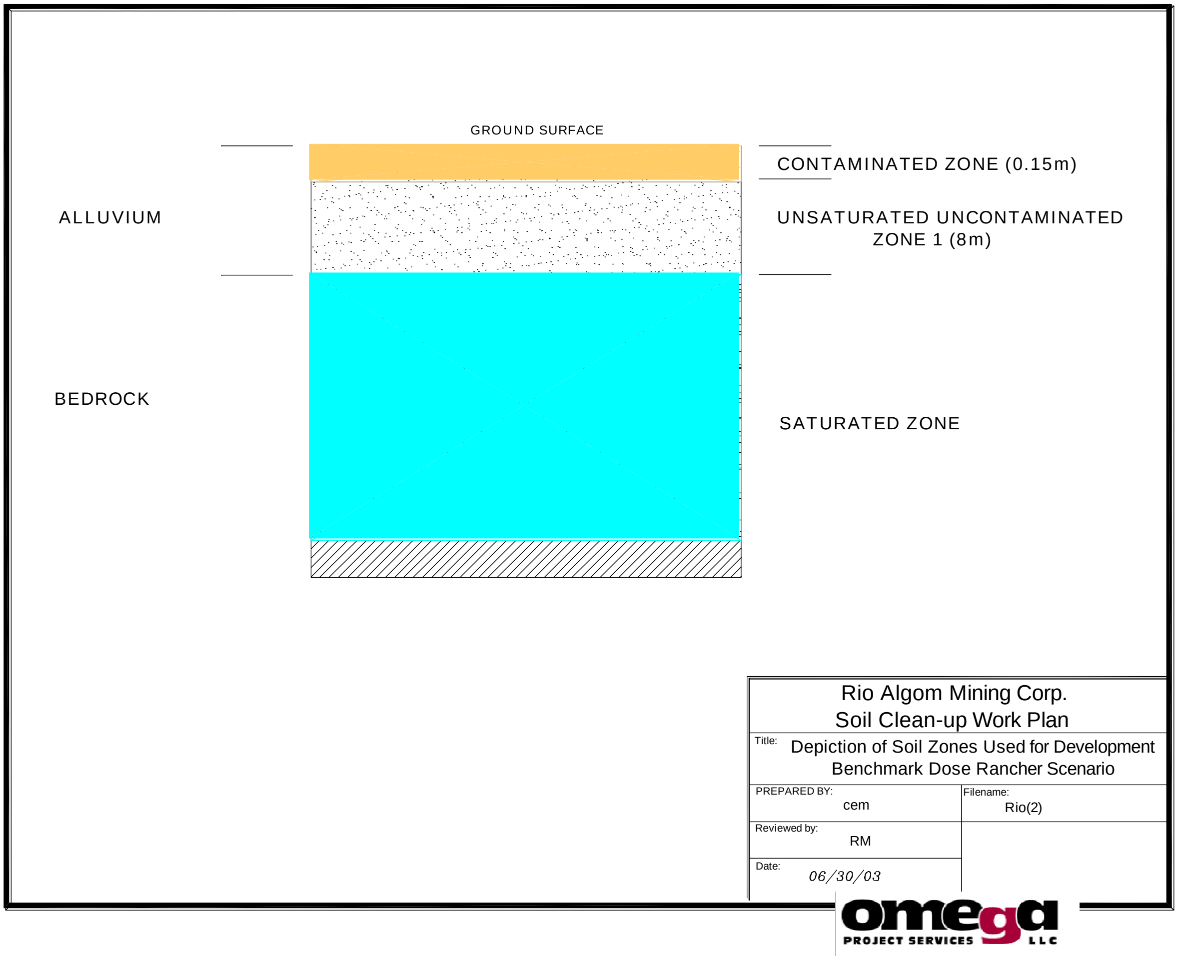


**Figure B-1. Soil Zones Used for Development of Radium Benchmark Dose Calculation**

# ATTACHMENT 1 (APPENDIX B)

# JUSTIFICATION OF PARAMETER VALUES FOR DEVELOPMENT OF RADIUM BENCHMARK DOSE

# INTRODUCTION

The following text provides the justification for the value chosen for each RESRAD parameter that required an input for development of the radium benchmark dose under a rancher 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 ($K_d$) describes the portioning of elements or compounds (radioactive material) in a soil column between the solid (soil) and liquid (groundwater). Distribution coefficient is not a function of isotope (i.e. mass or specific activity) therefore a distribution coefficient was determined or chosen only with respect to the element and soil zone.

### Radium-226

A site-specific distribution coefficient has been estimated here from a retardation factor provided elsewhere for uranium,[25,26] and from the *unsaturated zone 1 density* and *unsaturated zone 1 effective porosity* provided below. The distribution coefficients estimated here are rounded to one significant figure.

The value used in the dose assessment for the distribution coefficient of radium is 1 $cm^3/g$ for the *contaminated zone* and *unsaturated zone 1* (alluvium).

The value used in the dose assessment for the distribution coefficient of radium is 90 $cm^3/g$ for the *saturated zone* (uppermost bedrock).

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[25] "Corrective Action Program and Alternate Concentration Limits Petition for Uppermost Bedrock Units, Ambrosia Lake Uranium Mill Facility Near Grants, New Mexico", prepared for Quivera Mining Company by AVM Environmental Services, Inc. and Applied Hydrology Associates Inc., February 15, 2000. (Table 2-7)

[26] Rio Algom Mining Company, draft Response to Request for Additional Information, ["Corrective Action Program and Alternate Concentration Limits Petition for Uppermost Bedrock Units, Ambrosia Lake Uranium Mill Facility Near Grants, New Mexico and Application for Alternate Concentration Limits in the Alluvial Materials at the Quivera Mill Facility Ambrosia Lake, New Mexico"], March 25, 2003. (Response to Comments B.1 and B.2)

### Lead

A site-specific distribution coefficient has been chosen from the distribution coefficient estimated for uranium.[4,5]

The value used in the dose assessment for the distribution coefficient of lead is 1 $cm^3/g$ for the *contaminated zone* and *unsaturated zone 1* (alluvium).

The value used in the dose assessment for the distribution coefficient of lead is 90 $cm^3/g$ for the *saturated zone* (uppermost bedrock).

## TIME SINCE MATERIAL PLACEMENT (Y)

This parameter describes the duration between the placement of radioactive material in soil (contamination) and the performance of a radiological survey. This value is not applicable when transport distribution coefficients are available[27] as they are in this case.

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.

## GROUNDWATER CONCENTRATION (pCi/L)

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.[28] This parameter is not available in this case since *time since material placement* is zero.

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

## 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

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[27] 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)

[28] 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 33.2)

coefficient based on the input. This parameter is not applicable because a transport distribution coefficient is directly input to the model[29].

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.[30]

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 applicable value is the benchmark dose that is being derived here. The value supplied here does not impact the calculation of the benchmark dose.

The value used in the dose assessment for the basic radiation dose limit is the RESRAD default value.

### 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.

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[29] 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)

[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 34.2)

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

## CONTAMINATED ZONE PARAMETERS

### AREA OF CONTAMINATED ZONE ($M^2$)

This area is surface soils at the site that have been contaminated by windblown tailings from the tailings pile. This area contains the locations with radionuclide concentrations in soil clearly above background. The area does not include the mill area, the tailings pile, or the evaporation ponds. The size of this area reflects the reasonable estimate of an area that might be inhabited.[31]

The value used in the dose assessment for the area of the contaminated zone is 1214040 $m^2$ (300 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 value selected for this parameter represents an average thickness of the contaminated soil layer that will exist in the *area of contaminated zone* following reclamation.

The value used in the dose assessment for the thickness of the contaminated zone is 0.15 meters (0.5 foot).

### 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 300 acres, the *area of contaminated zone*. It is intended to represent the condition that there will be a large area of contaminated

[31] U.S. Nuclear Regulatory Commission, Commission Paper SECY 98 084, "Status of Efforts to Finalize Regulations for Radiological Criteria for License Termination: Uranium Recovery Facilities", April 15, 1998. (Attachment 3, Table 1)

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 622 meters.

## 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 site, 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 meter.

### 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 (i.e. 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 estimated from RESRAD guidance for the alluvium, a typical unconsolidated sand or silty sand.[32]

The value used in the dose assessment for density of the contaminated zone is 1.5 $g/cm^3$.

## 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 (i.e. running water, wind). The value for this parameter is chosen from an evaluation suggesting an erosion rate for the rancher scenario[33].

The value used in the dose assessment for erosion rate of the contaminated zone is 0.00001 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 taken from site-specific geotechnical information for the alluvium.[34]

The value used in the dose assessment for total porosity of the contaminated zone is 0.2.

## CONTAMINATED ZONE FIELD CAPACITY (DIMENSIONLESS)

Field capacity is the volumetric moisture content of soil at which (free) gravity drainage ceases. This is the amount of moisture that will be retained in a column of soil against the force of gravity. The field capacity is used as the lower bound of the moisture content in the soil layer.

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[32] 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 3.1)

[33] U.S. Nuclear Regulatory Commission, Commission Paper SECY 98 084, "Status of Efforts to Finalize Regulations for Radiological Criteria for License Termination: Uranium Recovery Facilities", April 15, 1998. (Attachment 3, Table 1)

[34] "Application for Alternate Concentration Limits in the Alluvial Materials at the Quivera Mill Facility Ambrosia Lake, New Mexico", prepared for Quivera Mining Company by MAXIM Technologies Inc., May 2001. (Section 2.2.3.2)

The field capacity of the alluvium is estimated as the difference between the *contaminated zone total porosity* and the *unsaturated zone 1 effective porosity*.

The value used in the dose assessment for field capacity of the contaminated zone is 0.05.

## 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 hydraulic conductivity.[35] The value for this parameter is an estimate for the alluvium from site-specific geotechnical information.[36]

The value used in the dose assessment for hydraulic conductivity of the contaminated zone is 2002 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 sand (i.e. alluvium) as an input for RESRAD.[37]

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

## HUMIDITY IN AIR (G/CM$^3$)

This parameter is used only for the computation of tritium concentration in air.[38] Since tritium is not a constituent of concern, this parameter is not applicable to the dose assessment.

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[35] 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)

[36] "Application for Alternate Concentration Limits in the Alluvial Materials at the Quivera Mill Facility Ambrosia Lake, New Mexico", prepared for Quivera Mining Company by MAXIM Technologies Inc., May 2001. (Section 2.2.3.2)

[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, Section 3.5)

[38] Yu, C., et. al. "Users Manual for RESRAD Version 6", Argonne, IL: Argonne National Laboratory. ANL/EAD-4. July 2001. (Section 4.4.6)

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

## 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 chosen from an evaluation suggesting an evapotranspiration coefficient for the rancher scenario .[39]

The value used in the dose assessment for evapotranspiration coefficient is 0.9.

## WIND SPEED (M/S)

This value is the average wind speed for a one-year period. The value used here is a ten-year annual average from a local monitoring station.[40]

The value used in the dose assessment for wind speed is 3.9 meters per second.

## PRECIPITATION (M/Y)

This value is the average rainfall for a one-year period. The value used here is an almost 50-year annual average from a local monitoring station.[41]

The value used in the dose assessment for precipitation is 0.266 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 for this parameter is chosen from an evaluation suggesting an irrigation rate for the rancher scenario .[42]

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[39] U.S. Nuclear Regulatory Commission, Commission Paper SECY 98 084, "Status of Efforts to Finalize Regulations for Radiological Criteria for License Termination: Uranium Recovery Facilities", April 15, 1998. (Attachment 3, Table 1)

[40] Western Regional Climate Center, Historical Climate Information, Average Wind Speeds by State, New Mexico, Grants Airport (www.wrcc.dri.edu)

[41] Western Regional Climate Center, Historical Climate Information, Western U.S. Historical Summaries, New Mexico, Grants Airport, Average Total Precipitation (www.wrcc.dri.edu)

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

## 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 site was made in accordance with the RESRAD guidance for "Rolling land …" and "Open sandy loam".[43]

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 watershed area is determined from site-specific information.[44]

The value used in the dose assessment for the watershed area is 1.56E+08 $m^2$.

## ACCURACY FOR WATER/SOIL COMPUTATIONS

The RESRAD default is used for this dose assessment.

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[42] U.S. Nuclear Regulatory Commission, Commission Paper SECY 98 084, "Status of Efforts to Finalize Regulations for Radiological Criteria for License Termination: Uranium Recovery Facilities", April 15, 1998. (Attachment 3, Table 1)

[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, Table 4.2-1)

[44] RAM

## SATURATED ZONE HYDROLOGICAL DATA

### DENSITY OF SATURATED ZONE (G/M$^3$)

This value describes the dry (bulk) density of the saturated zone. The bulk density of consolidated rock can be significantly higher than the same unconsolidated sediments. The estimated bulk density of a clean fine-medium sandstone (i.e. uppermost bedrock) is calculated from a solid quartz density of 2.65 g/cm3 and a total porosity of 0.08.

The value used in the dose assessment for density of the saturated zone is 2.4 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 a site-specific estimate for the saturated soils at the site.[45]

The value used in the dose assessment for total porosity of the saturated zone is 0.08.

### 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 an average for the uppermost bedrock from site-specific information.[46]

The value used in the dose assessment for effective porosity of the saturated zone is 0.04.

### SATURATED ZONE FIELD CAPACITY (DIMENSIONLESS)

Field capacity is the volumetric moisture content of soil at which (free) gravity drainage ceases. This is the amount of moisture that will be retained in a column of soil against the force of gravity. The field capacity is used as the lower bound of the moisture content in the soil layer.

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[45] "Corrective Action Program and Alternate Concentration Limits Petition for Uppermost Bedrock Units, Ambrosia Lake Uranium Mill Facility Near Grants, New Mexico", prepared for Quivera Mining Company by AVM Environmental Services, Inc. and Applied Hydrology Associates Inc., February 15, 2000. (page 2-26)

[46] "Corrective Action Program and Alternate Concentration Limits Petition for Uppermost Bedrock Units, Ambrosia Lake Uranium Mill Facility Near Grants, New Mexico", prepared for Quivera Mining Company by AVM Environmental Services, Inc. and Applied Hydrology Associates Inc., February 15, 2000. (page 2-26).

The field capacity of the uppermost bedrock is estimated as the difference between the *saturated zone total porosity* and the *saturated zone effective porosity*.

The value used in the dose assessment for field capacity of the saturated zone is 0.04.

## 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.[47] The value for this parameter is an average for the uppermost bedrock from site-specific information.[48]

The value used in the dose assessment for hydraulic conductivity of the saturated zone is 67 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 chosen from site-specific information.[49]

The value used in the dose assessment for hydraulic gradient of the saturated zone is 0.04.

## 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

[47] 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)

[48] "Corrective Action Program and Alternate Concentration Limits Petition for Uppermost Bedrock Units, Ambrosia Lake Uranium Mill Facility Near Grants, New Mexico", prepared for Quivera Mining Company by AVM Environmental Services, Inc. and Applied Hydrology Associates Inc., February 15, 2000. (page 2-26).

[49] "Corrective Action Program and Alternate Concentration Limits Petition for Uppermost Bedrock Units, Ambrosia Lake Uranium Mill Facility Near Grants, New Mexico", prepared for Quivera Mining Company by AVM Environmental Services, Inc. and Applied Hydrology Associates Inc., February 15, 2000. (page 2-26).

greater than zero.[50] The value used in the dose assessment is the mean value recommended for sand as an input for RESRAD.[51]

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

### 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 of the 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 a groundwater system that was initially created by anthropogenic charge but recharge is stopped after reclamation.

The value used in the dose assessment for water table drop rate is one m/y.

### 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.[52]

### 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 recommendation, based on the size of the contaminated area, is the nondispersion model.[53]

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[50] 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)

[51] 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)

[52] Yu, C., et. al. "Users Manual for RESRAD Version 6", Argonne, IL: Argonne National Laboratory. ANL/EAD-4. July 2001. (input screen message)

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. no withdrawal.

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

## 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 (i.e. saturated zone). The dose assessment here assumes one unsaturated zone: the uncontaminated alluvium overlying the uppermost bedrock.

### UNSATURATED ZONE 1, THICKNESS (M)

This parameter describes the thickness of the uncontaminated unsaturated soil below the *contaminated zone* and above the *saturated zone*. The value is an average thickness of soil in the *area of contaminated zone* minus the *thickness of the contaminated zone*. The selection of the subject thickness is an estimate from site specific information.

The value used in the dose assessment for thickness of unsaturated zone 1 is 8 meters.

### 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 1.5 g/$cm^3$.

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[53] Yu, C., et. al. "Users Manual for RESRAD Version 6", Argonne, IL: Argonne National Laboratory. ANL/EAD-4. July 2001. (Section E.3.1)

## 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 0.20.

## 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. The value for this parameter is an average for the alluvium from site-specific information.[54]

The value used in the dose assessment for effective porosity of the saturated zone is 0.15.

## UNSATURATED ZONE 1, FIELD CAPACITY (DIMENSIONLESS)

Field capacity is the volumetric moisture content of soil at which (free) gravity drainage ceases. This is the amount of moisture that will be retained in a column of soil against the force of gravity. The field capacity is used as the lower bound of the moisture content in the soil layer. This value is equivalent to that of the contaminated zone.

The value used in the dose assessment for field capacity of the unsaturated zone is 0.05.

## UNSATURATED ZONE 1, HYDRAULIC CONDUCTIVITY (M/Y)

This parameter measures a formation's ability to transmit water when subjected to a *hydraulic gradient*. This value is equivalent to that of the contaminated zone.

The value used in the dose assessment for hydraulic conductivity of the unsaturated zone 1 is 2002 m/y.

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[54] "Application for Alternate Concentration Limits in the Alluvial Materials at the Quivera Mill Facility Ambrosia Lake, New Mexico", prepared for Quivera Mining Company by MAXIM Technologies Inc., May 2001. (Section 2.2.3.2)

### UNSATURATED ZONE 1, B PARAMETER (DIMENSIONLESS)

The formation-specific b parameter is an empirical parameter used to evaluate the saturation ratio of the formation. This value is equivalent to that of the contaminated zone.

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

## 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 rancher.[55]

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

### MASS LOADING FOR INHALATION (G/$M^3$)

This parameter represents the concentration of soil particles in air.

The value used in the dose assessment for mass loading for inhalation is the RESRAD default of 0.0001 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 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

[55] 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). NUREG-1620. January 2002. (Section H2.1.3(2)(h))

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.[56]

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[57]; i.e. a reasonable guess (comparable to stucco 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.

### 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 for this parameter is chosen from an evaluation suggesting an indoor time fraction for the rancher scenario. [58]

The value used in the dose assessment for indoor time fraction is 0.45.

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[56] 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)

[57] 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)

[58] U.S. Nuclear Regulatory Commission, Commission Paper SECY 98 084, "Status of Efforts to Finalize Regulations for Radiological Criteria for License Termination: Uranium Recovery Facilities", April 15, 1998. (Attachment 3, Table 2)

## 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 for this parameter is chosen from an evaluation suggesting an outdoor time fraction for the rancher scenario.[59]

The value used in the dose assessment for outdoor time fraction is 0.2.

## 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 uncontaminated) consumed per year per individual. It is a composite value obtained by summing individual consumption rates for each of the food items.[60]

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

## LEAFY VEGETABLE CONSUMPTION (KG/Y)

This parameter describes the total quantity of this food item (contaminated and uncontaminated) consumed per year per individual. The value for this parameter was estimated to be 0.33 of a total vegetable consumption rate.[61]

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[59] U.S. Nuclear Regulatory Commission, Commission Paper SECY 98 084, "Status of Efforts to Finalize Regulations for Radiological Criteria for License Termination: Uranium Recovery Facilities", April 15, 1998. (Attachment 3, Table 2)

[60] 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)

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 milk pathway is not active in this dose assessment therefore this parameter is not available.[62]

The milk consumption rate is not used in the dose assessment.

### MEAT AND POULTRY CONSUMPTION (KG/Y)

This parameter describes the annual consumption of homegrown beef, poultry, and eggs. 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 aquatic pathway is not active in this dose assessment therefore this parameter is not available .[63]

The fish consumption rate is not used in the dose assessment.

### OTHER SEAFOOD CONSUMPTION

This parameter describes the annual average rate for consumption of nonfish seafood. The aquatic pathway is not active in this dose assessment therefore this parameter is not available .

The other seafood consumption rate is not used in the dose assessment.

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[61] 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)

[62] 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). NUREG-1620. January 2002. (Section H2.1.3(2)(a))

[63] 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). NUREG-1620. January 2002. (Section H2.1.3(2)(a))

### SOIL INGESTION (G/Y)

This parameter describes the accidental ingestion rate of soil from outdoor activities. The RESRAD default was chosen as the input.

The value used in the dose assessment for soil ingestion is 36.5 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 rate 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 pathway is not active therefore this parameter is not available.[64]

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

### 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 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 assumption that no irrigation occurs on site.

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

## CONTAMINATED FRACTION AQUATIC FOOD (DIMENSIONLESS)

This parameter specifies the fraction of *fish consumption* that is from sources on site and is assumed contaminated. The aquatic pathway is not active in this dose assessment therefore this parameter is not available .

The fish consumption rate is not used in the dose assessment.

## 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 for this parameter is chosen from an evaluation suggesting a contaminated fraction plant food for the rancher scenario.[65]

The value used in the dose assessment for contaminated fraction plant food is 0.05.

## 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

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[64] 10 CFR 40, Appendix A, Criterion 6(6)

[65] U.S. Nuclear Regulatory Commission, Commission Paper SECY 98 084, "Status of Efforts to Finalize Regulations for Radiological Criteria for License Termination: Uranium Recovery Facilities", April 15, 1998. (Attachment 3, Table 2)

uncontaminated. The value for this parameter is chosen from an evaluation suggesting a contaminated fraction meat for the rancher scenario.[66]

The value used in the dose assessment for contaminated fraction meat is 0.05.

### 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 milk pathway is not active in this dose assessment therefore this parameter is not available.

The contaminated fraction milk is not used in the dose assessment.

## 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 value used here is the RESRAD default.

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 milk pathway is not active in this dose assessment therefore this parameter is not available.

The livestock fodder intake for milk is not used in the dose assessment.

### LIVESTOCK WATER INTAKE FOR MEAT (L/D)

This is the daily intake of water for livestock kept for meat and poultry consumption. The value used here is the RESRAD default.

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

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[66] U.S. Nuclear Regulatory Commission, Commission Paper SECY 98 084, "Status of Efforts to Finalize Regulations for Radiological Criteria for License Termination: Uranium Recovery Facilities", April 15, 1998. (Attachment 3, Table 2)

### LIVESTOCK WATER INTAKE FOR MILK (KG/D)

This is the daily intake of water for livestock kept for *milk consumption*. The milk pathway is not active in this dose assessment therefore this parameter is not available.

The livestock water intake for milk is not used in the dose assessment.

### LIVESTOCK SOIL INTAKE (KG/D)

This is the daily intake of soil for livestock kept for *meat and poultry consumption* or *milk consumption*. The value used here is the RESRAD default.

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 value used here is the RESRAD default.

The value used in the dose assessment for mass loading for foliar deposition is 0.0001g/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 value used here is the RESRAD default.

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 value used here is from NRC guidance.[67]

The value used in the dose assessment for mass loading for depth of roots is 0.3 meter.

## 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 condition that there is no groundwater usage at the site (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 condition that there is no irrigation on site (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.

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[67] 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). NUREG-1620. January 2002. (Section H2.1.3(2)(j))

## 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. The value used here is the RESRAD default.

The value used in the dose assessment for wet weight crop yield for non-leafy vegetables is 0.7 kg/m2.

### 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 value used here is the RESRAD default.

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 value used here is the RESRAD default.

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 value used here is the RESRAD default.

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 uptake and water irrigation. The value used here is the RESRAD default.

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 value used here is the RESRAD default.

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 value used here is the RESRAD default.

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 value used here is the RESRAD default.

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 value used here is the RESRAD default.

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. The value used here is the RESRAD default.

The value used in the dose assessment for weathering removal constant for vegetation is 20.

### 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 value used here is the RESRAD default.

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. The value used here is the RESRAD default.

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

### 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 value used here is the RESRAD default.

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 value used here is the RESRAD default.

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

### 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 value used here is the RESRAD default.

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 value used here is the RESRAD default.

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

## ATTACHMENT 2 (APPENDIX B)

## SENSITIVITY ANALYSISOF RADIUM BENCHMARK DOSE

# SENSITIVITY ANALYSIS

## INTRODUCTION

To ensure that the radium benchmark dose described in Appendix B is unlikely to significantly overestimate potential dose, the analyses used a realistic scenario and conceptual model, and site-specific inputs or prudent estimates were used for key parameters. A sensitivity analysis of the benchmark dose was subsequently completed for which the primary objective was to identify input parameters that were major contributors to variation in the calculated dose.

The sensitivity analysis was 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 analysis was performed after completing the RESRAD calculations used to determine the radium benchmark dose. The sensitivity analysis was 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 radium benchmark dose described in Appendix B 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 B.2-1 through B.2-4**.

## DESCRIPTION

The sensitivity analysis of the rancher scenario was completed only for radium-226 since the benchmark concentrations are based directly on this radionuclide.

The RESRAD parameters available for input to evaluate the rancher scenario are listed in **Table B.2-1**. The parameters evaluated in the sensitivity analysis are marked accordingly in **Table B.2-1**.

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 B.2-2**.

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 (i.e. "Density of cover material"; there is no cover in the model), or the software did not allow a

sensitivity analysis of the parameter (i.e. "Plant Factors Wet weight crop yield"). The parameters not available to the RESRAD sensitivity analysis are listed in **Table B.2-3**.

## RESULTS

The results of the sensitivity analysis completed for the benchmark dose are summarized in **Table B.2-5**.

The results of the sensitivity analysis of the rancher scenario, as presented in the aforementioned tables, are discussed in the following sections. The sensitivity analysis did not indicate the change of any input value to cause the resulting dose to be less than the benchmark dose (18 mrem/y) by a significant amount (more than 25%; i.e. the dose was less than 13 mrem/y).

**Table B.2-1. Parameters of Rancher 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 field capacity | √ |
| | 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 field capacity | √ |
| | Saturated zone hydraulic conductivity | √ |
| | Saturated zone hydraulic gradient | √ |
| | Saturated zone b parameter | √ |
| | Water table drop rate | |
| | Well pump intake depth | |
| | Well pumping rate | |

**Table B.2-1 (continued). Parameters of Rancher 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 Field Capacity | |
| | 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 | √ |
| | Meat and poultry consumption | √ |
| | Soil ingestion | √ |
| | Contaminated fraction Livestock water | |
| | Contaminated fraction Irrigation water | |
| | Contaminated fraction Plant food | √ |
| | Contaminated fraction Meat | √ |
| | | |
| Ingestion Pathway, Nondietary Data | Livestock fodder intake for meat | √ |
| | Livestock water intake for meat | √ |
| | Livestock intake of soil | √ |
| | Mass loading for foliar deposition | √ |
| | Depth of soil mixing layer | √ |
| | Depth of roots | √ |
| | Groundwater Fractional Usage Livestock Water | |
| | Groundwater Fractional Usage Irrigation Water | |

**Table B.2-1 (continued). Parameters of Rancher Scenario Available for Sensitivity Analysis**

| PARAMETER CATEGORY | PARAMETER DESCRIPTION | SENSITIVITY ANALYSIS PERFORMED |
|---|---|---|
| Ingestion Pathway, Nondietary Data (continued) | 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 | |
| | | |
| Storage Times Before Use Data | Fruits, non-leafy vegetables, and grain | |
| | Leafy vegetables | |
| | Meat | |
| | Well water | |
| | Surface water | |
| | Livestock fodder | |

**Table B.2-2. Parameters of Rancher Scenario Available for Sensitivity Analysis but 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. |
| Thickness of Contaminated zone: | This parameter is fixed by 10 CFR 40, Appendix A, Criterion 6(6). |
| Cover depth: | The dose assessment included the actual condition that no cover will be applied. |
| Irrigation: | This parameter is not applicable to conditions of the scenario. |
| 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 actual condition that the groundwater system is unconfined. |
| Well pump intake depth: | Changing the value of this parameter from near zero would contradict the condition that groundwater is not an exposure pathway as a volumetric source of water. |
| Well pumping rate: | 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. |
| 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. |

**Table B.2-2. Parameters of Rancher Scenario Available for Sensitivity Analysis but not Evaluated (contd).**

| | |
|---|---|
| Contaminated fraction: | |
| Livestock water: | The model input for this parameter is 1, which is the maximum or conservative assumption. |
| Contaminated fraction: | |
| Irrigation water: | The model input for this parameter is 0, which is the most likely actual condition. |
| Groundwater fraction: | |
| 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 fraction: | |
| Usage Irrigation: | |
| Water: | Changing the value of this parameter from zero would contradict the condition that irrigation water is not an exposure pathway as a volumetric source of water. |
| Plant Factors (all): | No site specific information is available to contraindicate use of the RESRAD defaults. |
| 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. |

**Table B.2-3. Parameters of Rancher 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 | Milk consumption |
| | Fish consumption |
| | Other seafood consumption |
| | Drinking water intake |
| | Contaminated fraction Drinking water |
| | Contaminated fraction Household water |
| | Contaminated fraction Aquatic food |
| | Contaminated fraction Milk |
| | Contaminated fraction Household water |
| | |
| Ingestion Pathway, Nondietary Data | Livestock fodder intake for milk |
| | Livestock water intake for milk |
| | Groundwater Fractional Usage Drinking water |
| | Groundwater Fractional Usage Household water |

**Table B.2-4. Value and Basis of Multiplier for Sensitivity Analysis Range**

| DOSE ASSESSMENT PARAMETER | VALUE OF PARAMETER MODEL | MULTIPLIER |
|---|---|---|
| Transport Distribution coefficient all zones, Ra-226,Pb-210 | 1 | 500,270 |
| Basis for value of multiplier | An available value.[1] | |
| Area of contaminated zone, $m^2$ | 4048000 | 3 |
| Basis for value of multiplier | An upper bound based on size of the site. | |
| Length parallel to aquifer flow, m | 2270 | 3 |
| Basis for value of multiplier | An upper bound based on size of the site. | |
| Density of contaminated zone, $g/cm^3$ | 1.5 | 1.5 |
| Basis for value of multiplier | A maximum expected variation. | |
| Contaminated zone erosion rate, m/y | 0.00001 | 10 |
| Basis for value of multiplier | Arbitrary as an order of magnitude. | |
| Contaminated zone total porosity, dimensionless | 0.2 | 5 |
| Basis for value of multiplier | A maximum possible variation. | |
| Contaminated zone field capacity, dimensionless | 0.05 | 4 |
| Basis for value of multiplier | A maximum possible variation. | |
| Contaminated zone hydraulic conductivity, m/y | 2002 | 2 |
| Basis for value of multiplier | A maximum expected variation. | |
| Contaminated zone b parameter, dimensionless | 1 | 10 |
| Basis for value of multiplier | A maximum expected variation. | |
| Evapotranspiration coefficient, dimensionless | 0.9 | 1.5 |
| Basis for value of multiplier | A maximum expected variation.[1] | |
| Wind Speed, m/s | 3.9 | 1.5 |
| Basis for value of multiplier | A maximum expected variation. | |
| Precipitation, m/y | 0.266 | 1.5 |
| Basis for value of multiplier | A maximum expected variation. | |
| Runoff coefficient, dimensionless | 0.4 | 2 |
| Basis for value of multiplier | A maximum expected variation.[1] | |
| Density of saturated zone, $g/m^3$ | 2.4 | 1.5 |
| Basis for value of multiplier | A maximum expected variation. | |
| Saturated zone total porosity, dimensionless | 0.08 | 12.5 |
| Basis for value of multiplier | A maximum possible variation. | |
| Saturated zone effective porosity, dimensionless | 0.04 | 25 |
| Basis for value of multiplier | A maximum possible variation. | |

**Table B.2-4 (continued). Value and Basis of Multiplier for Sensitivity Analysis Range**

| DOSE ASSESSMENT PARAMETER | VALUE OF PARAMETER MODEL | MULTIPLIER |
|---|---|---|
| Saturated zone field capacity, dimensionless | 0.04 | 25 |
| Basis for value of multiplier | A maximum possible variation. | |
| Saturated zone hydraulic conductivity, m/y | 67 | 2 |
| Basis for value of multiplier | A maximum expected variation. | |
| Saturated zone hydraulic gradient, dimensionless | 0.04 | 2 |
| Basis for value of multiplier | A maximum expected variation. | |
| Saturated zone b parameter, dimensionless | 1 | 10 |
| Basis for value of multiplier | A maximum expected variation. | |
| Unsaturated zone 1 thickness, m | 8 | 4 |
| 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, $g/m^3$ | 0.0001 | 10 |
| 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 | 0.45 | 1.5 |
| Basis for value of multiplier | A maximum expected variation. | |
| Outdoor time fraction, dimensionless | 0.20 | 1.5 |
| Basis for value of multiplier | A maximum expected variation. | |
| 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. | |
| Meat and poultry consumption, kg/y | 63 | 2 |
| Basis for value of multiplier | Arbitrary. | |
| Soil ingestion, g/y | 36.5 | 2 |
| Basis for value of multiplier | A maximum expected variation.[1] | |
| Contamination fraction Plant food, dimensionless | 0.05 | 2 |
| Maximum Dose, mrem/y | A maximum expected variation. | |
| Contamination fraction Meat, dimensionless | 0.05 | 2 |
| Maximum Dose, mrem/y | A maximum expected variation. | |

**Table B.2-4 (continued). Value and Basis of Multiplier for Sensitivity Analysis Range**

| DOSE ASSESSMENT PARAMETER | VALUE OF PARAMETER | MODEL MULTIPLIER |
|---|---|---|
| Livestock fodder intake for meat, kg/d | 68 | 2 |
| Basis for value of multiplier | Arbitrary. | |
| Livestock water intake for meat, L/d | 50 | 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 | 0.3 | 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.

## Table B.2-5. Summary of Sensitivity Analysis for Rancher Scenario

**Ra-226 = Pb-210 = 5.0 pCi/g**

| DOSE ASSESSMENT PARAMETER | VALUE OF PARAMETER LOW | MODEL | HIGH |
|---|---|---|---|
| Transport Distribution coefficient all zones Ra-226,Pb-210 | -- | 1 | 500, 270 |
| Maximum Dose, mrem/y | -- | 18 | 18 |
| Area of contaminated zone, $m^2$ | 1349333 | 4048000 | 1.2E+7 |
| Maximum Dose, mrem/y | 18 | 18 | 18 |
| Length parallel to aquifer flow, m | 757 | 2270 | 6810 |
| Maximum Dose, mrem/y | 18 | 18 | 18 |
| Density of contaminated zone, $g/cm^3$ | 1 | 1.5 | 2.25 |
| Maximum Dose, mrem/y | 15 | 18 | 20 |
| Contaminated zone erosion rate, m/y | 0.000001 | 0.00001 | 0.0001 |
| Maximum Dose, mrem/y | 18 | 18 | 18 |
| Contaminated zone total porosity, dimensionless | 0.04 | 0.2 | 1 |
| Maximum Dose, mrem/y | 18 | 18 | 18 |
| Contaminated zone field capacity, dimensionless | 0.0125 | 0.05 | 0.2 |
| Maximum Dose, mrem/y | 18 | 18 | 18 |
| Contaminated zone hydraulic conductivity, m/y | 1001 | 2002 | 4004 |
| Maximum Dose, mrem/y | 18 | 18 | 18 |
| Contaminated zone b parameter, dimensionless | 0.1 | 1 | 10 |
| Maximum Dose, mrem/y | 18 | 18 | 18 |
| Evapotranspiration coefficient, dimensionless | 0.6 | 0.9 | 1 |
| Maximum Dose, mrem/y | 17 | 18 | 19 |
| Wind Speed, m/s | 2.6 | 3.9 | 5.9 |
| Maximum Dose, mrem/y | 18 | 18 | 18 |
| Precipitation, m/y | 0.177 | 0.266 | 0.399 |
| Maximum Dose, mrem/y | 18 | 18 | 18 |
| Runoff coefficient, dimensionless | 0.2 | 0.4 | 0.8 |
| Maximum Dose, mrem/y | 18 | 18 | 18 |
| Density of saturated zone, $g/m^3$ | 1.6 | 2.4 | 3.6 |
| Maximum Dose, mrem/y | 18 | 18 | 18 |
| Saturated zone total porosity, dimensionless | 0.0064 | 0.08 | 1 |
| Maximum Dose, mrem/y | 18 | 18 | 18 |
| Saturated zone effective porosity, dimensionless | 0.0016 | 0.04 | 1 |
| Maximum Dose, mrem/y | 18 | 18 | 18 |

**Table B.2-5 (continued). Summary of Sensitivity Analysis for Rancher Scenario**

**Ra-226 = Pb-210 = 5.0 pCi/g**

| DOSE ASSESSMENT PARAMETER | VALUE OF PARAMETER LOW | MODEL | HIGH |
|---|---|---|---|
| Saturated zone field capacity, dimensionless | 0.0016 | 0.04 | 1 |
| Maximum Dose, mrem/y | 18 | 18 | 18 |
| Saturated zone hydraulic conductivity, m/y | 33.5 | 67 | 134 |
| Maximum Dose, mrem/y | 18 | 18 | 18 |
| Saturated zone hydraulic gradient, dimensionless | 0.02 | 0.04 | 0.08 |
| Maximum Dose, mrem/y | 18 | 18 | 18 |
| Saturated zone b parameter, dimensionless | 0.1 | 1 | 10 |
| Maximum Dose, mrem/y | 18 | 18 | 18 |
| Unsaturated zone 1 thickness, m | 2 | 8 | 32 |
| Maximum Dose, mrem/y | 18 | 18 | 18 |
| Inhalation rate, $m^3/y$ | 5385 | 8400 | 13000 |
| Maximum Dose, mrem/y | 18 | 18 | 18 |
| Mass loading for inhalation, $g/m^3$ | 0.00001 | 0.0001 | 0.001 |
| Maximum Dose, mrem/y | 18 | 18 | 18 |
| Indoor dust filtration factor, dimensionless | 0.3 | 0.56 | 1 |
| Maximum Dose, mrem/y | 18 | 18 | 18 |
| External gamma shielding factor, dimensionless | 0.054 | 0.21 | 0.8 |
| Maximum Dose, mrem/y | 14 | 18 | 30 |
| Indoor time fraction, dimensionless | 0.3 | 0.45 | 0.68 |
| Maximum Dose, mrem/y | 15 | 18 | 20 |
| Outdoor time fraction, dimensionless | 0.13 | 0.2 | 0.3 |
| Maximum Dose, mrem/y | 14 | 18 | 22 |
| Fruit, vegetable, and grain consumption, kg/y | 148 | 178 | 214 |
| Maximum Dose, mrem/y | 17 | 18 | 19 |
| Leafy vegetable consumption, kg/y | 12.5 | 25 | 50 |
| Maximum Dose, mrem/y | 18 | 18 | 18 |
| Meat and poultry consumption, kg/y | 32 | 63 | 126 |
| Maximum Dose, mrem/y | 18 | 18 | 18 |
| Soil ingestion, g/y | 18.25 | 36.5 | 73 |
| Maximum Dose, mrem/y | 18 | 18 | 18 |
| Contamination fraction Plant food, dimensionless | 0.025 | 0.05 | 0.1 |
| Maximum Dose, mrem/y | 15 | 18 | 20 |
| Contamination fraction Meat, dimensionless | 0.025 | 0.05 | 0.1 |
| Maximum Dose, mrem/y | 18 | 18 | 18 |

**Table B.2-5 (continued). Summary of Sensitivity Analysis for Rancher Scenario**

**Ra-226 = Pb-210 = 5.0 pCi/g**

| DOSE ASSESSMENT PARAMETER | VALUE OF PARAMETER LOW | MODEL | HIGH |
|---|---|---|---|
| Livestock fodder intake for meat, kg/d | 34 | 68 | 136 |
| Maximum Dose, mrem/y | 18 | 18 | 18 |
| Livestock water intake for meat, L/d | 25 | 50 | 100 |
| Maximum Dose, mrem/y | 18 | 18 | 18 |
| Livestock intake of soil, kg/d | 0.25 | 0.5 | 1 |
| Maximum Dose, mrem/y | 18 | 18 | 18 |
| Mass loading for foliar deposition, $g/m^3$ | 0.00001 | 0.0001 | 0.001 |
| Maximum Dose, mrem/y | 18 | 18 | 18 |
| Depth of soil mixing layer, m | 0.0375 | 0.15 | 0.6 |
| Maximum Dose, mrem/y | 18 | 18 | 18 |
| Depth of roots, m | 0.075 | 0.3 | 1.2 |
| Maximum Dose, mrem/y | 15 | 18 | 20 |

# APPENDIX C

# DOSE ASSESSMENT FOR PONDS 4, 5, AND 6

## INTRODUCTION

Several lined and unlined evaporation ponds at the site were used to evaporate the liquid mill effluents that contained natural uranium, thorium 230, and radium 226. The concentrations of these radionuclides in evaporation ponds exceed the likely soil concentration limits that would be established for the site.

The Reclamation Plan does not include complete excavation of the evaporation ponds. A dose assessment, described below, has been completed demonstrating that the contribution to total effective dose equivalent (TEDE) at the site is small. The dose assessment is centered on the rancher scenario used to establish the benchmark dose.

Exposure pathway modeling was used to calculate the dose to the rancher from the planned final condition of evaporation Ponds 4, 5, and 6. 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.

The exposure pathway modeling completed here was a deterministic analysis of the peak annual dose to the average member of the critical group for a rancher exposure scenario. The dose assessment 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.

## SCOPE OF DOSE ASSESSMENT

The dose assessment was developed in particular for the case of license termination. The dose assessment was 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 dose assessment was completed solely with respect to dose received due to pathways related to residual radioactive material in subsurface soil at an evaporation pond. There were several pathways not included in the dose assessment. Some pathways were not included because they are not applicable; i.e. drinking water. Other pathways were not included because they cannot be considered directly by the conceptual model applied; i.e. exposure rate from the disposal cell. These and other pathway exceptions are discussed in a following section of this appendix.

# SOURCE TERM

## CONFIGURATION

The physical layout of evaporation Ponds 4, 5, and 6 is shown in **Figures 1-2 and 1-3**. The figure includes approximate boundaries of each of the distinct soil units in the area; i.e. surface soils, halos, and pond footprints.

The radionuclides that have the potential to contribute the dose against which the dose limit criteria are compared are identified as the radionuclides of concern (RoC). The RoCs are specifically evaluated for the development of site-specific dose assessment. The RoCs were chosen based on historical information and findings of site investigations[68]. The RoCs were determined to be natural uranium, thorium-230, and radium-226. The contamination levels are described in Table C-1.

The source term is assumed to be covered contaminated soil of cylindrical shape. The cover is 0.3 meter of uncontaminated alluvial soil. The contaminated soil is modeled as a 2-meter thick zone of unconsolidated soil. The contaminated soil is known underlain by one uncontaminated unsaturated soil zone; this zone is modeled as a 6-meter thick zone of alluvium (unconsolidated soil). The next zone is an uncontaminated saturated zone; this zone is modeled as the uppermost bedrock and is independent of thickness. The source term is shown in **Figure C-1**.

## RESIDUAL RADIOACTIVITY

The RoCs are assumed homogenously distributed within the contaminated soil at concentrations equivalent to the maximum concentration provided in tables 2-9, 2-10, and 2-11.

## CHEMICAL FORM

In an effort to quantify the mobility of the RoCs in soil at the site, a distribution coefficient ($K_d$) was respectively selected for each of the soil units in the model. Description of the selection and application of the $K_d$ is provided in Appendix B, Attachment 2.

[68] Rio Algom Mining Corporation, site characterization data.

## CRITICAL GROUP, SCENARIO, AND PATHWAYS IDENTIFICATION AND SELECTION

### SCENARIO IDENTIFICATION

The exposure scenario applied here may be described as representing a local rancher. The rancher scenario accounts for exposure involving residual radioactivity that is initially in the subsurface soil at the locations of the lined and unlined evaporation ponds. A rancher periodically is present on the site and retrieves some of his diet from the site. The scenario assumes no disturbance of the subsurface soils.

### CRITICAL GROUP DETERMINATION

The average member of the critical group is the rancher. 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 RoCs is the contaminated soil zone. The RoCs are assumed potentially released from the soil by erosion, plant uptake, direct ingestion, infiltration, and leaching. The RoCs 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 RoCs.

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
- Ingestion of animal products grown onsite using feed and surface water from potentially contaminated sources.

Three exposure pathways not included in the dose assessment are groundwater usage, intrusion of the subsurface soils, 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.

Limited yield of groundwater wells is typical throughout this part of New Mexico and has resulted in the reliance on surface water as their source(s).

Localized areas of groundwater at the Site have been created by recharge from existing surface sources or man-made subsurface reservoirs such as utility trenches and foundation backfill areas. Once these features are removed during reclamation, these groundwater sources will disappear.

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 RoCs at the Site.

### Subsurface Soil Intrusion

Deliberate intrusion into the subsurface soil was not considered during development of the dose assessment.

### Radon

The radon pathway was not considered because it is specifically excluded from the scope of the technical criteria.[69]

[69] 10 CFR 40, Appendix A, Criterion 6 (6)

## CONCEPTUAL MODEL

The conceptual model used to evaluate the previously described exposure scenario and pathways was the RESRAD[70] computer code version 6.21. 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.[71]

RESRAD models external exposure from volume sources when the individual is outside, using volume dose rate factors. 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 in a single homogenous stratum, under steady-state, unidirectional flow, with constant

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[70] Yu, C., et. al. "Users Manual for RESRAD Version 6", Argonne, IL: Argonne National Laboratory. ANL/EAD-4. July 2001.

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

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 rancher spends 45% of the time indoors on site, 25% of the time outdoors on site, and 35% of the time away from the site.[72] Food production is assumed to occur in the contaminated area: 5% of the resident's vegetable, grain, and fruit diet assumed produced from the contaminated area; 5% of the resident's meat diet is assumed

[72] SECY 98 084, Attachment 3, Table 1.

produced from the contaminated area.[8] Neither milk nor aquatic food is included in the rancher's diet.[8] Dust levels represent ambient suspension of soil particles in air.

Vegetables, fruits, and grains are not irrigated with water from the contaminated area. Some contaminated water is used for watering livestock on site. The rancher's drinking water is assumed from an uncontaminated 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 C-1.

Appendix B, Attachment 2 provides description of the rationale for the value of each parameter.

## SENSITIVITY ANALYSIS

A sensitivity analysis was not performed for this dose assessment.

## COMPLIANCE WITH REGULATORY CRITERIA

This dose assessment was performed to compare the residual radioactivity in subsurface soils of Evaporation Ponds 4, 5, and 6 to the radium benchmark dose limit of 18 mrem per year. The result of the dose assessment for Evaporation Ponds 4, 5, and 6 was 11 mrem per year. This value is less than the radium benchmark dose, therefore stabilization in place of Evaporation Ponds 4, 5, and 6 is an approvable alternative to application of soil concentration limits.

| Table C-1: Selected Model inputs for Evaporation Ponds 4, 5, & 6 | | |
|---|---|---|
| **Parameter** | **Input** | **Background Information** |
| **Source** | | |
| Nuclide concentration for U-238 (pCi/g) | 24 | A maximum determined from site characterization information. |
| **Transport Distribution coefficients for U-238** | | |
| Contaminated zone (cm**3/g) | 1 | Site-specific estimate. |
| Unsaturated zone 1 (cm**3/g) | 1 | Site-specific estimate. |
| Saturated zone (cm**3/g) | 90 | Site-specific estimate. |
| 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)** | 1 | A maximum determined from site characterization information. |
| **Transport Distribution coefficients for U-235** | | |
| Contaminated zone (cm**3/g) | 1 | Site-specific estimate. |
| Unsaturated zone 1 (cm**3/g) | 1 | Site-specific estimate. |
| Saturated zone (cm**3/g) | 90 | Site-specific estimate. |
| 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)** | -- | Estimated from *nuclide concentration for U-235*. |
| **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)** | -- | Estimated from *nuclide concentration for U-235*. |
| **Transport Distribution coefficients for** | | |

| Table C-1: Selected Model inputs for Evaporation Ponds 4, 5, & 6 | | |
|---|---|---|
| **Parameter** | **Input** | **Background Information** |
| **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)** | 24 | A maximum determined from site characterization information. |
| **Transport Distribution coefficients for U-234** | | |
| Contaminated zone (cm**3/g) | 1 | Site-specific estimate. |
| Unsaturated zone 1 (cm**3/g) | 1 | Site-specific estimate. |
| Saturated zone (cm**3/g) | 90 | Site-specific estimate. |
| 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)** | 4470 | A maximum determined from site characterization information. |
| **Transport Distribution coefficients for Th-230** | | |
| Contaminated zone (cm**3/g) | 1 | Site-specific estimate. |
| Unsaturated zone 1 (cm**3/g) | 1 | Site-specific estimate. |
| Saturated zone (cm**3/g) | 90 | Site-specific estimate. |
| 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)** | 62 | A maximum determined from site characterization information. |
| **Transport Distribution coefficients for Ra-226** | | |
| Contaminated zone (cm**3/g) | 1 | Site-specific estimate. |
| Unsaturated zone 1 (cm**3/g) | 1 | Site-specific estimate. |

| Table C-1: Selected Model inputs for Evaporation Ponds 4, 5, & 6 | | |
|---|---|---|
| **Parameter** | **Input** | **Background Information** |
| Saturated zone (cm**3/g) | 90 | Site-specific estimate. |
| 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 Pb-210 (pCi/g)** | 62 | Estimated from *nuclide concentration for Ra-226*. |
| **Transport Distribution coefficients for Pb-210** | | |
| Contaminated zone (cm**3/g) | 1 | Site-specific estimate. |
| Unsaturated zone 1 (cm**3/g) | 1 | Site-specific estimate. |
| Saturated zone (cm**3/g) | 90 | Site-specific estimate. |
| 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) | 25 | RESRAD default |
| Times for Calculations (years) | 0 | 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) | 465000 | Site-specific value. |
| Thickness of contaminated zone (m) | 2 | Estimate from site characterization data. |
| Length parallel to aquifer flow (m) | 769 | Diameter of circle of area equal contaminated zone. |
| | | |
| **Cover and Contaminated Zone Hydrological Data** | | |
| Cover depth (m) | 0.3 | Planned actual conditions: equivalent to one foot alluvium cover. |
| Density of cover material (g/cm**3) | 1.5 | Site-specific estimate. |
| Cover erosion rate (m/yr) | 1 E-05 | Estimate from NRC evaluation.[3]. |

| Table C-1: Selected Model inputs for Evaporation Ponds 4, 5, & 6 | | |
|---|---|---|
| **Parameter** | **Input** | **Background Information** |
| | | |
| Density of contaminated zone (g/cm**3) | 1.5 | Site-specific estimate. |
| Contaminated zone erosion rate (m/yr) | 1 E-05 | Estimate from NRC evaluation.[3] |
| Contaminated zone total porosity | 0.20 | Site-specific estimate. |
| Contaminated zone field capacity | 0.05 | Site-specific estimate. |
| Contaminated zone hydraulic conductivity (m/yr) | 2002 | Site-specific estimate. |
| Contaminated zone b parameter | 1 | Estimate for sand from RESRAD guidance.[2] |
| | | |
| Humidity in air (g/cm**3) | -- | Not available; reflects absence of radon pathway.[1] |
| Evapotranspiration coefficient | 0.9 | Estimate from NRC evaluation.[3] |
| Wind Speed (m/sec) | 3.9 | Site-specific estimate. |
| Precipitation (m/yr) | 0.266 | Site-specific estimate. |
| Irrigation (m/yr) | 0 | Assumed site condition. |
| 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) | 1.56 E+08 | Site-specific estimate. |
| Accuracy for water/soil computations | 0.001 | RESRAD default |
| | | |
| **Saturated Zone Hydrological Data** | | |
| Density of saturated zone (g/cm**3) | 2.4 | Site-specific estimate. |
| Saturated zone total porosity | 0.08 | Site-specific estimate. |
| Saturated zone effective porosity | 0.04 | Site-specific estimate. |
| Saturated zone field capacity | 0.04 | Site-specific estimate. |
| Saturated zone hydraulic conductivity (m/yr) | 67 | Site-specific estimate. |
| Saturated zone hydraulic gradient | 0.04 | Site-specific estimate. |
| Saturated zone b parameter | 1 | Estimate sand from RESRAD guidance.[2] |
| Water table drop rate (m/yr) | 1 | Assume recharge from mine water stops after reclamation. |
| 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). |
| | | |

| Table C-1: Selected Model inputs for Evaporation Ponds 4, 5, & 6 | | |
|---|---|---|
| **Parameter** | **Input** | **Background Information** |
| **Uncontaminated Unsaturated Zone Parameters** | | |
| Unsaturated Zones | 1 | Site-specific condition. |
| Unsaturated Zone 1, Thickness (m) | 6 | Site-specific estimate. |
| Unsaturated Zone 1, Density (g/cm**3) | 1.5 | Site-specific estimate. |
| Unsaturated Zone 1, Total Porosity | 0.20 | Site-specific estimate. |
| Unsaturated Zone 1, Effective Porosity | 0.15 | Site-specific estimate. |
| Unsaturated Zone 1, Field Capacity | 0.05 | Site-specific estimate. |
| Unsaturated Zone 1, Hydraulic Conductivity (m/yr) | 2002 | Site-specific estimate. |
| Unsaturated Zone 1, b Parameter | 1 | Estimate for sand from RESRAD guidance.[2] |
| | | |
| **Occupancy, Inhalation, and External Gamma Data** | | |
| Inhalation rate (m**3/yr) | 8400 | Recommendation from RESRAD guidance.[2] |
| Mass loading for inhalation (g/m**3) | 0.0001 | RESRAD default. |
| 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 | 0.45 | Estimate from NRC evaluation.[3] |
| Outdoor time fraction | 0.20 | Estimate from NRC evaluation.[3] |
| 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) | -- | Not available; reflects absence of milk pathway.[1] |
| Meat and poultry consumption (kg/yr) | 63 | RESRAD default. |
| Fish consumption (kg/yr) | -- | Not available; reflects absence of aquatic pathway.[1] |
| Other seafood consumption | -- | Not available; reflects absence of aquatic pathway.[1] |
| Soil ingestion (g/yr) | 36.5 | RESRAD default. |
| 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 |

| Table C-1: Selected Model inputs for Evaporation Ponds 4, 5, & 6 | | |
|---|---|---|
| **Parameter** | **Input** | **Background Information** |
| | | pathway.[1] |
| Contaminated fraction Livestock water | 1 | Assume all from onsite surface water. |
| Contaminated fraction Irrigation water | 0 | Reflects absence of irrigation. |
| Contaminated fraction Aquatic food | -- | Not available; reflects absence of aquatic pathway.[1] |
| Contaminated fraction Plant food | 0.05 | Estimate from NRC evaluation.[3] |
| Contaminated fraction Meat | 0.05 | Estimate from NRC evaluation.[3] |
| Contaminated fraction Milk | -- | Not available; reflects absence of milk pathway.[1] |
| | | |
| **Ingestion Pathway, Nondietary Data** | | |
| Livestock fodder intake for meat (kg/day) | 68 | RESRAD default |
| Livestock fodder intake for milk (kg/day) | -- | Not available; reflects absence of milk pathway.[1] |
| Livestock water intake for meat (L/day) | 50 | RESRAD default |
| Livestock water intake for milk (L/day) | -- | Not available; reflects absence of milk pathway.[1] |
| Livestock soil intake (kg/day) | 0.5 | RESRAD default |
| | | |
| Mass loading for foliar deposition (g/m**3) | 1 E-04 | RESRAD default |
| Depth of soil mixing layer (m) | 0.15 | RESRAD default |
| Depth of roots (m) | 0.3 | Estimate from NRC evaluation.[3] |
| | | |
| 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; i.e. *well pumping rate* equal zero. |
| Groundwater Fractional Usage Irrigation water | 0 | Reflects the absence of groundwater usage; i.e. *well pumping rate* equal zero. |
| | | |
| **Plant Factors** | | |
| Wet weight crop yield for Non-Leafy (kg/m**2) | 0.7 | RESRAD default |
| 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 | 0.25 | RESRAD default |

| Table C-1: Selected Model inputs for Evaporation Ponds 4, 5, & 6 | | |
|---|---|---|
| **Parameter** | **Input** | **Background Information** |
| (years) | | |
| 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 | 20 | RESRAD default |
| Wet foliar interception fraction for Non-Leafy | 0.25 | RESRAD default |
| Wet foliar interception fraction for leafy | 0.25 | RESRAD default |
| 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 |
| Dry foliar interception fraction for Fodder | 0.25 | RESRAD default |

[1] Yu, C., et. al. "Users Manual for RESRAD Version 6", Argonne, IL: Argonne National Laboratory. ANL/EAD-4. July 2001.

[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] U.S. Nuclear Regulatory Commission, Commission Paper SECY 98 084, "Status of Efforts to Finalize Regulations for Radiological Criteria for License Termination: Uranium Recovery Facilities", April 15, 1998.

# APPENDIX D

# DOSE ASSESSMENT FOR PONDS 7 AND 8

## INTRODUCTION

Several lined and unlined evaporation ponds at the site were used to evaporate the liquid mill effluents that contained natural uranium, thorium 230, and radium 226. The concentrations of these radionuclides in evaporation ponds exceed the likely soil concentration limits that would be established for the site.

The Reclamation Plan does not include complete excavation of the evaporation ponds. A dose assessment, described below, has been completed demonstrating that the contribution to total effective dose equivalent (TEDE) at the site is small. The dose assessment is centered on the rancher scenario used to establish the benchmark dose.

Exposure pathway modeling was used to calculate the dose to the rancher from the planned final condition of Evaporation Ponds 7 and 8. 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.

The exposure pathway modeling completed here was a deterministic analysis of the peak annual dose to the average member of the critical group for a rancher exposure scenario. The dose assessment 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.

## SCOPE OF DOSE ASSESSMENT

The dose assessment was developed in particular for the case of license termination. The dose assessment was 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 dose assessment was completed solely with respect to dose received due to pathways related to residual radioactive material in subsurface soil at an evaporation pond. There were several pathways not included in the dose assessment. Some pathways were not included because they are not applicable; i.e. drinking water. Other pathways were not included because they cannot be considered directly by the conceptual model applied; i.e. exposure rate from the disposal cell. These and other pathway exceptions are discussed in a following section of this Appendix.

# 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 radionuclides of concern (RoC). The RoCs are specifically evaluated for the development of site-specific dose assessment. The RoCs were chosen based on historical information and findings of site investigations[73]. The RoCs were determined to be natural uranium, thorium-230, and radium-226.

The source term is assumed to be covered contaminated soil of cylindrical shape. The contaminated soil is modeled as a 2-meter thick zone of unconsolidated soil. The contaminated soil is known underlain by one uncontaminated unsaturated soil zone; this zone is modeled as a 6-meter thick zone of alluvium (unconsolidated soil). The next zone is an uncontaminated saturated zone; this zone is modeled as the uppermost bedrock and is independent of thickness.

## RESIDUAL RADIOACTIVITY

The RoCs are assumed homogenously distributed within the contaminated soil at concentrations equivalent to the maximum concentration provided in tables 2-12 and 2-13.

## CHEMICAL FORM

In an effort to quantify the mobility of the RoCs in soil at the site, a distribution coefficient ($K_d$) was respectively selected for each of the soil units in the model. Description of the selection and application of the $K_d$ is provided in Appendix B, Attachment 2.

# CRITICAL GROUP, SCENARIO, AND PATHWAYS IDENTIFICATION AND SELECTION

## SCENARIO IDENTIFICATION

The exposure scenario applied here may be described as representing a local rancher. The rancher scenario accounts for exposure involving residual radioactivity that is initially in the subsurface soil at the locations of the lined and unlined evaporation ponds. A rancher

[73] Rio Algom Mining Corporation, site characterization data.

periodically is present on the site and retrieves some of his diet from the site. The scenario assumes no disturbance of the disposal cell or the subsurface soils (this qualification is discussed later).

## CRITICAL GROUP DETERMINATION

The average member of the critical group is the rancher. 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 RoCs is the contaminated soil zone. The RoCs are assumed potentially released from the soil by erosion, plant uptake, direct ingestion, infiltration, and leaching. The RoCs 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 RoCs.

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
- Ingestion of animal products grown onsite using feed and surface water from potentially contaminated sources.

Three exposure pathways not included in the dose assessment are groundwater usage, intrusion of the subsurface soils, 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.

Limited yield of groundwater wells is typical throughout this part of New Mexico and has resulted in the reliance on surface water as their source(s).

Localized areas of groundwater at the Site have been created by recharge from existing surface sources or man-made subsurface reservoirs such as utility trenches and foundation backfill areas. Once these features are removed during reclamation, these groundwater sources will disappear.

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 RoCs at the Site.

### Subsurface Soil Intrusion

Deliberate intrusion into the subsurface soil was not considered during development of the dose assessment.

### Radon

The radon pathway was not considered because it is specifically excluded from the scope of the technical criteria.[74]

## CONCEPTUAL MODEL

The conceptual model used to evaluate the previously described exposure scenario and pathways was the RESRAD[75] computer code version 6.21. 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.[76]

RESRAD models external exposure from volume sources when the individual is outside, using volume dose rate factors. Correction factors are used to account for soil density, areal extent of

[74] 10 CFR 40, Appendix A, Criterion 6 (6)

[75] Yu, C., et. al. "Users Manual for RESRAD Version 6", Argonne, IL: Argonne National Laboratory. ANL/EAD-4. July 2001.

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

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 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 rancher spends 45% of the time indoors on site, 25% of the time outdoors on site, and 35% of the time away from the site.[77] Food production is assumed to occur in the contaminated area: 5% of the resident's vegetable, grain, and fruit diet assumed produced from the contaminated area; 5% of the resident's meat diet is assumed produced from the contaminated area.[8] Neither milk nor aquatic food is included in the rancher's diet.[8] Dust levels represent ambient suspension of soil particles in air.

Vegetables, fruits, and grains are not irrigated with water from the contaminated area. Some contaminated water is used for watering livestock on site. The rancher's drinking water is assumed from an uncontaminated 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 D-1.

Appendix B, Attachment 2 provides description of the rationale for the value of each parameter.

[77] SECY 98 084, Attachment 3, Table 1.

## SENSITIVITY ANALYSIS

A sensitivity analysis was not performed for this dose assessment.

## COMPLIANCE WITH REGULATORY CRITERIA

This dose assessment was performed to compare the residual radioactivity in subsurface soils of Evaporation Ponds 7 and 8 to the radium benchmark dose limit of 18 mrem per year. The result of the dose assessment for Evaporation Ponds 7 and 8 was seven mrem per year. This value is substantially smaller than the radium benchmark dose, therefore stabilization in place of Evaporation Ponds 7 and 8 is an approvable alternative to application of soil concentration limits.

| Table D-1. Model Selected Values for Evaporation Ponds 7 & 8 | | |
|---|---|---|
| **Parameter** | **Input** | **Background Information** |
| **Source** | | |
| **Nuclide concentration for U-238 (pCi/g)** | 11 | A maximum determined from site characterization information. |
| **Transport Distribution coefficients for U-238** | | |
| Contaminated zone (cm**3/g) | 1 | Site-specific estimate. |
| Unsaturated zone 1 (cm**3/g) | 1 | Site-specific estimate. |
| Saturated zone (cm**3/g) | 90 | Site-specific estimate. |
| 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)** | 0.5 | A maximum determined from site characterization information. |
| **Transport Distribution coefficients for U-235** | | |
| Contaminated zone (cm**3/g) | 1 | Site-specific estimate. |
| Unsaturated zone 1 (cm**3/g) | 1 | Site-specific estimate. |
| Saturated zone (cm**3/g) | 90 | Site-specific estimate. |
| 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)** | -- | Estimated from *nuclide concentration for U-235*. |
| **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 |

| Table D-1. Model Selected Values for Evaporation Ponds 7 & 8 | | |
|---|---|---|
| **Parameter** | **Input** | **Background Information** |
| **Nuclide concentration for Ac-227 (pCi/g)** | -- | Estimated from *nuclide concentration for U-235*. |
| **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)** | 11 | A maximum determined from site characterization information. |
| **Transport Distribution coefficients for U-234** | | |
| Contaminated zone (cm**3/g) | 1 | Site-specific estimate. |
| Unsaturated zone 1 (cm**3/g) | 1 | Site-specific estimate. |
| Saturated zone (cm**3/g) | 90 | Site-specific estimate. |
| 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)** | 2070 | A maximum determined from site characterization information. |
| **Transport Distribution coefficients for Th-230** | | |
| Contaminated zone (cm**3/g) | 1 | Site-specific estimate. |
| Unsaturated zone 1 (cm**3/g) | 1 | Site-specific estimate. |
| Saturated zone (cm**3/g) | 90 | Site-specific estimate. |
| 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)** | 78 | A maximum determined from site |

| Table D-1. Model Selected Values for Evaporation Ponds 7 & 8 | | |
|---|---|---|
| **Parameter** | **Input** | **Background Information** |
| | | characterization information. |
| **Transport Distribution coefficients for Ra-226** | | |
| Contaminated zone (cm**3/g) | 1 | Site-specific estimate. |
| Unsaturated zone 1 (cm**3/g) | 1 | Site-specific estimate. |
| Saturated zone (cm**3/g) | 90 | Site-specific estimate. |
| 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 Pb-210 (pCi/g)** | 78 | Estimated from *nuclide concentration for Ra-226*. |
| **Transport Distribution coefficients for Pb-210** | | |
| Contaminated zone (cm**3/g) | 1 | Site-specific estimate. |
| Unsaturated zone 1 (cm**3/g) | 1 | Site-specific estimate. |
| Saturated zone (cm**3/g) | 90 | Site-specific estimate. |
| 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) | 25 | RESRAD default |
| Times for Calculations (years) | 0 | 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) | 265000 | Site-specific value. |
| Thickness of contaminated zone (m) | 2 | Estimate from site characterization data. |
| Length parallel to aquifer flow (m) | 581 | Diameter of circle of contam zone |
| **Cover and Contaminated Zone Hydrological Data** | | |
| Cover depth (m) | 0.3 | Planned actual conditions: equivalent to one |

| Table D-1. Model Selected Values for Evaporation Ponds 7 & 8 | | |
|---|---|---|
| **Parameter** | **Input** | **Background Information** |
| | | foot alluvium cover. |
| Density of cover material (g/cm**3) | 1.5 | Site-specific estimate. |
| Cover erosion rate (m/yr) | 1 E-05 | Estimate from NRC evaluation.[3]. |
| | | |
| Density of contaminated zone (g/cm**3) | 1.5 | Site-specific estimate. |
| Contaminated zone erosion rate (m/yr) | 1 E-05 | Estimate from NRC evaluation.[3] |
| Contaminated zone total porosity | 0.20 | Site-specific estimate. |
| Contaminated zone field capacity | 0.05 | Site-specific estimate. |
| Contaminated zone hydraulic conductivity (m/yr) | 2002 | Site-specific estimate. |
| Contaminated zone b parameter | 1 | Estimate for sand from RESRAD guidance.[2] |
| Humidity in air (g/cm**3) | -- | Not available; reflects absence of radon pathway.[1] |
| Evapotranspiration coefficient | 0.9 | Estimate from NRC evaluation.[3] |
| Wind Speed (m/sec) | 3.9 | Site-specific estimate. |
| Precipitation (m/yr) | 0.266 | Site-specific estimate. |
| Irrigation (m/yr) | 0 | Assumed site condition. |
| 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) | 1.56 E+08 | Site-specific estimate. |
| Accuracy for water/soil computations | 0.001 | RESRAD default |
| | | |
| **Saturated Zone Hydrological Data** | | |
| Density of saturated zone (g/cm**3) | 2.4 | Site-specific estimate. |
| Saturated zone total porosity | 0.08 | Site-specific estimate. |
| Saturated zone effective porosity | 0.04 | Site-specific estimate. |
| Saturated zone field capacity | 0.04 | Site-specific estimate. |
| Saturated zone hydraulic conductivity (m/yr) | 67 | Site-specific estimate. |
| Saturated zone hydraulic gradient | 0.04 | Site-specific estimate. |
| Saturated zone b parameter | 1 | Estimate sand from RESRAD guidance.[2] |
| Water table drop rate (m/yr) | 1 | Assume recharge from mine water stops after reclamation. |
| 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 |

| Table D-1. Model Selected Values for Evaporation Ponds 7 & 8 | | |
|---|---|---|
| **Parameter** | **Input** | **Background Information** |
| | | usage). |
| | | |
| **Uncontaminated Unsaturated Zone Parameters** | | |
| Unsaturated Zones | 1 | Site-specific condition. |
| Unsaturated Zone 1, Thickness (m) | 6 | Site-specific estimate. |
| Unsaturated Zone 1, Density (g/cm**3) | 1.5 | Site-specific estimate. |
| Unsaturated Zone 1, Total Porosity | 0.20 | Site-specific estimate. |
| Unsaturated Zone 1, Effective Porosity | 0.15 | Site-specific estimate. |
| Unsaturated Zone 1, Field Capacity | 0.05 | Site-specific estimate. |
| Unsaturated Zone 1, Hydraulic Conductivity (m/yr) | 2002 | Site-specific estimate. |
| Unsaturated Zone 1, b Parameter | 1 | Estimate for sand from RESRAD guidance.[2] |
| | | |
| **Occupancy, Inhalation, and External Gamma Data** | | |
| Inhalation rate (m**3/yr) | 8400 | Recommendation from RESRAD guidance.[2] |
| Mass loading for inhalation (g/m**3) | 0.0001 | RESRAD default. |
| 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 | 0.45 | Estimate from NRC evaluation.[3] |
| Outdoor time fraction | 0.20 | Estimate from NRC evaluation.[3] |
| 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) | -- | Not available; reflects absence of pathway.[1] |
| Meat and poultry consumption (kg/yr) | 63 | RESRAD default. |
| Fish consumption (kg/yr) | -- | Not available; reflects absence of aquatic pathway.[1] |
| Other seafood consumption | -- | Not available; reflects absence of aquatic pathway.[1] |
| Soil ingestion (g/yr) | 36.5 | RESRAD default. |
| Drinking water intake (L/yr) | -- | Not available; reflects absence of drinking water pathway.[1] |
| | | |

| Table D-1. Model Selected Values for Evaporation Ponds 7 & 8 | | |
|---|---|---|
| **Parameter** | **Input** | **Background Information** |
| 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 surface water. |
| Contaminated fraction Irrigation water | 0 | Reflects absence of irrigation. |
| Contaminated fraction Aquatic food | -- | Not available; reflects absence of aquatic pathway.[1] |
| Contaminated fraction Plant food | 0.05 | Estimate from NRC evaluation.[3] |
| Contaminated fraction Meat | 0.05 | Estimate from NRC evaluation.[3] |
| Contaminated fraction Milk | -- | Not available; reflects absence of milk pathway.[1] |
| | | |
| **Ingestion Pathway, Nondietary Data** | | |
| Livestock fodder intake for meat (kg/day) | 68 | RESRAD default |
| Livestock fodder intake for milk (kg/day) | -- | Not available; reflects absence of milk pathway.[1] |
| Livestock water intake for meat (L/day) | 50 | RESRAD default |
| Livestock water intake for milk (L/day) | -- | Not available; reflects absence of milk pathway.[1] |
| Livestock soil intake (kg/day) | 0.5 | RESRAD default |
| | | |
| Mass loading for foliar deposition (g/m**3) | 1 E-04 | RESRAD default |
| Depth of soil mixing layer (m) | 0.15 | RESRAD default |
| Depth of roots (m) | 0.3 | Estimate from NRC evaluation.[3] |
| | | |
| 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 |
| Groundwater Fractional Usage Irrigation water | 0 | Reflects the absence of groundwater usage; i.e. *well pumping rate* equal zero. |
| | | |
| **Plant Factors** | | |
| Wet weight crop yield for Non-Leafy (kg/m**2) | 0.7 | RESRAD default |
| (continued, 7 of 7) | | |
| Wet weight crop yield for Leafy | 1.5 | RESRAD default |

| Table D-1. Model Selected Values for Evaporation Ponds 7 & 8 | | |
|---|---|---|
| **Parameter** | **Input** | **Background Information** |
| (kg/m**2) | | |
| 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 | 20 | RESRAD default |
| Wet foliar interception fraction for Non-Leafy | 0.25 | RESRAD default |
| Wet foliar interception fraction for leafy | 0.25 | RESRAD default |
| 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 |
| Dry foliar interception fraction for Fodder | 0.25 | RESRAD default |

[1] Yu, C., et. al. “Users Manual for RESRAD Version 6”, Argonne, IL: Argonne National Laboratory. ANL/EAD-4. July 2001.

[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] U.S. Nuclear Regulatory Commission, Commission Paper SECY 98 084, “Status of Efforts to Finalize Regulations for Radiological Criteria for License Termination: Uranium Recovery Facilities”, April 15, 1998.

# APPENDIX E

# DOSE ASSESSMENT FOR PONDS 9 AND 10

4/2/2014

# Report of Dose Modeling for Ponds 9 and 10 and the Mill Area at the Rio Algom Mining LLC Ambrosia Lake Facility, Grants, New Mexico.

April 2014

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The Ambrosia Lake Facility is undergoing a remediation to decommission the entire facility. A previous report prepared by KOMEX, 300 Jackson Street, Suite 200, Golden, CO 80401 dated November 9, 2004 (KOMEX report), includes dose modeling for much of the facility but that report did not include the area of evaporation Ponds 9 and 10 or the Mill Area. This report discusses the dose modeling for those areas.

There is a scarcity of information regarding the concentration of the radionuclide of concern (RoC) in the specified areas included in this report. A set of soil sample data is available for Pond 9. These samples were collected after the remediation in the pond area was completed by removing the soil in areas where the gamma scan result were below 27,000 cpm following the protocol discussed the KOMEX report. This data is expected to representative of data for areas that have the soil removed to similar levels such as the Mill Area. This data was compared to the background soil sampling data contained in the KOMEX report. The comparison data is contained in Table 1 on the following pages. The data in Table 1 shows that the area sampled in Pond 9 were lower in the ROC's than the background area.

There is some limited soil sampling data available for Pond 10. Two composite soil samples were collected from previously collected soil samples from that area, one from soil from the top 0" to 6" and another from 6" to 12" from the surface. The 0' to 6" inch composite contained that contained 6.41, 444, 41.8 pCi/g for Ra-226, Th-230, and U-total, respectively. The 6"-12" composite sample had 1.12, 66, and 19.9 pCi/g for Ra-226, Th-230, and $U_{total}$, respectively.

Table 1 Comparison Between Pond 9 Surface Soil Samples and Background Surface Soil Samples

| Pond 9 Surface Soil Samples | | | | Background Surface Soil Samples | | | |
|---|---|---|---|---|---|---|---|
| | Th-230 | Ra-226 | U-238 | | Th-230 | Ra-226 | U-Total |
| Label | pCi/g | pCi/g | pCi/g | Location | pCi/g | pCi/g | pCi/g |
| P-9 #-101 | 1.6 | 0.5 | 0 | W-17 | 4.5 | 6.49 | 4.95 |
| P-9 #-102 | 3.3 | 1.8 | 0 | W-18 | 22.5 | 7.06 | 6.21 |
| P-9 #-103 | 1.1 | 1.1 | 0 | W-19 | 9.03 | 1.47 | 1.09 |
| P-9 #01 | 1.3 | 1.2 | 0 | W-21 | 13.2 | 5.1 | 5.24 |
| P-9 #02 | 0.9 | 1.1 | 0 | W-8 | 1.62 | 1.82 | 0.39 |
| P-9 #04 | 1 | 0 | 0 | W-9 | 2.13 | 2.47 | 0.74 |
| P-9 #05 | 9.9 | 4 | 0 | X-11 | 0.65 | 1.02 | 1.03 |
| P-9 #08 | 16.5 | 3 | 0 | X-12 | 3.63 | 3.61 | 1.54 |
| P-9 #09 | 1.7 | 0.8 | 0 | X-12-SE | 1.23 | 1.66 | 1.23 |
| P-9 #10 | 1 | 0.8 | 0 | X-13 | 0.48 | 0.62 | 0.61 |
| P-9 #100 | 0.6 | 0.6 | 0 | X-13-SE | 0.83 | 1.07 | 0.77 |
| P-9 #11 | 0.9 | 0.5 | 0 | X-14 | 0.51 | 0.78 | 0.64 |
| P-9 #12 | 0.7 | 0.6 | 0 | X-14-SE | 0.79 | 0.88 | 0.43 |
| P-9 #13 | 0.4 | 2.5 | 0 | X-15 | 0.71 | 0.54 | 0.42 |
| P-9 #14 | 0.5 | 1.6 | 0 | X-15-SE | 1.48 | 1.72 | 1.22 |
| P-9 #15 | 0.9 | 1.1 | 0.56 | X-16 | 1.43 | 0.77 | 1.09 |
| P-9 #16 | 2 | 1.7 | 0 | X-16-SE | 2.28 | 1.82 | 1 |
| P-9 #17 | 0 | 1.2 | 0 | X-17 | 0.81 | 0.69 | 0.61 |
| P-9 #18 | 0.9 | 1.4 | 0 | X-17-SE | 2.27 | 2.01 | 1.48 |
| P-9 #19 | 13.3 | 1.9 | 0 | X-18-SE | 17.8 | 7.5 | 2.99 |
| P-9 #20 | 5.2 | 1 | 0 | X-19 | 15.1 | 8.7 | 22.8 |
| P-9 #21 | 7.1 | 1.6 | 0 | X-9 | 2.11 | 2.72 | 0.64 |
| P-9 #22 | 3 | 2.1 | 0 | Y-10 | 2.1 | 2.21 | 1.38 |
| P-9 #23 | 6.9 | 1.8 | 0 | Y-11 | 1.67 | 1.84 | 0.74 |
| P-9 #24 | 3.9 | 1.2 | 0 | Y-11-SE | 0.75 | 1.12 | 0.87 |
| P-9 #27 | 1.7 | 1.3 | 0 | Y-12 | 2.73 | 3.12 | 1.26 |
| P-9 #28 | 1.3 | 1.1 | 0 | Y-12 | | 1.86 | |
| P-9 #29 | 1.4 | 1.1 | 0 | Y-12-SE | 5.79 | 6.03 | 1.53 |
| P-9 #30 | 5.7 | 2 | 0 | Y-13 | 0.43 | 0.63 | 0.35 |
| P-9 #33 | 13.5 | 1.5 | 0 | Y-13-SE | 3.19 | 3.66 | 0.84 |
| P-9 #34 | 2 | 1.8 | 0 | Y-14 | 2.62 | 1.95 | 0.87 |
| P-9 #35 | 1.5 | 1.6 | 2.2 | Y-14-SE | 3.51 | 3.11 | 0.81 |
| P-9 #36 | 1.3 | 1.2 | 0 | Y-15 | 5.63 | 3.85 | 1.32 |
| P-9 #37 | 3.5 | 1.5 | 0 | Y-15-SE | 8.85 | 7.14 | 2.3 |
| P-9 #38 | 0.6 | 1.4 | 0 | Y-16-SE | 14.4 | 11.2 | 0.19 |
| P-9 #39 | 0.5 | 2.3 | 0 | Y-17 | 4.38 | 2.14 | 1.35 |
| P-9 #40 | 1.2 | 1.3 | 0 | Y-17-SE | 12.8 | 8.33 | 0.01 |
| P-9 #41 | 2.1 | 0.4 | 0 | Y-18-SE | 13.5 | 6.21 | 2.22 |
| P-9 #42 | 1.4 | 0.9 | 0 | Z-10 | 2.42 | 2.43 | 0.84 |
| P-9 #43 | 0.9 | 1.5 | 0 | Z-11 | 1.91 | 1.87 | 0.96 |
| P-9 #44 | 14.7 | 2.1 | 0 | Z-11-SE | 3.19 | 3.55 | 1.38 |
| P-9 #45 | 14.2 | 1.2 | 0.38 | Z-12 | 3.47 | 3.14 | 1.12 |

## Table 1 Continued

| Pond 9 Surface Soil Samples | | | |
|---|---|---|---|
| Label | Th-230 pCi/g | Ra-226 pCi/g | U-238 pCi/g |
| P-9 #45 | 14.2 | 1.2 | 0.38 |
| P-9 #46 | 9.1 | 1.9 | 0 |
| P-9 #47 | 3.4 | 1.2 | 0 |
| P-9 #48 | 7.8 | 2.5 | 0 |
| P-9 #49 | 3.6 | 1 | 0 |
| P-9 #50 | 1.4 | 0.8 | 0 |
| P-9 #53 | 5.5 | 3.1 | 0 |
| P-9 #54 | 12.9 | 1.8 | 0 |
| P-9 #56 | 12.7 | 1.8 | 0 |
| P-9 #57 | 10.5 | 1.6 | 0 |
| P-9 #58 | 10.4 | 1.2 | 0 |
| P-9 #59 | 0.8 | 1.9 | 0 |
| P-9 #60 | 4.3 | 3 | 0 |
| P-9 #61 | 6.1 | 1.5 | 0 |
| P-9 #62 | 3.8 | 2.5 | 0 |
| P-9 #63 | 13.1 | 1 | 0 |
| P-9 #64 | 0.8 | 1.8 | 0 |
| P-9 #67 | 4.4 | 1.4 | 0 |
| P-9 #70 | 10.4 | 1.2 | 0 |
| P-9 #71 | 4.2 | 2 | 0 |
| P-9 #72 | 12.8 | 3.9 | 0 |
| P-9 #73 | 11.8 | 1 | 0 |
| P-9 #74 | 6.2 | 6.2 | 0 |
| P-9 #75 | 15 | 1.4 | 2.98 |
| P-9 #76 | 15 | 1.7 | 0 |
| P-9 #77 | 2.5 | 2.1 | 0 |
| P-9 #78 | 4 | 3.1 | 0 |
| P-9 #79 | 7 | 2.5 | 0 |
| P-9 #80 | 2.9 | 1.3 | 0 |
| P-9 #81 | 7.3 | 2.5 | 0 |
| P-9 #82 | 1.3 | 0.8 | 0 |
| P-9 #83 | 10.1 | 1.1 | 0 |
| P-9 #86 | 1.5 | 1.2 | 1.74 |
| P-9 #88 | 5.4 | 0.9 | 0 |
| P-9 #93 | 14 | 0.6 | 0 |
| P-9 #94 | 2.7 | 1.8 | 0 |
| P-9 #95 | 5.7 | 1.5 | 0.63 |
| P-9 #97 | 2.1 | 1.3 | 0 |
| P-9 #98 | 1.4 | 1.3 | 0 |
| Average | 5.1 | 1.6 | 0.1 |
| ST DEV | 4.7 | 0.9 | 0.5 |
| 95th Conf | 14.4 | 3.4 | 1.0 |

| Background Surface Soil Samples | | | |
|---|---|---|---|
| Location | Th-230 pCi/g | Ra-226 pCi/g | U-Total pCi/g |
| Z-12 | 3.47 | 3.14 | 1.12 |
| Z-12-SE | 4.65 | 4.66 | 1.32 |
| Z-13-SE | 2.11 | 2.11 | 0.72 |
| Z-14-SE | 12.2 | 12.8 | 4.96 |
| Z-15 | 7.05 | 5.96 | 2.35 |
| Z-15-SE | 11.5 | 7.56 | 2.44 |
| Z-16-SE | 7.3 | 5.18 | 1.48 |
| Z-17-SE | | | |
| Z-9 | 1.71 | 2.33 | 0.87 |
| Average | 5.1 | 3.6 | 1.9 |
| ST DEV | 5.3 | 2.9 | 3.4 |
| 95th Conf | 15.5 | 9.3 | 8.5 |
| Average | 5.1 | 3.6 | 1.9 |
| ST DEV | 5.3 | 2.9 | 3.4 |
| 95th Conf | 15.5 | 9.3 | 8.5 |

**Figure 1 Scan Results for the Mill Area**

Color Code: Blue <29,000; Green > 29,000< 35,000; Yellow >35,000 <40,000; Red >40,000 >50,000 Black >50,000

In the Mill area, some surface gamma scan data is available. This scan data extends over the entire Mill and includes the areas that are likely most affected by the mill operations. See Figure 1. The scan information is useful to show give information about the potential ROC contamination. Much of the area, s depicted by the black symbols, has contamination greater than the 30,000 cpm that would be indicative of ROC contamination below the guideline limit value. However the detailed information used to depict the contamination with the colored symbols has no gamma measurements above the level of concern for the ARC.

Before undertaking the dose modeling for this report, the current version of RESRAD, version 6.5, was used with the same parameters used in the KOMEX report to assure that the two different versions of RESRAD calculated the same projected doses. The version 6.5 program output matched the results for the

Ra-226 Baseline dose modeling and for the Ponds 4 – 8 dose modeling. This gave confidence that any modeling undertaken using the latest version of RESRAD would project reasonable doses for the area under consideration in this report.

The KOMEX report had use of more data but not enough to enable a definitive and defendable soil concentration value for the areas modeled – Ponds 4 through 8. There was information available including concentration measurements of RoC concentrations in individual soil samples. In the KOMEX report it is recognized that the data is insufficient to allow "normal" dose modeling for these areas. The use of the maximum concentration values by the KOMEX report found in the ponds for the dose modeling gives an extremely conservative dose projection.

It is not anticipated that the RoC concentration in Ponds 9 and 10 will be significantly different than the concentrations in Evaporation Ponds 4 through 8 based on the available data. However, the data for those areas does not give a maximum value. Using the concentrations of RoC as used for Ponds 7 and 8 along with the same site specific parameters, should make it possible to derive a dose value that is convincingly conservative for Ponds 9 and 10. The KOMEX Report shows a dose of less than 10 mrem/yr for Ponds 4 – 8. The results for ponds 9 and 10 using the same data as for Ponds 7 and 8 are shown on in Table 2 on the following page. Figure 2 is the graphic output from the RESRAD output. The maximum dose for the 1000 year period after The ARC is complete is 9.8 mrem/yr. The complete RESRAD[1] report is included as Attachment 1 to this report.

[1] Yu, C., et. al., 2009. "RESRAD for Windows," Version 6.5, Argonne National Laboratory, October 30, 2009

As indicated above, no soil sampling data is available for the Mill Area. The scan data covers a large portion of the Mill Area and the scans shows a similar picture of the surface conditions as shown in scans of the areas where soil samples were collected.

Table 2 RESRAD Dose Modeling Summary for Ponds 9 and 10

RESRAD, Version 6.5 T« Limit = 180 days 03/12/2014 20:48 Page 11
Summary : RAM Evaporation Ponds 9 & 10
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\RAM PONDS 9 AND 10.RAD

| Contaminated Zone Dimensions | | Initial Soil Concentrations, pCi/g | |
|---|---|---|---|
| Area: | 100000.00 square meters | Pb-210 | 7.800E+01 |
| Thickness: | 2.00 meters | Ra-226 | 7.800E+01 |
| Cover Depth: | 0.30 meters | Th-230 | 2.070E+03 |
| | | U-234 | 1.100E+01 |
| | | U-235 | 1.000E+00 |
| | | U-238 | 1.100E+01 |

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 2.500E+01 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

| t (years): | 0.000E+00 | 1.000E+00 | 3.000E+00 | 1.000E+01 | 3.000E+01 | 1.000E+02 | 3.000E+02 | 1.000E+03 |
|---|---|---|---|---|---|---|---|---|
| TDOSE(t): | 7.510E+00 | 7.558E+00 | 7.652E+00 | 7.960E+00 | 8.679E+00 | 9.789E+00 | 7.565E+00 | 6.566E-01 |
| M(t): | 3.004E-01 | 3.023E-01 | 3.061E-01 | 3.184E-01 | 3.471E-01 | 3.916E-01 | 3.026E-01 | 2.626E-02 |

**Maximum TDOSE(t): 9.819E+00 mrem/yr at t = 115.5 ñ 0.2 years**

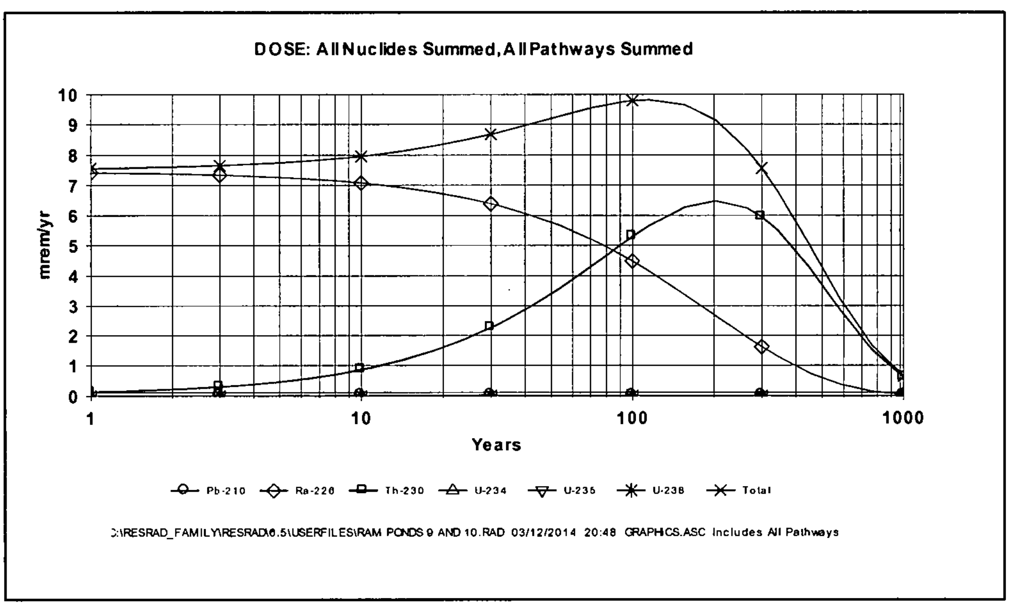


**Figure 2. Graphic Result of the Dose Modeling**

Figure 1 is a cropped section of a larger map showing primarily the Mill Area. The color code for the scan values is shown below the figure. The base data for the scanning was made available for this analysis. The cpm values ranged from 18,600 to 212,400 cpm. The KOMEX report has a graphical correlation between the gamma scanning and the measured soil RoC concentrations. This graph was extended so it covered the entire range of the scan data. The 212,000 cpm equated to 40.4 pCi/g. Appling the same ratio as applied for the original graphical data to derive the UCL this upper concentration would be 74.8 pCi/g.

Before the scan base data was made available, it was decided to use RESRAD to determine the maximum concentration that would be within the limiting dose of 18 mrem/yr in the rancher resident scenario. RESRAD was set up using the same parameters as in the KORMAX study with the concentration of ROC set to 1 pCi/g of Ra-226 and the proportional amount of the other ROC in the Ponds 4-8 data. These values were:

| | |
|---|---|
| Ra-226 | 1 pCi/g |
| Pb-210 | 1 pCi/g |
| Th-230 | 78.5 pCi/g |
| U-234 | 1.4 pCi/g |
| U-235 | 0.013 pCi/g |
| U-238 | 1.4 pCi/g |

The summary of the results are shown in Table 3 on the next page. The dose from the mix of RoC shown above is 0.1262 mrem/yr. When this dose is incremented to the limiting dose of 18 mrem/yr, the Ra-226 concentration would be 142 pCi/g. Using the projected maximum pCi/g value from the scan data for the mill area of 74.8 pCi/g gives a resulting dose of 9.5 mrem/yr. This is much the same as the result of the Ponds 9 and 10 where 78 pCi/g of Ra-226 gave a dose of 9.8 mrem/yr. The complete RESRAD program output for the 1 pCi/g calculation is in Attachment 2.

Table 3 RESRAD Dose Modeling Summary for the Mill Area with 1 pCi/g of Ra-226

```
RESRAD, Version 6.5      T« Limit = 180 days       03/25/2014  12:52  Page  11
 Summary :  Mill Area with 1 pCi/g and proportional amounts of Th and U from Pond areas
 File    : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\RAM MILL AREA 1 PCI-G.RAD

      Contaminated Zone Dimensions            Initial Soil Concentrations, pCi/g
      ============================            ==================================
        Area: 100000.00 square meters                Pb-210      1.000E+00
   Thickness:       2.00 meters                      Ra-226      1.000E+00
 Cover Depth:       0.30 meters                      Th-230      2.650E+01
                                                     U-234       1.400E+00
                                                     U-235       1.300E-02
                                                     U-238       1.400E+00
0
                                   Total Dose TDOSE(t), mrem/yr
                             Basic Radiation Dose Limit = 2.500E+01 mrem/yr
              Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)
              ====================================================================
T (years): 0.000E+00  1.000E+00  3.000E+00  1.000E+01  3.000E+01  1.000E+02  3.000E+02  1.000E+03
TDOSE(t):  9.706E-02  9.767E-02  9.886E-02  1.028E-01  1.119E-01  1.259E-01  9.708E-02  8.415E-03
    M(t):  3.883E-03  3.907E-03  3.955E-03  4.111E-03  4.476E-03  5.036E-03  3.883E-03  3.366E-04

Maximum TDOSE(t):  1.262E-01 mrem/yr   at t =   114.9 ± 0.2 years
```

The dose modeling based on the maximum concentrations of ROC either measured or projected from scan data is different from the general procedure which uses the upper control limit (UCL) of the ***average*** concentration of ROC. The average value, even taken to the UCL, is seldom a large fraction of the maximum value measured. In any case, the calculated doses for Ponds 9 and 10 and the Mill Area are well below the dose guideline value of 18 mrem/yr.

In conclusion, the modeling result for Ponds 9 and 10 and the Mill Area were determined using the same parameters used in the KOMEX Report after verifying that the later version of RESRAD would give the same results as fund in the KOMEX Report. The data used has been identified in this report and includes maximum concentration of soil samples found in areas outside the area of Ponds 9 and 10 modeled in this report but are values that are not expected to be exceeded in Ponds 9 and 10 based on the information available. The modeling for the Mill Area is based on scan information and the results are projected to a level that is above any measured soil samples found at the site. The results indicate that the dose guideline

limit of 18 mrem/yr will not be exceeded if the alternate remediation criteria (ARC) procedures are followed. The removal of all soil with gamma scan values >27,000 cpm will also assure that the dose levels will be extremely low in all the area modeled in this report. The parameters used in the modeling include a cover of one foot of soil (0.3 meters) which is a primary parameter for the ARC. In the professional judgment of this author, there is sufficient data available to determine that the areas considered in this report will meet the criteria for ARC.

**ATTACHMENT 1 - RESRAD Results for Ponds 9 and 10**

RESRAD, Version 6.5    T« Limit = 180 days    03/12/2014  21:49  Page  1
Summary : RAM Evaporation Ponds 9 & 10
File    : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\RAM EVAP PONDS 9 AND 10.RAD

Table of Contents
=================

Part I: Mixture Sums and Single Radionuclide Guidelines

Dose Conversion Factor (and Related) Parameter Summary
Dose Library: ICRP 72 Plus FGR 12 & ICRP 72 (Adult)

| 0 Menu | Parameter | Current Value# | Base Case* | Parameter Name |
|---|---|---|---|---|
| A-1 | DCF's for external ground radiation, (mrem/yr)/(pCi/g) | | | |
| A-1 | Ac-227 (Source: FGR 12) | 4.951E-04 | 4.951E-04 | DCF1( 1) |
| A-1 | At-218 (Source: FGR 12) | 5.847E-03 | 5.847E-03 | DCF1( 2) |
| A-1 | Bi-210 (Source: FGR 12) | 3.606E-03 | 3.606E-03 | DCF1( 3) |
| A-1 | Bi-211 (Source: FGR 12) | 2.559E-01 | 2.559E-01 | DCF1( 4) |
| A-1 | Bi-214 (Source: FGR 12) | 9.808E+00 | 9.808E+00 | DCF1( 5) |
| A-1 | Fr-223 (Source: FGR 12) | 1.980E-01 | 1.980E-01 | DCF1( 6) |
| A-1 | Pa-231 (Source: FGR 12) | 1.906E-01 | 1.906E-01 | DCF1( 7) |
| A-1 | Pa-234 (Source: FGR 12) | 1.155E+01 | 1.155E+01 | DCF1( 8) |
| A-1 | Pa-234m (Source: FGR 12) | 8.967E-02 | 8.967E-02 | DCF1( 9) |
| A-1 | Pb-210 (Source: FGR 12) | 2.447E-03 | 2.447E-03 | DCF1( 10) |
| A-1 | Pb-211 (Source: FGR 12) | 3.064E-01 | 3.064E-01 | DCF1( 11) |
| A-1 | Pb-214 (Source: FGR 12) | 1.341E+00 | 1.341E+00 | DCF1( 12) |
| A-1 | Po-210 (Source: FGR 12) | 5.231E-05 | 5.231E-05 | DCF1( 13) |
| A-1 | Po-211 (Source: FGR 12) | 4.764E-02 | 4.764E-02 | DCF1( 14) |
| A-1 | Po-214 (Source: FGR 12) | 5.138E-04 | 5.138E-04 | DCF1( 15) |
| A-1 | Po-215 (Source: FGR 12) | 1.016E-03 | 1.016E-03 | DCF1( 16) |
| A-1 | Po-218 (Source: FGR 12) | 5.642E-05 | 5.642E-05 | DCF1( 17) |
| A-1 | Ra-223 (Source: FGR 12) | 6.034E-01 | 6.034E-01 | DCF1( 18) |
| A-1 | Ra-226 (Source: FGR 12) | 3.176E-02 | 3.176E-02 | DCF1( 19) |
| A-1 | Rn-219 (Source: FGR 12) | 3.083E-01 | 3.083E-01 | DCF1( 20) |
| A-1 | Rn-222 (Source: FGR 12) | 2.354E-03 | 2.354E-03 | DCF1( 21) |
| A-1 | Th-227 (Source: FGR 12) | 5.212E-01 | 5.212E-01 | DCF1( 22) |
| A-1 | Th-230 (Source: FGR 12) | 1.209E-03 | 1.209E-03 | DCF1( 23) |
| A-1 | Th-231 (Source: FGR 12) | 3.643E-02 | 3.643E-02 | DCF1( 24) |
| A-1 | Th-234 (Source: FGR 12) | 2.410E-02 | 2.410E-02 | DCF1( 25) |
| A-1 | Tl-207 (Source: FGR 12) | 1.980E-02 | 1.980E-02 | DCF1( 26) |
| A-1 | Tl-210 (Source: no data) | 0.000E+00 | -2.000E+00 | DCF1( 27) |
| A-1 | U-234 (Source: FGR 12) | 4.017E-04 | 4.017E-04 | DCF1( 28) |
| A-1 | U-235 (Source: FGR 12) | 7.211E-01 | 7.211E-01 | DCF1( 29) |
| A-1 | U-238 (Source: FGR 12) | 1.031E-04 | 1.031E-04 | DCF1( 30) |
| | | | | |
| B-1 | Dose conversion factors for inhalation, mrem/pCi: | | | |
| B-1 | Ac-227+D | 2.109E+00 | 2.035E+00 | DCF2( 1) |
| B-1 | Pa-231 | 5.180E-01 | 5.180E-01 | DCF2( 2) |
| B-1 | Pb-210+D | 3.694E-02 | 2.072E-02 | DCF2( 3) |
| B-1 | Ra-226+D | 3.531E-02 | 3.515E-02 | DCF2( 4) |
| B-1 | Th-230 | 3.700E-01 | 3.700E-01 | DCF2( 5) |
| B-1 | U-234 | 3.480E-02 | 3.478E-02 | DCF2( 6) |
| B-1 | U-235+D | 3.150E-02 | 3.145E-02 | DCF2( 7) |
| B-1 | U-238 | 2.960E-02 | 2.960E-02 | DCF2( 8) |
| B-1 | U-238+D | 2.963E-02 | 2.960E-02 | DCF2( 9) |
| | | | | |
| D-1 | Dose conversion factors for ingestion, mrem/pCi: | | | |
| D-1 | Ac-227+D | 4.473E-03 | 4.070E-03 | DCF3( 1) |
| D-1 | Pa-231 | 2.630E-03 | 2.627E-03 | DCF3( 2) |
| D-1 | Pb-210+D | 6.995E-03 | 2.553E-03 | DCF3( 3) |
| D-1 | Ra-226+D | 1.041E-03 | 1.036E-03 | DCF3( 4) |
| D-1 | Th-230 | 7.770E-04 | 7.770E-04 | DCF3( 5) |
| D-1 | U-234 | 1.810E-04 | 1.813E-04 | DCF3( 6) |

Dose Conversion Factor (and Related) Parameter Summary (continued)
Dose Library: ICRP 72 Plus FGR 12 & ICRP 72 (Adult)

| Menu | Parameter | Current Value# | Base Case* | Parameter Name |
|---|---|---|---|---|
| D-1 | U-235+D | 1.753E-04 | 1.739E-04 | DCF3( 7) |
| D-1 | U-238 | 1.670E-04 | 1.665E-04 | DCF3( 8) |
| D-1 | U-238+D | 1.796E-04 | 1.665E-04 | DCF3( 9) |
| | | | | |
| D-34 | Food transfer factors: | | | |
| D-34 | Ac-227+D , plant/soil concentration ratio, dimensionless | 2.500E-03 | 2.500E-03 | RTF( 1,1) |
| D-34 | Ac-227+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d) | 2.000E-05 | 2.000E-05 | RTF( 1,2) |
| D-34 | Ac-227+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d) | 2.000E-05 | 2.000E-05 | RTF( 1,3) |
| D-34 | | | | |
| D-34 | Pa-231 , plant/soil concentration ratio, dimensionless | 1.000E-02 | 1.000E-02 | RTF( 2,1) |
| D-34 | Pa-231 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d) | 5.000E-03 | 5.000E-03 | RTF( 2,2) |
| D-34 | Pa-231 , milk/livestock-intake ratio, (pCi/L)/(pCi/d) | 5.000E-06 | 5.000E-06 | RTF( 2,3) |
| D-34 | | | | |
| D-34 | Pb-210+D , plant/soil concentration ratio, dimensionless | 1.000E-02 | 1.000E-02 | RTF( 3,1) |
| D-34 | Pb-210+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d) | 8.000E-04 | 8.000E-04 | RTF( 3,2) |
| D-34 | Pb-210+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d) | 3.000E-04 | 3.000E-04 | RTF( 3,3) |
| D-34 | | | | |
| D-34 | Ra-226+D , plant/soil concentration ratio, dimensionless | 4.000E-02 | 4.000E-02 | RTF( 4,1) |
| D-34 | Ra-226+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d) | 1.000E-03 | 1.000E-03 | RTF( 4,2) |
| D-34 | Ra-226+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d) | 1.000E-03 | 1.000E-03 | RTF( 4,3) |
| D-34 | | | | |
| D-34 | Th-230 , plant/soil concentration ratio, dimensionless | 1.000E-03 | 1.000E-03 | RTF( 5,1) |
| D-34 | Th-230 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d) | 1.000E-04 | 1.000E-04 | RTF( 5,2) |
| D-34 | Th-230 , milk/livestock-intake ratio, (pCi/L)/(pCi/d) | 5.000E-06 | 5.000E-06 | RTF( 5,3) |
| D-34 | | | | |
| D-34 | U-234 , plant/soil concentration ratio, dimensionless | 2.500E-03 | 2.500E-03 | RTF( 6,1) |
| D-34 | U-234 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d) | 3.400E-04 | 3.400E-04 | RTF( 6,2) |
| D-34 | U-234 , milk/livestock-intake ratio, (pCi/L)/(pCi/d) | 6.000E-04 | 6.000E-04 | RTF( 6,3) |
| D-34 | | | | |
| D-34 | U-235+D , plant/soil concentration ratio, dimensionless | 2.500E-03 | 2.500E-03 | RTF( 7,1) |
| D-34 | U-235+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d) | 3.400E-04 | 3.400E-04 | RTF( 7,2) |
| D-34 | U-235+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d) | 6.000E-04 | 6.000E-04 | RTF( 7,3) |
| D-34 | | | | |
| D-34 | U-238 , plant/soil concentration ratio, dimensionless | 2.500E-03 | 2.500E-03 | RTF( 8,1) |
| D-34 | U-238 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d) | 3.400E-04 | 3.400E-04 | RTF( 8,2) |
| D-34 | U-238 , milk/livestock-intake ratio, (pCi/L)/(pCi/d) | 6.000E-04 | 6.000E-04 | RTF( 8,3) |
| D-34 | | | | |
| D-34 | U-238+D , plant/soil concentration ratio, dimensionless | 2.500E-03 | 2.500E-03 | RTF( 9,1) |
| D-34 | U-238+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d) | 3.400E-04 | 3.400E-04 | RTF( 9,2) |
| D-34 | U-238+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d) | 6.000E-04 | 6.000E-04 | RTF( 9,3) |
| | | | | |
| D-5 | Bioaccumulation factors, fresh water, L/kg: | | | |
| D-5 | Ac-227+D , fish | 1.500E+01 | 1.500E+01 | BIOFAC( 1,1) |
| D-5 | Ac-227+D , crustacea and mollusks | 1.000E+03 | 1.000E+03 | BIOFAC( 1,2) |
| D-5 | | | | |
| D-5 | Pa-231 , fish | 1.000E+01 | 1.000E+01 | BIOFAC( 2,1) |
| D-5 | Pa-231 , crustacea and mollusks | 1.100E+02 | 1.100E+02 | BIOFAC( 2,2) |
| D-5 | | | | |
| D-5 | Pb-210+D , fish | 3.000E+02 | 3.000E+02 | BIOFAC( 3,1) |
| D-5 | Pb-210+D , crustacea and mollusks | 1.000E+02 | 1.000E+02 | BIOFAC( 3,2) |

Dose Conversion Factor (and Related) Parameter Summary (continued)
Dose Library: ICRP 72 Plus FGR 12 & ICRP 72 (Adult)

| 0 Menu | Parameter | Current Value# | Base Case* | Parameter Name |
|---|---|---|---|---|
| D-5 | Ra-226+D , fish | 5.000E+01 | 5.000E+01 | BIOFAC( 4,1) |
| D-5 | Ra-226+D , crustacea and mollusks | 2.500E+02 | 2.500E+02 | BIOFAC( 4,2) |
| D-5 | | | | |
| D-5 | Th-230 , fish | 1.000E+02 | 1.000E+02 | BIOFAC( 5,1) |
| D-5 | Th-230 , crustacea and mollusks | 5.000E+02 | 5.000E+02 | BIOFAC( 5,2) |
| D-5 | | | | |
| D-5 | U-234 , fish | 1.000E+01 | 1.000E+01 | BIOFAC( 6,1) |
| D-5 | U-234 , crustacea and mollusks | 6.000E+01 | 6.000E+01 | BIOFAC( 6,2) |
| D-5 | | | | |
| D-5 | U-235+D , fish | 1.000E+01 | 1.000E+01 | BIOFAC( 7,1) |
| D-5 | U-235+D , crustacea and mollusks | 6.000E+01 | 6.000E+01 | BIOFAC( 7,2) |
| D-5 | | | | |
| D-5 | U-238 , fish | 1.000E+01 | 1.000E+01 | BIOFAC( 8,1) |
| D-5 | U-238 , crustacea and mollusks | 6.000E+01 | 6.000E+01 | BIOFAC( 8,2) |
| D-5 | | | | |
| D-5 | U-238+D , fish | 1.000E+01 | 1.000E+01 | BIOFAC( 9,1) |
| D-5 | U-238+D , crustacea and mollusks | 6.000E+01 | 6.000E+01 | BIOFAC( 9,2) |

#For DCF1(xxx) only, factors are for infinite depth & area. See ETFG table in Ground Pathway of Detailed Report.
*Base Case means Default.Lib w/o Associate Nuclide contributions.

Site-Specific Parameter Summary

| 0 Menu | Parameter | User Input | Default | Used by RESRAD (If different from user input) | Parameter Name |
|---|---|---|---|---|---|
| R011 | Area of contaminated zone (m**2) | 1.000E+05 | 1.000E+04 | --- | AREA |
| R011 | Thickness of contaminated zone (m) | 2.000E+00 | 2.000E+00 | --- | THICK0 |
| R011 | Fraction of contamination that is submerged | 0.000E+00 | 0.000E+00 | --- | SUBMFRACT |
| R011 | Length parallel to aquifer flow (m) | 5.810E+02 | 1.000E+02 | --- | LCZPAQ |
| R011 | Basic radiation dose limit (mrem/yr) | 2.500E+01 | 3.000E+01 | --- | BRDL |
| R011 | Time since placement of material (yr) | 0.000E+00 | 0.000E+00 | --- | TI |
| R011 | Times for calculations (yr) | 1.000E+00 | 1.000E+00 | --- | T( 2) |
| R011 | Times for calculations (yr) | 3.000E+00 | 3.000E+00 | --- | T( 3) |
| R011 | Times for calculations (yr) | 1.000E+01 | 1.000E+01 | --- | T( 4) |
| R011 | Times for calculations (yr) | 3.000E+01 | 3.000E+01 | --- | T( 5) |
| R011 | Times for calculations (yr) | 1.000E+02 | 1.000E+02 | --- | T( 6) |
| R011 | Times for calculations (yr) | 3.000E+02 | 3.000E+02 | --- | T( 7) |
| R011 | Times for calculations (yr) | 1.000E+03 | 1.000E+03 | --- | T( 8) |
| R011 | Times for calculations (yr) | not used | 0.000E+00 | --- | T( 9) |
| R011 | Times for calculations (yr) | not used | 0.000E+00 | --- | T(10) |
| | | | | | |
| R012 | Initial principal radionuclide (pCi/g): Pb-210 | 7.800E+01 | 0.000E+00 | --- | S1(3) |
| R012 | Initial principal radionuclide (pCi/g): Ra-226 | 7.800E+01 | 0.000E+00 | --- | S1(4) |
| R012 | Initial principal radionuclide (pCi/g): Th-230 | 2.070E+03 | 0.000E+00 | --- | S1(5) |
| R012 | Initial principal radionuclide (pCi/g): U-234 | 1.100E+01 | 0.000E+00 | --- | S1(6) |
| R012 | Initial principal radionuclide (pCi/g): U-235 | 1.000E+00 | 0.000E+00 | --- | S1(7) |
| R012 | Initial principal radionuclide (pCi/g): U-238 | 1.100E+01 | 0.000E+00 | --- | S1(8) |
| R012 | Concentration in groundwater (pCi/L): Pb-210 | not used | 0.000E+00 | --- | W1( 3) |
| R012 | Concentration in groundwater (pCi/L): Ra-226 | not used | 0.000E+00 | --- | W1( 4) |
| R012 | Concentration in groundwater (pCi/L): Th-230 | not used | 0.000E+00 | --- | W1( 5) |
| R012 | Concentration in groundwater (pCi/L): U-234 | not used | 0.000E+00 | --- | W1( 6) |
| R012 | Concentration in groundwater (pCi/L): U-235 | not used | 0.000E+00 | --- | W1( 7) |
| R012 | Concentration in groundwater (pCi/L): U-238 | not used | 0.000E+00 | --- | W1( 8) |
| | | | | | |
| R013 | Cover depth (m) | 3.000E-01 | 0.000E+00 | --- | COVER0 |
| R013 | Density of cover material (g/cm**3) | 1.500E+00 | 1.500E+00 | --- | DENSCV |
| R013 | Cover depth erosion rate (m/yr) | 1.000E-05 | 1.000E-03 | --- | VCV |
| R013 | Density of contaminated zone (g/cm**3) | 1.500E+00 | 1.500E+00 | --- | DENSCZ |
| R013 | Contaminated zone erosion rate (m/yr) | 1.000E-05 | 1.000E-03 | --- | VCZ |
| R013 | Contaminated zone total porosity | 2.000E-01 | 4.000E-01 | --- | TPCZ |
| R013 | Contaminated zone field capacity | 5.000E-02 | 2.000E-01 | --- | FCCZ |
| R013 | Contaminated zone hydraulic conductivity (m/yr) | 2.002E+03 | 1.000E+01 | --- | HCCZ |
| R013 | Contaminated zone b parameter | 1.000E+00 | 5.300E+00 | --- | BCZ |
| R013 | Average annual wind speed (m/sec) | 3.900E+00 | 2.000E+00 | --- | WIND |
| R013 | Humidity in air (g/m**3) | not used | 8.000E+00 | --- | HUMID |
| R013 | Evapotranspiration coefficient | 9.000E-01 | 5.000E-01 | --- | EVAPTR |
| R013 | Precipitation (m/yr) | 2.660E-01 | 1.000E+00 | --- | PRECIP |
| R013 | Irrigation (m/yr) | 0.000E+00 | 2.000E-01 | --- | RI |
| R013 | Irrigation mode | overhead | overhead | --- | IDITCH |
| R013 | Runoff coefficient | 4.000E-01 | 2.000E-01 | --- | RUNOFF |
| R013 | Watershed area for nearby stream or pond (m**2) | 1.560E+08 | 1.000E+06 | --- | WAREA |
| R013 | Accuracy for water/soil computations | 1.000E-03 | 1.000E-03 | --- | EPS |
| | | | | | |
| R014 | Density of saturated zone (g/cm**3) | 2.400E+00 | 1.500E+00 | --- | DENSAQ |
| R014 | Saturated zone total porosity | 8.000E-02 | 4.000E-01 | --- | TPSZ |

Site-Specific Parameter Summary (continued)

| 0 Menu | Parameter | User Input | Default | Used by RESRAD (If different from user input) | Parameter Name |
|---|---|---|---|---|---|
| R014 | Saturated zone effective porosity | 4.000E-02 | 2.000E-01 | --- | EPSZ |
| R014 | Saturated zone field capacity | 4.000E-02 | 2.000E-01 | --- | FCSZ |
| R014 | Saturated zone hydraulic conductivity (m/yr) | 6.700E+01 | 1.000E+02 | --- | HCSZ |
| R014 | Saturated zone hydraulic gradient | 4.000E-02 | 2.000E-02 | --- | HGWT |
| R014 | Saturated zone b parameter | 1.000E+00 | 5.300E+00 | --- | BSZ |
| R014 | Water table drop rate (m/yr) | 1.000E+00 | 1.000E-03 | --- | VWT |
| R014 | Well pump intake depth (m below water table) | 1.000E-05 | 1.000E+01 | --- | DWIBWT |
| R014 | Model: Nondispersion (ND) or Mass-Balance (MB) | ND | ND | --- | MODEL |
| R014 | Well pumping rate (m**3/yr) | 0.000E+00 | 2.500E+02 | --- | UW |
| | | | | | |
| R015 | Number of unsaturated zone strata | 1 | 1 | --- | NS |
| R015 | Unsat. zone 1, thickness (m) | 6.000E+00 | 4.000E+00 | --- | H(1) |
| R015 | Unsat. zone 1, soil density (g/cm**3) | 1.500E+00 | 1.500E+00 | --- | DENSUZ(1) |
| R015 | Unsat. zone 1, total porosity | 2.000E-01 | 4.000E-01 | --- | TPUZ(1) |
| R015 | Unsat. zone 1, effective porosity | 1.500E-01 | 2.000E-01 | --- | EPUZ(1) |
| R015 | Unsat. zone 1, field capacity | 5.000E-02 | 2.000E-01 | --- | FCUZ(1) |
| R015 | Unsat. zone 1, soil-specific b parameter | 1.000E+00 | 5.300E+00 | --- | BUZ(1) |
| R015 | Unsat. zone 1, hydraulic conductivity (m/yr) | 2.002E+03 | 1.000E+01 | --- | HCUZ(1) |
| | | | | | |
| R016 | Distribution coefficients for Pb-210 | | | | |
| R016 | Contaminated zone (cm**3/g) | 1.000E+00 | 1.000E+02 | --- | DCNUCC( 3) |
| R016 | Unsaturated zone 1 (cm**3/g) | 1.000E+00 | 1.000E+02 | --- | DCNUCU( 3,1) |
| R016 | Saturated zone (cm**3/g) | 9.000E+01 | 1.000E+02 | --- | DCNUCS( 3) |
| R016 | Leach rate (/yr) | 0.000E+00 | 0.000E+00 | 5.148E-03 | ALEACH( 3) |
| R016 | Solubility constant | 0.000E+00 | 0.000E+00 | not used | SOLUBK( 3) |
| | | | | | |
| R016 | Distribution coefficients for Ra-226 | | | | |
| R016 | Contaminated zone (cm**3/g) | 1.000E+00 | 7.000E+01 | --- | DCNUCC( 4) |
| R016 | Unsaturated zone 1 (cm**3/g) | 1.000E+00 | 7.000E+01 | --- | DCNUCU( 4,1) |
| R016 | Saturated zone (cm**3/g) | 9.000E+01 | 7.000E+01 | --- | DCNUCS( 4) |
| R016 | Leach rate (/yr) | 0.000E+00 | 0.000E+00 | 5.148E-03 | ALEACH( 4) |
| R016 | Solubility constant | 0.000E+00 | 0.000E+00 | not used | SOLUBK( 4) |
| | | | | | |
| R016 | Distribution coefficients for Th-230 | | | | |
| R016 | Contaminated zone (cm**3/g) | 1.000E+00 | 6.000E+04 | --- | DCNUCC( 5) |
| R016 | Unsaturated zone 1 (cm**3/g) | 1.000E+00 | 6.000E+04 | --- | DCNUCU( 5,1) |
| R016 | Saturated zone (cm**3/g) | 9.000E+01 | 6.000E+04 | --- | DCNUCS( 5) |
| R016 | Leach rate (/yr) | 0.000E+00 | 0.000E+00 | 5.148E-03 | ALEACH( 5) |
| R016 | Solubility constant | 0.000E+00 | 0.000E+00 | not used | SOLUBK( 5) |
| | | | | | |
| R016 | Distribution coefficients for U-234 | | | | |
| R016 | Contaminated zone (cm**3/g) | 1.000E+00 | 5.000E+01 | --- | DCNUCC( 6) |
| R016 | Unsaturated zone 1 (cm**3/g) | 1.000E+00 | 5.000E+01 | --- | DCNUCU( 6,1) |
| R016 | Saturated zone (cm**3/g) | 9.000E+01 | 5.000E+01 | --- | DCNUCS( 6) |
| R016 | Leach rate (/yr) | 0.000E+00 | 0.000E+00 | 5.148E-03 | ALEACH( 6) |
| R016 | Solubility constant | 0.000E+00 | 0.000E+00 | not used | SOLUBK( 6) |

Site-Specific Parameter Summary (continued)

| 0 Menu | Parameter | User Input | Default | Used by RESRAD (If different from user input) | Parameter Name |
|---|---|---|---|---|---|
| R016 | Distribution coefficients for U-235 | | | | |
| R016 | Contaminated zone (cm**3/g) | 1.000E+00 | 5.000E+01 | --- | DCNUCC( 7) |
| R016 | Unsaturated zone 1 (cm**3/g) | 1.000E+00 | 5.000E+01 | --- | DCNUCU( 7,1) |
| R016 | Saturated zone (cm**3/g) | 9.000E+01 | 5.000E+01 | --- | DCNUCS( 7) |
| R016 | Leach rate (/yr) | 0.000E+00 | 0.000E+00 | 5.148E-03 | ALEACH( 7) |
| R016 | Solubility constant | 0.000E+00 | 0.000E+00 | not used | SOLUBK( 7) |
| | | | | | |
| R016 | Distribution coefficients for U-238 | | | | |
| R016 | Contaminated zone (cm**3/g) | 1.000E+00 | 5.000E+01 | --- | DCNUCC( 8) |
| R016 | Unsaturated zone 1 (cm**3/g) | 1.000E+00 | 5.000E+01 | --- | DCNUCU( 8,1) |
| R016 | Saturated zone (cm**3/g) | 9.000E+01 | 5.000E+01 | --- | DCNUCS( 8) |
| R016 | Leach rate (/yr) | 0.000E+00 | 0.000E+00 | 5.148E-03 | ALEACH( 8) |
| R016 | Solubility constant | 0.000E+00 | 0.000E+00 | not used | SOLUBK( 8) |
| | | | | | |
| R016 | Distribution coefficients for daughter Ac-227 | | | | |
| R016 | Contaminated zone (cm**3/g) | 2.000E+01 | 2.000E+01 | --- | DCNUCC( 1) |
| R016 | Unsaturated zone 1 (cm**3/g) | 2.000E+01 | 2.000E+01 | --- | DCNUCU( 1,1) |
| R016 | Saturated zone (cm**3/g) | 2.000E+01 | 2.000E+01 | --- | DCNUCS( 1) |
| R016 | Leach rate (/yr) | 0.000E+00 | 0.000E+00 | 2.656E-04 | ALEACH( 1) |
| R016 | Solubility constant | 0.000E+00 | 0.000E+00 | not used | SOLUBK( 1) |
| | | | | | |
| R016 | Distribution coefficients for daughter Pa-231 | | | | |
| R016 | Contaminated zone (cm**3/g) | 5.000E+01 | 5.000E+01 | --- | DCNUCC( 2) |
| R016 | Unsaturated zone 1 (cm**3/g) | 5.000E+01 | 5.000E+01 | --- | DCNUCU( 2,1) |
| R016 | Saturated zone (cm**3/g) | 5.000E+01 | 5.000E+01 | --- | DCNUCS( 2) |
| R016 | Leach rate (/yr) | 0.000E+00 | 0.000E+00 | 1.063E-04 | ALEACH( 2) |
| R016 | Solubility constant | 0.000E+00 | 0.000E+00 | not used | SOLUBK( 2) |
| | | | | | |
| R017 | Inhalation rate (m**3/yr) | 8.400E+03 | 8.400E+03 | --- | INHALR |
| R017 | Mass loading for inhalation (g/m**3) | 1.000E-04 | 1.000E-04 | --- | MLINH |
| R017 | Exposure duration | 1.000E+00 | 3.000E+01 | --- | ED |
| R017 | Shielding factor, inhalation | 5.600E-01 | 4.000E-01 | --- | SHF3 |
| R017 | Shielding factor, external gamma | 2.100E-01 | 7.000E-01 | --- | SHF1 |
| R017 | Fraction of time spent indoors | 4.500E-01 | 5.000E-01 | --- | FIND |
| R017 | Fraction of time spent outdoors (on site) | 2.100E-01 | 2.500E-01 | --- | FOTD |
| R017 | Shape factor flag, external gamma | 1.000E+00 | 1.000E+00 | >0 shows circular AREA. | FS |
| R017 | Radii of shape factor array (used if FS = -1): | | | | |
| R017 | Outer annular radius (m), ring 1: | not used | 5.000E+01 | --- | RAD_SHAPE( 1) |
| R017 | Outer annular radius (m), ring 2: | not used | 7.071E+01 | --- | RAD_SHAPE( 2) |
| R017 | Outer annular radius (m), ring 3: | not used | 0.000E+00 | --- | RAD_SHAPE( 3) |
| R017 | Outer annular radius (m), ring 4: | not used | 0.000E+00 | --- | RAD_SHAPE( 4) |
| R017 | Outer annular radius (m), ring 5: | not used | 0.000E+00 | --- | RAD_SHAPE( 5) |
| R017 | Outer annular radius (m), ring 6: | not used | 0.000E+00 | --- | RAD_SHAPE( 6) |
| R017 | Outer annular radius (m), ring 7: | not used | 0.000E+00 | --- | RAD_SHAPE( 7) |
| R017 | Outer annular radius (m), ring 8: | not used | 0.000E+00 | --- | RAD_SHAPE( 8) |
| R017 | Outer annular radius (m), ring 9: | not used | 0.000E+00 | --- | RAD_SHAPE( 9) |
| R017 | Outer annular radius (m), ring 10: | not used | 0.000E+00 | --- | RAD_SHAPE(10) |
| R017 | Outer annular radius (m), ring 11: | not used | 0.000E+00 | --- | RAD_SHAPE(11) |
| R017 | Outer annular radius (m), ring 12: | not used | 0.000E+00 | --- | RAD_SHAPE(12) |

Site-Specific Parameter Summary (continued)

| Menu | Parameter | User Input | Default | Used by RESRAD (If different from user input) | Parameter Name |
|---|---|---|---|---|---|
| R017 | Fractions of annular areas within AREA: | | | | |
| R017 | Ring 1 | not used | 1.000E+00 | --- | FRACA( 1) |
| R017 | Ring 2 | not used | 2.732E-01 | --- | FRACA( 2) |
| R017 | Ring 3 | not used | 0.000E+00 | --- | FRACA( 3) |
| R017 | Ring 4 | not used | 0.000E+00 | --- | FRACA( 4) |
| R017 | Ring 5 | not used | 0.000E+00 | --- | FRACA( 5) |
| R017 | Ring 6 | not used | 0.000E+00 | --- | FRACA( 6) |
| R017 | Ring 7 | not used | 0.000E+00 | --- | FRACA( 7) |
| R017 | Ring 8 | not used | 0.000E+00 | --- | FRACA( 8) |
| R017 | Ring 9 | not used | 0.000E+00 | --- | FRACA( 9) |
| R017 | Ring 10 | not used | 0.000E+00 | --- | FRACA(10) |
| R017 | Ring 11 | not used | 0.000E+00 | --- | FRACA(11) |
| R017 | Ring 12 | not used | 0.000E+00 | --- | FRACA(12) |
| | | | | | |
| R018 | Fruits, vegetables and grain consumption (kg/yr) | 1.780E+02 | 1.600E+02 | --- | DIET(1) |
| R018 | Leafy vegetable consumption (kg/yr) | 2.500E+01 | 1.400E+01 | --- | DIET(2) |
| R018 | Milk consumption (L/yr) | not used | 9.200E+01 | --- | DIET(3) |
| R018 | Meat and poultry consumption (kg/yr) | 6.300E+01 | 6.300E+01 | --- | DIET(4) |
| R018 | Fish consumption (kg/yr) | not used | 5.400E+00 | --- | DIET(5) |
| R018 | Other seafood consumption (kg/yr) | not used | 9.000E-01 | --- | DIET(6) |
| R018 | Soil ingestion rate (g/yr) | 3.650E+01 | 3.650E+01 | --- | SOIL |
| R018 | Drinking water intake (L/yr) | not used | 5.100E+02 | --- | DWI |
| R018 | Contamination fraction of drinking water | not used | 1.000E+00 | --- | FDW |
| R018 | Contamination fraction of household water | not used | 1.000E+00 | --- | FHHW |
| R018 | Contamination fraction of livestock water | 1.000E+00 | 1.000E+00 | --- | FLW |
| R018 | Contamination fraction of irrigation water | 0.000E+00 | 1.000E+00 | --- | FIRW |
| R018 | Contamination fraction of aquatic food | not used | 5.000E-01 | --- | FR9 |
| R018 | Contamination fraction of plant food | 5.000E-02 | -1 | --- | FPLANT |
| R018 | Contamination fraction of meat | 5.000E-02 | -1 | --- | FMEAT |
| R018 | Contamination fraction of milk | not used | -1 | --- | FMILK |
| | | | | | |
| R019 | Livestock fodder intake for meat (kg/day) | 6.800E+01 | 6.800E+01 | --- | LFI5 |
| R019 | Livestock fodder intake for milk (kg/day) | not used | 5.500E+01 | --- | LFI6 |
| R019 | Livestock water intake for meat (L/day) | 5.000E+01 | 5.000E+01 | --- | LWI5 |
| R019 | Livestock water intake for milk (L/day) | not used | 1.600E+02 | --- | LWI6 |
| R019 | Livestock soil intake (kg/day) | 5.000E-01 | 5.000E-01 | --- | LSI |
| R019 | Mass loading for foliar deposition (g/m**3) | 1.000E-04 | 1.000E-04 | --- | MLFD |
| R019 | Depth of soil mixing layer (m) | 1.500E-01 | 1.500E-01 | --- | DM |
| R019 | Depth of roots (m) | 3.000E-01 | 9.000E-01 | --- | DROOT |
| R019 | Drinking water fraction from ground water | not used | 1.000E+00 | --- | FGWDW |
| R019 | Household water fraction from ground water | not used | 1.000E+00 | --- | FGWHH |
| R019 | Livestock water fraction from ground water | 0.000E+00 | 1.000E+00 | --- | FGWLW |
| R019 | Irrigation fraction from ground water | 0.000E+00 | 1.000E+00 | --- | FGWIR |
| | | | | | |
| R19B | Wet weight crop yield for Non-Leafy (kg/m**2) | 7.000E-01 | 7.000E-01 | --- | YV(1) |
| R19B | Wet weight crop yield for Leafy (kg/m**2) | 1.500E+00 | 1.500E+00 | --- | YV(2) |
| R19B | Wet weight crop yield for Fodder (kg/m**2) | 1.100E+00 | 1.100E+00 | --- | YV(3) |
| R19B | Growing Season for Non-Leafy (years) | 1.700E-01 | 1.700E-01 | --- | TE(1) |
| R19B | Growing Season for Leafy (years) | 2.500E-01 | 2.500E-01 | --- | TE(2) |
| R19B | Growing Season for Fodder (years) | 8.000E-02 | 8.000E-02 | --- | TE(3) |

Site-Specific Parameter Summary (continued)

| Menu | Parameter | User Input | Default | Used by RESRAD (If different from user input) | Parameter Name |
|---|---|---|---|---|---|
| R19B | Translocation Factor for Non-Leafy | 1.000E-01 | 1.000E-01 | --- | TIV(1) |
| R19B | Translocation Factor for Leafy | 1.000E+00 | 1.000E+00 | --- | TIV(2) |
| R19B | Translocation Factor for Fodder | 1.000E+00 | 1.000E+00 | --- | TIV(3) |
| R19B | Dry Foliar Interception Fraction for Non-Leafy | 2.500E-01 | 2.500E-01 | --- | RDRY(1) |
| R19B | Dry Foliar Interception Fraction for Leafy | 2.500E-01 | 2.500E-01 | --- | RDRY(2) |
| R19B | Dry Foliar Interception Fraction for Fodder | 2.500E-01 | 2.500E-01 | --- | RDRY(3) |
| R19B | Wet Foliar Interception Fraction for Non-Leafy | 2.500E-01 | 2.500E-01 | --- | RWET(1) |
| R19B | Wet Foliar Interception Fraction for Leafy | 2.500E-01 | 2.500E-01 | --- | RWET(2) |
| R19B | Wet Foliar Interception Fraction for Fodder | 2.500E-01 | 2.500E-01 | --- | RWET(3) |
| R19B | Weathering Removal Constant for Vegetation | 2.000E+01 | 2.000E+01 | --- | WLAM |
| | | | | | |
| C14 | C-12 concentration in water (g/cm**3) | not used | 2.000E-05 | --- | C12WTR |
| C14 | C-12 concentration in contaminated soil (g/g) | not used | 3.000E-02 | --- | C12CZ |
| C14 | Fraction of vegetation carbon from soil | not used | 2.000E-02 | --- | CSOIL |
| C14 | Fraction of vegetation carbon from air | not used | 9.800E-01 | --- | CAIR |
| C14 | C-14 evasion layer thickness in soil (m) | not used | 3.000E-01 | --- | DMC |
| C14 | C-14 evasion flux rate from soil (1/sec) | not used | 7.000E-07 | --- | EVSN |
| C14 | C-12 evasion flux rate from soil (1/sec) | not used | 1.000E-10 | --- | REVSN |
| C14 | Fraction of grain in beef cattle feed | not used | 8.000E-01 | --- | AVFG4 |
| C14 | Fraction of grain in milk cow feed | not used | 2.000E-01 | --- | AVFG5 |
| | | | | | |
| STOR | Storage times of contaminated foodstuffs (days): | | | | |
| STOR | Fruits, non-leafy vegetables, and grain | 1.400E+01 | 1.400E+01 | --- | STOR_T(1) |
| STOR | Leafy vegetables | 1.000E+00 | 1.000E+00 | --- | STOR_T(2) |
| STOR | Milk | 1.000E+00 | 1.000E+00 | --- | STOR_T(3) |
| STOR | Meat and poultry | 2.000E+01 | 2.000E+01 | --- | STOR_T(4) |
| STOR | Fish | 7.000E+00 | 7.000E+00 | --- | STOR_T(5) |
| STOR | Crustacea and mollusks | 7.000E+00 | 7.000E+00 | --- | STOR_T(6) |
| STOR | Well water | 1.000E+00 | 1.000E+00 | --- | STOR_T(7) |
| STOR | Surface water | 1.000E+00 | 1.000E+00 | --- | STOR_T(8) |
| STOR | Livestock fodder | 4.500E+01 | 4.500E+01 | --- | STOR_T(9) |
| | | | | | |
| R021 | Thickness of building foundation (m) | not used | 1.500E-01 | --- | FLOOR1 |
| R021 | Bulk density of building foundation (g/cm**3) | not used | 2.400E+00 | --- | DENSFL |
| R021 | Total porosity of the cover material | not used | 4.000E-01 | --- | TPCV |
| R021 | Total porosity of the building foundation | not used | 1.000E-01 | --- | TPFL |
| R021 | Volumetric water content of the cover material | not used | 5.000E-02 | --- | PH2OCV |
| R021 | Volumetric water content of the foundation | not used | 3.000E-02 | --- | PH2OFL |
| R021 | Diffusion coefficient for radon gas (m/sec): | | | | |
| R021 | in cover material | not used | 2.000E-06 | --- | DIFCV |
| R021 | in foundation material | not used | 3.000E-07 | --- | DIFFL |
| R021 | in contaminated zone soil | not used | 2.000E-06 | --- | DIFCZ |
| R021 | Radon vertical dimension of mixing (m) | not used | 2.000E+00 | --- | HMIX |
| R021 | Average building air exchange rate (1/hr) | not used | 5.000E-01 | --- | REXG |
| R021 | Height of the building (room) (m) | not used | 2.500E+00 | --- | HRM |
| R021 | Building interior area factor | not used | 0.000E+00 | --- | FAI |
| R021 | Building depth below ground surface (m) | not used | -1.000E+00 | --- | DMFL |
| R021 | Emanating power of Rn-222 gas | not used | 2.500E-01 | --- | EMANA(1) |
| R021 | Emanating power of Rn-220 gas | not used | 1.500E-01 | --- | EMANA(2) |
| | | | | | |
| TITL | Number of graphical time points | 32 | --- | --- | NPTS |

Site-Specific Parameter Summary (continued)

| 0 Menu | Parameter | User Input | Default | Used by RESRAD (If different from user input) | Parameter Name |
|---|---|---|---|---|---|
| TITL | Maximum number of integration points for dose | 17 | --- | --- | LYMAX |
| TITL | Maximum number of integration points for risk | 257 | --- | --- | KYMAX |

Summary of Pathway Selections

| Pathway | User Selection |
|---|---|
| 1 -- external gamma | active |
| 2 -- inhalation (w/o radon) | active |
| 3 -- plant ingestion | active |
| 4 -- meat ingestion | active |
| 5 -- milk ingestion | suppressed |
| 6 -- aquatic foods | suppressed |
| 7 -- drinking water | suppressed |
| 8 -- soil ingestion | active |
| 9 -- radon | suppressed |
| Find peak pathway doses | active |

Contaminated Zone Dimensions

Area: 100000.00 square meters
Thickness: 2.00 meters
Cover Depth: 0.30 meters

Initial Soil Concentrations, pCi/g

| | |
|---|---|
| Pb-210 | 7.800E+01 |
| Ra-226 | 7.800E+01 |
| Th-230 | 2.070E+03 |
| U-234 | 1.100E+01 |
| U-235 | 1.000E+00 |
| U-238 | 1.100E+01 |

0

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 2.500E+01 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

| t (years): | 0.000E+00 | 1.000E+00 | 3.000E+00 | 1.000E+01 | 3.000E+01 | 1.000E+02 | 3.000E+02 | 1.000E+03 |
|---|---|---|---|---|---|---|---|---|
| TDOSE(t): | 7.510E+00 | 7.558E+00 | 7.652E+00 | 7.960E+00 | 8.679E+00 | 9.789E+00 | 7.565E+00 | 6.566E-01 |
| M(t): | 3.004E-01 | 3.023E-01 | 3.061E-01 | 3.184E-01 | 3.471E-01 | 3.916E-01 | 3.026E-01 | 2.626E-02 |

0Maximum TDOSE(t): 9.819E+00 mrem/yr at t = 115.5 ñ 0.2 years
0

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.155E+02 years
0 Water Independent Pathways (Inhalation excludes radon)
0

| Radio- Nuclide | Ground | | Inhalation | | Radon | | Plant | | Meat | | Milk | | Soil | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Pb-210 | 3.168E-06 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 3.202E-03 | 0.0003 | 5.403E-05 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Ra-226 | 3.966E+00 | 0.4039 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.774E-01 | 0.0181 | 3.304E-03 | 0.0003 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Th-230 | 5.422E+00 | 0.5522 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.387E-01 | 0.0243 | 3.937E-03 | 0.0004 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-234 | 1.526E-05 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.082E-04 | 0.0000 | 7.809E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-235 | 2.383E-04 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.198E-05 | 0.0000 | 2.679E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-238 | 3.804E-03 | 0.0004 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.067E-04 | 0.0000 | 7.652E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Total | 9.392E+00 | 0.9565 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 4.196E-01 | 0.0427 | 7.297E-03 | 0.0007 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.155E+02 years

Water Dependent Pathways

| Radio-Nuclide | Water mrem/yr | Water fract. | Fish mrem/yr | Fish fract. | Radon mrem/yr | Radon fract. | Plant mrem/yr | Plant fract. | Meat mrem/yr | Meat fract. | Milk mrem/yr | Milk fract. | All Pathways* mrem/yr | All Pathways* fract. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 3.259E-03 | 0.0003 |
| Ra-226 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 4.147E+00 | 0.4223 |
| Th-230 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 5.665E+00 | 0.5769 |
| U-234 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.242E-04 | 0.0000 |
| U-235 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.505E-04 | 0.0000 |
| U-238 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 3.911E-03 | 0.0004 |
| Total | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 9.819E+00 | 1.0000 |

0*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

0 Water Independent Pathways (Inhalation excludes radon)

| Radio-Nuclide | Ground mrem/yr | Ground fract. | Inhalation mrem/yr | Inhalation fract. | Radon mrem/yr | Radon fract. | Plant mrem/yr | Plant fract. | Meat mrem/yr | Meat fract. | Milk mrem/yr | Milk fract. | Soil mrem/yr | Soil fract. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | 2.034E-04 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 8.489E-04 | 0.0001 | 1.057E-05 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Ra-226 | 7.458E+00 | 0.9931 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 5.364E-04 | 0.0001 | 8.465E-06 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Th-230 | 4.299E-02 | 0.0057 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.594E-04 | 0.0000 | 4.502E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-234 | 1.576E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 7.908E-07 | 0.0000 | 4.190E-09 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-235 | 4.121E-04 | 0.0001 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 6.967E-08 | 0.0000 | 3.728E-10 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-238 | 6.787E-03 | 0.0009 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 7.847E-07 | 0.0000 | 4.158E-09 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Total | 7.509E+00 | 0.9998 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.646E-03 | 0.0002 | 1.950E-05 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |

0

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

0 Water Dependent Pathways

| Radio-Nuclide | Water mrem/yr | Water fract. | Fish mrem/yr | Fish fract. | Radon mrem/yr | Radon fract. | Plant mrem/yr | Plant fract. | Meat mrem/yr | Meat fract. | Milk mrem/yr | Milk fract. | All Pathways* mrem/yr | All Pathways* fract. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.063E-03 | 0.0001 |
| Ra-226 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 7.459E+00 | 0.9931 |
| Th-230 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 4.325E-02 | 0.0058 |
| U-234 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 9.526E-07 | 0.0000 |
| U-235 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 4.122E-04 | 0.0001 |
| U-238 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 6.788E-03 | 0.0009 |
| Total | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 7.510E+00 | 1.0000 |

0*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

| Radio- Nuclide | Ground mrem/yr | Ground fract. | Inhalation mrem/yr | Inhalation fract. | Radon mrem/yr | Radon fract. | Plant mrem/yr | Plant fract. | Meat mrem/yr | Meat fract. | Milk mrem/yr | Milk fract. | Soil mrem/yr | Soil fract. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | 1.962E-04 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.558E-03 | 0.0003 | 3.899E-05 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Ra-226 | 7.418E+00 | 0.9814 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.732E-03 | 0.0002 | 3.312E-05 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Th-230 | 1.281E-01 | 0.0169 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 8.207E-04 | 0.0001 | 2.024E-06 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-234 | 1.609E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.449E-06 | 0.0000 | 1.587E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-235 | 4.101E-04 | 0.0001 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.160E-07 | 0.0000 | 1.434E-09 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-238 | 6.753E-03 | 0.0009 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.430E-06 | 0.0000 | 1.575E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Total | 7.553E+00 | 0.9993 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 5.116E-03 | 0.0007 | 7.416E-05 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Dependent Pathways

| Radio- Nuclide | Water mrem/yr | Water fract. | Fish mrem/yr | Fish fract. | Radon mrem/yr | Radon fract. | Plant mrem/yr | Plant fract. | Meat mrem/yr | Meat fract. | Milk mrem/yr | Milk fract. | All Pathways* mrem/yr | All Pathways* fract. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.793E-03 | 0.0004 |
| Ra-226 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 7.419E+00 | 0.9816 |
| Th-230 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.289E-01 | 0.0171 |
| U-234 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.626E-06 | 0.0000 |
| U-235 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 4.103E-04 | 0.0001 |
| U-238 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 6.755E-03 | 0.0009 |
| Total | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 7.558E+00 | 1.0000 |

0*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years
0 Water Independent Pathways (Inhalation excludes radon)

| Radio-Nuclide | Ground mrem/yr | Ground fract. | Inhalation mrem/yr | Inhalation fract. | Radon mrem/yr | Radon fract. | Plant mrem/yr | Plant fract. | Meat mrem/yr | Meat fract. | Milk mrem/yr | Milk fract. | Soil mrem/yr | Soil fract. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | 1.826E-04 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 5.632E-03 | 0.0007 | 9.122E-05 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Ra-226 | 7.337E+00 | 0.9588 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 4.406E-03 | 0.0006 | 8.802E-05 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Th-230 | 2.956E-01 | 0.0386 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.017E-03 | 0.0003 | 6.955E-06 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-234 | 1.795E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 5.733E-06 | 0.0000 | 3.946E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-235 | 4.061E-04 | 0.0001 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 5.070E-07 | 0.0000 | 3.695E-09 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-238 | 6.686E-03 | 0.0009 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 5.689E-06 | 0.0000 | 3.916E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Total | 7.640E+00 | 0.9984 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.207E-02 | 0.0016 | 1.863E-04 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |

0

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years
0 Water Dependent Pathways

| Radio-Nuclide | Water mrem/yr | Water fract. | Fish mrem/yr | Fish fract. | Radon mrem/yr | Radon fract. | Plant mrem/yr | Plant fract. | Meat mrem/yr | Meat fract. | Milk mrem/yr | Milk fract. | All Pathways* mrem/yr | All Pathways* fract. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 5.906E-03 | 0.0008 |
| Ra-226 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 7.341E+00 | 0.9594 |
| Th-230 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.976E-01 | 0.0389 |
| U-234 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 5.952E-06 | 0.0000 |
| U-235 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 4.066E-04 | 0.0001 |
| U-238 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 6.691E-03 | 0.0009 |
| Total | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 7.652E+00 | 1.0000 |

0*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

0 Water Independent Pathways (Inhalation excludes radon)

| Radio-Nuclide | Ground mrem/yr | Ground fract. | Inhalation mrem/yr | Inhalation fract. | Radon mrem/yr | Radon fract. | Plant mrem/yr | Plant fract. | Meat mrem/yr | Meat fract. | Milk mrem/yr | Milk fract. | Soil mrem/yr | Soil fract. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | 1.419E-04 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.321E-02 | 0.0017 | 2.200E-04 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Ra-226 | 7.061E+00 | 0.8871 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.599E-02 | 0.0020 | 3.162E-04 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Th-230 | 8.544E-01 | 0.1073 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 7.036E-03 | 0.0009 | 4.420E-05 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-234 | 3.644E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.670E-05 | 0.0000 | 1.183E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-235 | 3.924E-04 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.491E-06 | 0.0000 | 1.248E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-238 | 6.455E-03 | 0.0008 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.657E-05 | 0.0000 | 1.174E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Total | 7.923E+00 | 0.9954 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 3.627E-02 | 0.0046 | 5.807E-04 | 0.0001 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |

0

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

0 Water Dependent Pathways

| Radio-Nuclide | Water mrem/yr | Water fract. | Fish mrem/yr | Fish fract. | Radon mrem/yr | Radon fract. | Plant mrem/yr | Plant fract. | Meat mrem/yr | Meat fract. | Milk mrem/yr | Milk fract. | All Pathways* mrem/yr | All Pathways* fract. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.357E-02 | 0.0017 |
| Ra-226 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 7.078E+00 | 0.8892 |
| Th-230 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 8.615E-01 | 0.1082 |
| U-234 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.719E-05 | 0.0000 |
| U-235 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 3.939E-04 | 0.0000 |
| U-238 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 6.472E-03 | 0.0008 |
| Total | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 7.960E+00 | 1.0000 |

0*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

0 Water Independent Pathways (Inhalation excludes radon)

| Radio-Nuclide | Ground mrem/yr | Ground fract. | Inhalation mrem/yr | Inhalation fract. | Radon mrem/yr | Radon fract. | Plant mrem/yr | Plant fract. | Meat mrem/yr | Meat fract. | Milk mrem/yr | Milk fract. | Soil mrem/yr | Soil fract. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | 6.901E-05 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.863E-02 | 0.0021 | 3.132E-04 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Ra-226 | 6.330E+00 | 0.7294 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 5.761E-02 | 0.0066 | 1.100E-03 | 0.0001 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Th-230 | 2.234E+00 | 0.2574 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 3.012E-02 | 0.0035 | 3.430E-04 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-234 | 1.769E-06 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 4.389E-05 | 0.0000 | 3.137E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-235 | 3.562E-04 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 4.048E-06 | 0.0000 | 4.455E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-238 | 5.839E-03 | 0.0007 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 4.352E-05 | 0.0000 | 3.110E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Total | 8.571E+00 | 0.9875 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.064E-01 | 0.0123 | 1.756E-03 | 0.0002 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |

0

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

0 Water Dependent Pathways

| Radio-Nuclide | Water mrem/yr | Water fract. | Fish mrem/yr | Fish fract. | Radon mrem/yr | Radon fract. | Plant mrem/yr | Plant fract. | Meat mrem/yr | Meat fract. | Milk mrem/yr | Milk fract. | All Pathways* mrem/yr | All Pathways* fract. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.901E-02 | 0.0022 |
| Ra-226 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 6.389E+00 | 0.7361 |
| Th-230 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.265E+00 | 0.2609 |
| U-234 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 4.597E-05 | 0.0000 |
| U-235 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 3.603E-04 | 0.0000 |
| U-238 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 5.883E-03 | 0.0007 |
| Total | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 8.679E+00 | 1.0000 |

0*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years
0 Water Independent Pathways (Inhalation excludes radon)

| Radio-Nuclide | Ground mrem/yr | Ground fract. | Inhalation mrem/yr | Inhalation fract. | Radon mrem/yr | Radon fract. | Plant mrem/yr | Plant fract. | Meat mrem/yr | Meat fract. | Milk mrem/yr | Milk fract. | Soil mrem/yr | Soil fract. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | 5.538E-06 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 4.864E-03 | 0.0005 | 8.205E-05 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Ra-226 | 4.317E+00 | 0.4410 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.658E-01 | 0.0169 | 3.089E-03 | 0.0003 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Th-230 | 5.096E+00 | 0.5206 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.944E-01 | 0.0199 | 3.142E-03 | 0.0003 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-234 | 1.244E-05 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.013E-04 | 0.0000 | 7.301E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-235 | 2.560E-04 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.081E-05 | 0.0000 | 2.194E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-238 | 4.111E-03 | 0.0004 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.001E-04 | 0.0000 | 7.179E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Total | 9.418E+00 | 0.9620 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 3.652E-01 | 0.0373 | 6.315E-03 | 0.0006 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |

0

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years
0 Water Dependent Pathways

| Radio-Nuclide | Water mrem/yr | Water fract. | Fish mrem/yr | Fish fract. | Radon mrem/yr | Radon fract. | Plant mrem/yr | Plant fract. | Meat mrem/yr | Meat fract. | Milk mrem/yr | Milk fract. | All Pathways* mrem/yr | All Pathways* fract. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 4.951E-03 | 0.0005 |
| Ra-226 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 4.486E+00 | 0.4583 |
| Th-230 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 5.294E+00 | 0.5408 |
| U-234 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.145E-04 | 0.0000 |
| U-235 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.671E-04 | 0.0000 |
| U-238 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 4.212E-03 | 0.0004 |
| Total | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 9.789E+00 | 1.0000 |

0*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

0 Water Independent Pathways (Inhalation excludes radon)

| Radio-Nuclide | Ground mrem/yr | Ground fract. | Inhalation mrem/yr | Inhalation fract. | Radon mrem/yr | Radon fract. | Plant mrem/yr | Plant fract. | Meat mrem/yr | Meat fract. | Milk mrem/yr | Milk fract. | Soil mrem/yr | Soil fract. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | 4.103E-09 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.037E-05 | 0.0000 | 1.751E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Ra-226 | 1.446E+00 | 0.1912 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.672E-01 | 0.0221 | 3.110E-03 | 0.0004 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Th-230 | 5.329E+00 | 0.7045 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 6.065E-01 | 0.0802 | 1.078E-02 | 0.0014 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-234 | 3.918E-05 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.121E-04 | 0.0000 | 8.481E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-235 | 1.051E-04 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.133E-05 | 0.0000 | 9.626E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-238 | 1.508E-03 | 0.0002 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.070E-04 | 0.0000 | 7.679E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Total | 6.778E+00 | 0.8959 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 7.739E-01 | 0.1023 | 1.390E-02 | 0.0018 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |

0

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

0 Water Dependent Pathways

| Radio-Nuclide | Water mrem/yr | Water fract. | Fish mrem/yr | Fish fract. | Radon mrem/yr | Radon fract. | Plant mrem/yr | Plant fract. | Meat mrem/yr | Meat fract. | Milk mrem/yr | Milk fract. | All Pathways* mrem/yr | All Pathways* fract. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.055E-05 | 0.0000 |
| Ra-226 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.617E+00 | 0.2137 |
| Th-230 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 5.947E+00 | 0.7861 |
| U-234 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.521E-04 | 0.0000 |
| U-235 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.274E-04 | 0.0000 |
| U-238 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.616E-03 | 0.0002 |
| Total | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 7.565E+00 | 1.0000 |

0*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

0 Water Independent Pathways (Inhalation excludes radon)

| Radio-Nuclide | Ground mrem/yr | Ground fract. | Inhalation mrem/yr | Inhalation fract. | Radon mrem/yr | Radon fract. | Plant mrem/yr | Plant fract. | Meat mrem/yr | Meat fract. | Milk mrem/yr | Milk fract. | Soil mrem/yr | Soil fract. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | 4.544E-20 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 3.339E-16 | 0.0000 | 5.641E-18 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Ra-226 | 3.148E-02 | 0.0480 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.119E-02 | 0.0170 | 2.082E-04 | 0.0003 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Th-230 | 4.511E-01 | 0.6871 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.595E-01 | 0.2429 | 2.922E-03 | 0.0045 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-234 | 1.158E-05 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.382E-05 | 0.0000 | 1.437E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-235 | 1.875E-05 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 4.758E-05 | 0.0001 | 3.483E-06 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-238 | 4.514E-05 | 0.0001 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 9.720E-06 | 0.0000 | 6.983E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Total | 4.827E-01 | 0.7352 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.707E-01 | 0.2600 | 3.134E-03 | 0.0048 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |

0

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

0 Water Dependent Pathways

| Radio-Nuclide | Water mrem/yr | Water fract. | Fish mrem/yr | Fish fract. | Radon mrem/yr | Radon fract. | Plant mrem/yr | Plant fract. | Meat mrem/yr | Meat fract. | Milk mrem/yr | Milk fract. | All Pathways* mrem/yr | All Pathways* fract. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 3.396E-16 | 0.0000 |
| Ra-226 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 4.288E-02 | 0.0653 |
| Th-230 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 6.135E-01 | 0.9345 |
| U-234 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.554E-05 | 0.0000 |
| U-235 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 6.982E-05 | 0.0001 |
| U-238 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 5.493E-05 | 0.0001 |
| Total | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 6.565E-01 | 1.0000 |

0*Sum of all water independent and dependent pathways.

Dose/Source Ratios Summed Over All Pathways
Parent and Progeny Principal Radionuclide Contributions Indicated

| 0 Parent (i) | Product (j) | Thread Fraction | DSR(j,t) At Time in Years (mrem/yr)/(pCi/g) 0.000E+00 | 1.000E+00 | 3.000E+00 | 1.000E+01 | 3.000E+01 | 1.000E+02 | 3.000E+02 | 1.000E+03 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210+D | Pb-210+D | 1.000E+00 | 1.363E-05 | 3.581E-05 | 7.572E-05 | 1.739E-04 | 2.437E-04 | 6.348E-05 | 1.352E-07 | 4.354E-18 |
| 0Ra-226+D | Ra-226+D | 1.000E+00 | 9.563E-02 | 9.512E-02 | 9.411E-02 | 9.067E-02 | 8.152E-02 | 5.617E-02 | 1.935E-02 | 4.577E-04 |
| Ra-226+D | Pb-210+D | 1.000E+00 | 3.098E-07 | 1.887E-06 | 9.030E-06 | 6.782E-05 | 3.844E-04 | 1.341E-03 | 1.376E-03 | 9.205E-05 |
| Ra-226+D | =DSR(j) | | 9.563E-02 | 9.512E-02 | 9.412E-02 | 9.074E-02 | 8.191E-02 | 5.751E-02 | 2.073E-02 | 5.497E-04 |
| 0Th-230 | Th-230 | 1.000E+00 | 1.938E-07 | 4.529E-07 | 9.659E-07 | 2.679E-06 | 6.920E-06 | 1.581E-05 | 1.682E-05 | 1.514E-06 |
| Th-230 | Ra-226+D | 1.000E+00 | 2.070E-05 | 6.181E-05 | 1.428E-04 | 4.134E-04 | 1.084E-03 | 2.498E-03 | 2.687E-03 | 2.471E-04 |
| Th-230 | Pb-210+D | 1.000E+00 | 5.407E-11 | 6.964E-10 | 7.265E-09 | 1.647E-07 | 2.956E-06 | 4.304E-05 | 1.693E-04 | 4.774E-05 |
| Th-230 | =DSR(j) | | 2.089E-05 | 6.227E-05 | 1.438E-04 | 4.162E-04 | 1.094E-03 | 2.557E-03 | 2.873E-03 | 2.964E-04 |
| 0U-234 | U-234 | 1.000E+00 | 8.653E-08 | 2.383E-07 | 5.388E-07 | 1.542E-06 | 4.028E-06 | 9.241E-06 | 9.859E-06 | 8.915E-07 |
| U-234 | Th-230 | 1.000E+00 | 1.120E-12 | 6.489E-12 | 3.104E-11 | 2.546E-10 | 1.903E-09 | 1.431E-08 | 4.556E-08 | 1.368E-08 |
| U-234 | Ra-226+D | 1.000E+00 | 6.208E-11 | 4.327E-10 | 2.265E-09 | 1.956E-08 | 1.492E-07 | 1.138E-06 | 3.713E-06 | 1.194E-06 |
| U-234 | Pb-210+D | 1.000E+00 | 1.375E-16 | 3.621E-15 | 8.057E-14 | 5.396E-12 | 2.920E-10 | 1.569E-08 | 2.115E-07 | 2.230E-07 |
| U-234 | =DSR(j) | | 8.660E-08 | 2.387E-07 | 5.411E-07 | 1.562E-06 | 4.179E-06 | 1.041E-05 | 1.383E-05 | 2.322E-06 |
| 0U-235+D | U-235+D | 1.000E+00 | 4.122E-04 | 4.103E-04 | 4.065E-04 | 3.937E-04 | 3.592E-04 | 2.604E-04 | 1.031E-04 | 3.811E-06 |
| U-235+D | Pa-231 | 1.000E+00 | 3.144E-09 | 9.686E-09 | 2.391E-08 | 8.535E-08 | 3.532E-07 | 2.118E-06 | 1.031E-05 | 3.755E-05 |
| U-235+D | Ac-227+D | 1.000E+00 | 3.740E-10 | 2.593E-09 | 1.342E-08 | 1.113E-07 | 7.649E-07 | 4.582E-06 | 1.392E-05 | 2.846E-05 |
| U-235+D | =DSR(j) | | 4.122E-04 | 4.103E-04 | 4.066E-04 | 3.939E-04 | 3.603E-04 | 2.671E-04 | 1.274E-04 | 6.982E-05 |
| 0U-238 | U-238 | 5.400E-05 | 3.601E-12 | 1.117E-11 | 2.614E-11 | 7.618E-11 | 2.001E-10 | 4.601E-10 | 4.915E-10 | 4.454E-11 |
| 0U-238+D | U-238+D | 9.999E-01 | 6.171E-04 | 6.141E-04 | 6.083E-04 | 5.883E-04 | 5.348E-04 | 3.829E-04 | 1.469E-04 | 4.990E-06 |
| U-238+D | U-234 | 9.999E-01 | 1.580E-13 | 1.049E-12 | 5.381E-12 | 4.595E-11 | 3.483E-10 | 2.633E-09 | 8.402E-09 | 2.532E-09 |
| U-238+D | Th-230 | 9.999E-01 | 1.204E-18 | 1.509E-17 | 1.581E-16 | 3.813E-15 | 8.244E-14 | 2.040E-12 | 1.942E-11 | 1.944E-11 |
| U-238+D | Ra-226+D | 9.999E-01 | 4.399E-17 | 6.570E-16 | 7.592E-15 | 1.945E-13 | 4.305E-12 | 1.085E-10 | 1.066E-09 | 1.169E-09 |
| U-238+D | Pb-210+D | 9.999E-01 | 8.518E-23 | 4.522E-21 | 2.112E-19 | 4.132E-17 | 6.618E-15 | 1.256E-12 | 5.553E-11 | 2.117E-10 |
| U-238+D | =DSR(j) | | 6.171E-04 | 6.141E-04 | 6.083E-04 | 5.883E-04 | 5.348E-04 | 3.829E-04 | 1.469E-04 | 4.994E-06 |

The DSR includes contributions from associated (half-life ó 180 days) daughters.
0

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 2.500E+01 mrem/yr

| 0Nuclide (i) | t= 0.000E+00 | 1.000E+00 | 3.000E+00 | 1.000E+01 | 3.000E+01 | 1.000E+02 | 3.000E+02 | 1.000E+03 |
|---|---|---|---|---|---|---|---|---|
| Pb-210 | 1.835E+06 | 6.981E+05 | 3.302E+05 | 1.437E+05 | 1.026E+05 | 3.939E+05 | 1.849E+08 | *7.634E+13 |
| Ra-226 | 2.614E+02 | 2.628E+02 | 2.656E+02 | 2.755E+02 | 3.052E+02 | 4.347E+02 | 1.206E+03 | 4.548E+04 |
| Th-230 | 1.197E+06 | 4.015E+05 | 1.739E+05 | 6.007E+04 | 2.285E+04 | 9.776E+03 | 8.702E+03 | 8.435E+04 |
| U-234 | 2.887E+08 | 1.047E+08 | 4.620E+07 | 1.600E+07 | 5.982E+06 | 2.402E+06 | 1.808E+06 | 1.077E+07 |
| U-235 | 6.066E+04 | 6.093E+04 | 6.149E+04 | 6.347E+04 | 6.938E+04 | 9.361E+04 | 1.963E+05 | 3.581E+05 |
| U-238 | 4.051E+04 | 4.071E+04 | 4.110E+04 | 4.249E+04 | 4.674E+04 | 6.529E+04 | 1.702E+05 | *3.361E+05 |

*At specific activity limit

Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
at tmin = time of minimum single radionuclide soil guideline
and at tmax = time of maximum total dose = 115.5 ñ 0.2 years

| 0Nuclide (i) | Initial (pCi/g) | tmin (years) | DSR(i,tmin) | G(i,tmin) (pCi/g) | DSR(i,tmax) | G(i,tmax) (pCi/g) |
|---|---|---|---|---|---|---|
| Pb-210 | 7.800E+01 | 27.05 ñ 0.05 | 2.450E-04 | 1.020E+05 | 4.178E-05 | 5.983E+05 |
| Ra-226 | 7.800E+01 | 0.000E+00 | 9.563E-02 | 2.614E+02 | 5.317E-02 | 4.702E+02 |
| Th-230 | 2.070E+03 | 203.8 ñ 0.4 | 3.130E-03 | 7.986E+03 | 2.737E-03 | 9.136E+03 |
| U-234 | 1.100E+01 | 244.5 ñ 0.5 | 1.415E-05 | 1.767E+06 | 1.129E-05 | 2.214E+06 |
| U-235 | 1.000E+00 | 0.000E+00 | 4.122E-04 | 6.066E+04 | 2.505E-04 | 9.979E+04 |
| U-238 | 1.100E+01 | 0.000E+00 | 6.171E-04 | 4.051E+04 | 3.556E-04 | 7.031E+04 |

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RESRAD, Version 6.5      T« Limit = 180 days        03/12/2014  21:49  Page  23
 Summary : RAM Evaporation Ponds 9 & 10
 File    : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\RAM EVAP PONDS 9 AND 10.RAD
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Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated

| 0Nuclide (j) | Parent (i) | THF(i) | DOSE(j,t), mrem/yr t= 0.000E+00 | 1.000E+00 | 3.000E+00 | 1.000E+01 | 3.000E+01 | 1.000E+02 | 3.000E+02 | 1.000E+03 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | Pb-210 | 1.000E+00 | 1.063E-03 | 2.793E-03 | 5.906E-03 | 1.357E-02 | 1.901E-02 | 4.951E-03 | 1.055E-05 | 3.396E-16 |
| Pb-210 | Ra-226 | 1.000E+00 | 2.416E-05 | 1.472E-04 | 7.043E-04 | 5.290E-03 | 2.999E-02 | 1.046E-01 | 1.073E-01 | 7.180E-03 |
| Pb-210 | Th-230 | 1.000E+00 | 1.119E-07 | 1.442E-06 | 1.504E-05 | 3.410E-04 | 6.118E-03 | 8.909E-02 | 3.505E-01 | 9.883E-02 |
| Pb-210 | U-234 | 1.000E+00 | 1.512E-15 | 3.983E-14 | 8.863E-13 | 5.936E-11 | 3.212E-09 | 1.726E-07 | 2.327E-06 | 2.453E-06 |
| Pb-210 | U-238 | 9.999E-01 | 9.370E-22 | 4.974E-20 | 2.324E-18 | 4.545E-16 | 7.280E-14 | 1.381E-11 | 6.109E-10 | 2.328E-09 |
| Pb-210 | =DOSE(j) | | 1.087E-03 | 2.942E-03 | 6.625E-03 | 1.920E-02 | 5.512E-02 | 1.987E-01 | 4.578E-01 | 1.060E-01 |
| 0Ra-226 | Ra-226 | 1.000E+00 | 7.459E+00 | 7.419E+00 | 7.341E+00 | 7.073E+00 | 6.359E+00 | 4.381E+00 | 1.509E+00 | 3.570E-02 |
| Ra-226 | Th-230 | 1.000E+00 | 4.284E-02 | 1.280E-01 | 2.956E-01 | 8.556E-01 | 2.244E+00 | 5.172E+00 | 5.561E+00 | 5.116E-01 |
| Ra-226 | U-234 | 1.000E+00 | 6.829E-10 | 4.760E-09 | 2.491E-08 | 2.152E-07 | 1.641E-06 | 1.252E-05 | 4.085E-05 | 1.313E-05 |
| Ra-226 | U-238 | 9.999E-01 | 4.839E-16 | 7.227E-15 | 8.351E-14 | 2.139E-12 | 4.735E-11 | 1.194E-09 | 1.173E-08 | 1.286E-08 |
| Ra-226 | =DOSE(j) | | 7.502E+00 | 7.547E+00 | 7.636E+00 | 7.928E+00 | 8.603E+00 | 9.553E+00 | 7.071E+00 | 5.473E-01 |
| 0Th-230 | Th-230 | 1.000E+00 | 4.013E-04 | 9.375E-04 | 1.999E-03 | 5.545E-03 | 1.432E-02 | 3.272E-02 | 3.482E-02 | 3.134E-03 |
| Th-230 | U-234 | 1.000E+00 | 1.232E-11 | 7.138E-11 | 3.415E-10 | 2.801E-09 | 2.094E-08 | 1.574E-07 | 5.011E-07 | 1.505E-07 |
| Th-230 | U-238 | 9.999E-01 | 1.324E-17 | 1.660E-16 | 1.739E-15 | 4.195E-14 | 9.068E-13 | 2.244E-11 | 2.136E-10 | 2.138E-10 |
| Th-230 | =DOSE(j) | | 4.013E-04 | 9.375E-04 | 1.999E-03 | 5.545E-03 | 1.432E-02 | 3.272E-02 | 3.482E-02 | 3.134E-03 |
| 0U-234 | U-234 | 1.000E+00 | 9.519E-07 | 2.621E-06 | 5.927E-06 | 1.697E-05 | 4.430E-05 | 1.017E-04 | 1.084E-04 | 9.807E-06 |
| U-234 | U-238 | 9.999E-01 | 1.738E-12 | 1.154E-11 | 5.919E-11 | 5.054E-10 | 3.831E-09 | 2.897E-08 | 9.242E-08 | 2.785E-08 |
| U-234 | =DOSE(j) | | 9.519E-07 | 2.621E-06 | 5.927E-06 | 1.697E-05 | 4.431E-05 | 1.017E-04 | 1.085E-04 | 9.835E-06 |
| 0U-235 | U-235 | 1.000E+00 | 4.122E-04 | 4.103E-04 | 4.065E-04 | 3.937E-04 | 3.592E-04 | 2.604E-04 | 1.031E-04 | 3.811E-06 |
| 0Pa-231 | U-235 | 1.000E+00 | 3.144E-09 | 9.686E-09 | 2.391E-08 | 8.535E-08 | 3.532E-07 | 2.118E-06 | 1.031E-05 | 3.755E-05 |
| 0Ac-227 | U-235 | 1.000E+00 | 3.740E-10 | 2.593E-09 | 1.342E-08 | 1.113E-07 | 7.649E-07 | 4.582E-06 | 1.392E-05 | 2.846E-05 |
| 0U-238 | U-238 | 5.400E-05 | 3.961E-11 | 1.228E-10 | 2.876E-10 | 8.379E-10 | 2.201E-09 | 5.061E-09 | 5.406E-09 | 4.899E-10 |
| U-238 | U-238 | 9.999E-01 | 6.788E-03 | 6.755E-03 | 6.691E-03 | 6.472E-03 | 5.883E-03 | 4.212E-03 | 1.616E-03 | 5.489E-05 |
| U-238 | =DOSE(j) | | 6.788E-03 | 6.755E-03 | 6.691E-03 | 6.472E-03 | 5.883E-03 | 4.212E-03 | 1.616E-03 | 5.489E-05 |

THF(i) is the thread fraction of the parent nuclide.

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

S(j,t), pCi/g

| 0Nuclide (j) | Parent (i) | THF(i) | t= 0.000E+00 | 1.000E+00 | 3.000E+00 | 1.000E+01 | 3.000E+01 | 1.000E+02 | 3.000E+02 | 1.000E+03 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | Pb-210 | 1.000E+00 | 7.800E+01 | 7.522E+01 | 6.997E+01 | 5.429E+01 | 2.631E+01 | 2.083E+00 | 1.485E-03 | 1.436E-14 |
| Pb-210 | Ra-226 | 1.000E+00 | 0.000E+00 | 2.374E+00 | 6.834E+00 | 1.975E+01 | 4.023E+01 | 4.316E+01 | 1.482E+01 | 2.979E-01 |
| Pb-210 | Th-230 | 1.000E+00 | 0.000E+00 | 1.372E-02 | 1.197E-01 | 1.195E+00 | 8.023E+00 | 3.647E+01 | 4.830E+01 | 4.098E+00 |
| Pb-210 | U-234 | 1.000E+00 | 0.000E+00 | 2.194E-10 | 5.771E-09 | 1.954E-07 | 4.121E-06 | 7.018E-05 | 3.199E-04 | 1.017E-04 |
| Pb-210 | U-238 | 9.999E-01 | 0.000E+00 | 1.557E-16 | 1.233E-14 | 1.406E-12 | 9.147E-11 | 5.578E-09 | 8.381E-08 | 9.642E-08 |
| Pb-210 | =S(j): | | 7.800E+01 | 7.761E+01 | 7.692E+01 | 7.524E+01 | 7.456E+01 | 8.171E+01 | 6.312E+01 | 4.396E+00 |
| 0Ra-226 | Ra-226 | 1.000E+00 | 7.800E+01 | 7.757E+01 | 7.670E+01 | 7.377E+01 | 6.597E+01 | 4.464E+01 | 1.462E+01 | 2.938E-01 |
| Ra-226 | Th-230 | 1.000E+00 | 0.000E+00 | 8.920E-01 | 2.647E+00 | 8.499E+00 | 2.290E+01 | 5.242E+01 | 5.377E+01 | 4.207E+00 |
| Ra-226 | U-234 | 1.000E+00 | 0.000E+00 | 2.134E-08 | 1.900E-07 | 2.034E-06 | 1.647E-05 | 1.263E-04 | 3.942E-04 | 1.079E-04 |
| Ra-226 | U-238 | 9.999E-01 | 0.000E+00 | 2.016E-14 | 5.387E-13 | 1.923E-11 | 4.674E-10 | 1.198E-08 | 1.130E-07 | 1.057E-07 |
| Ra-226 | =S(j): | | 7.800E+01 | 7.846E+01 | 7.935E+01 | 8.226E+01 | 8.887E+01 | 9.706E+01 | 6.838E+01 | 4.501E+00 |
| 0Th-230 | Th-230 | 1.000E+00 | 2.070E+03 | 2.059E+03 | 2.038E+03 | 1.966E+03 | 1.773E+03 | 1.236E+03 | 4.406E+02 | 1.192E+01 |
| Th-230 | U-234 | 1.000E+00 | 0.000E+00 | 9.851E-05 | 2.925E-04 | 9.405E-04 | 2.545E-03 | 5.914E-03 | 6.329E-03 | 5.718E-04 |
| Th-230 | U-238 | 9.999E-01 | 0.000E+00 | 1.396E-10 | 1.244E-09 | 1.333E-08 | 1.082E-07 | 8.384E-07 | 2.693E-06 | 8.121E-07 |
| Th-230 | =S(j): | | 2.070E+03 | 2.059E+03 | 2.038E+03 | 1.966E+03 | 1.773E+03 | 1.236E+03 | 4.406E+02 | 1.192E+01 |
| 0U-234 | U-234 | 1.000E+00 | 1.100E+01 | 1.094E+01 | 1.083E+01 | 1.045E+01 | 9.425E+00 | 6.572E+00 | 2.346E+00 | 6.372E-02 |
| U-234 | U-238 | 9.999E-01 | 0.000E+00 | 3.102E-05 | 9.211E-05 | 2.962E-04 | 8.016E-04 | 1.863E-03 | 1.996E-03 | 1.809E-04 |
| U-234 | =S(j): | | 1.100E+01 | 1.094E+01 | 1.083E+01 | 1.045E+01 | 9.426E+00 | 6.574E+00 | 2.348E+00 | 6.390E-02 |
| 0U-235 | U-235 | 1.000E+00 | 1.000E+00 | 9.949E-01 | 9.847E-01 | 9.498E-01 | 8.569E-01 | 5.976E-01 | 2.134E-01 | 5.809E-03 |
| 0Pa-231 | U-235 | 1.000E+00 | 0.000E+00 | 2.110E-05 | 6.298E-05 | 2.061E-04 | 5.870E-04 | 1.642E-03 | 3.157E-03 | 3.685E-03 |
| 0Ac-227 | U-235 | 1.000E+00 | 0.000E+00 | 3.326E-07 | 2.921E-06 | 2.981E-05 | 2.131E-04 | 1.200E-03 | 2.976E-03 | 3.665E-03 |
| 0U-238 | U-238 | 5.400E-05 | 5.940E-04 | 5.909E-04 | 5.849E-04 | 5.642E-04 | 5.090E-04 | 3.550E-04 | 1.268E-04 | 3.450E-06 |
| U-238 | U-238 | 9.999E-01 | 1.100E+01 | 1.094E+01 | 1.083E+01 | 1.045E+01 | 9.425E+00 | 6.573E+00 | 2.347E+00 | 6.389E-02 |
| U-238 | =S(j): | | 1.100E+01 | 1.094E+01 | 1.083E+01 | 1.045E+01 | 9.426E+00 | 6.574E+00 | 2.348E+00 | 6.390E-02 |

THF(i) is the thread fraction of the parent nuclide.
0RESCALC.EXE execution time = 1.56 seconds

## Attachment 2 – RESRAD Results for the Mill Area with 1 pCi/g Ra-226 and Proportional Concentrations of ROC

```
RESRAD, Version 6.5      T« Limit = 180 days       03/25/2014  12:52  Page   1
 Summary :  Mill Area with 1 pCi/g and proportional amounts of Th and U from Pond areas
 File    : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\RAM MILL AREA 1 PCI-G.RAD
```

Table of Contents
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Part I: Mixture Sums and Single Radionuclide Guidelines

Dose Conversion Factor (and Related) Parameter Summary
Dose Library: ICRP 72 Plus FGR 12 & ICRP 72 (Adult)

| Menu | Parameter | Current Value# | Base Case* | Parameter Name |
|---|---|---|---|---|
| A-1 | DCF's for external ground radiation, (mrem/yr)/(pCi/g) | | | |
| A-1 | Ac-227 (Source: FGR 12) | 4.951E-04 | 4.951E-04 | DCF1( 1) |
| A-1 | At-218 (Source: FGR 12) | 5.847E-03 | 5.847E-03 | DCF1( 2) |
| A-1 | Bi-210 (Source: FGR 12) | 3.606E-03 | 3.606E-03 | DCF1( 3) |
| A-1 | Bi-211 (Source: FGR 12) | 2.559E-01 | 2.559E-01 | DCF1( 4) |
| A-1 | Bi-214 (Source: FGR 12) | 9.808E+00 | 9.808E+00 | DCF1( 5) |
| A-1 | Fr-223 (Source: FGR 12) | 1.980E-01 | 1.980E-01 | DCF1( 6) |
| A-1 | Pa-231 (Source: FGR 12) | 1.906E-01 | 1.906E-01 | DCF1( 7) |
| A-1 | Pa-234 (Source: FGR 12) | 1.155E+01 | 1.155E+01 | DCF1( 8) |
| A-1 | Pa-234m (Source: FGR 12) | 8.967E-02 | 8.967E-02 | DCF1( 9) |
| A-1 | Pb-210 (Source: FGR 12) | 2.447E-03 | 2.447E-03 | DCF1( 10) |
| A-1 | Pb-211 (Source: FGR 12) | 3.064E-01 | 3.064E-01 | DCF1( 11) |
| A-1 | Pb-214 (Source: FGR 12) | 1.341E+00 | 1.341E+00 | DCF1( 12) |
| A-1 | Po-210 (Source: FGR 12) | 5.231E-05 | 5.231E-05 | DCF1( 13) |
| A-1 | Po-211 (Source: FGR 12) | 4.764E-02 | 4.764E-02 | DCF1( 14) |
| A-1 | Po-214 (Source: FGR 12) | 5.138E-04 | 5.138E-04 | DCF1( 15) |
| A-1 | Po-215 (Source: FGR 12) | 1.016E-03 | 1.016E-03 | DCF1( 16) |
| A-1 | Po-218 (Source: FGR 12) | 5.642E-05 | 5.642E-05 | DCF1( 17) |
| A-1 | Ra-223 (Source: FGR 12) | 6.034E-01 | 6.034E-01 | DCF1( 18) |
| A-1 | Ra-226 (Source: FGR 12) | 3.176E-02 | 3.176E-02 | DCF1( 19) |
| A-1 | Rn-219 (Source: FGR 12) | 3.083E-01 | 3.083E-01 | DCF1( 20) |
| A-1 | Rn-222 (Source: FGR 12) | 2.354E-03 | 2.354E-03 | DCF1( 21) |
| A-1 | Th-227 (Source: FGR 12) | 5.212E-01 | 5.212E-01 | DCF1( 22) |
| A-1 | Th-230 (Source: FGR 12) | 1.209E-03 | 1.209E-03 | DCF1( 23) |
| A-1 | Th-231 (Source: FGR 12) | 3.643E-02 | 3.643E-02 | DCF1( 24) |
| A-1 | Th-234 (Source: FGR 12) | 2.410E-02 | 2.410E-02 | DCF1( 25) |
| A-1 | Tl-207 (Source: FGR 12) | 1.980E-02 | 1.980E-02 | DCF1( 26) |
| A-1 | Tl-210 (Source: no data) | 0.000E+00 | -2.000E+00 | DCF1( 27) |
| A-1 | U-234 (Source: FGR 12) | 4.017E-04 | 4.017E-04 | DCF1( 28) |
| A-1 | U-235 (Source: FGR 12) | 7.211E-01 | 7.211E-01 | DCF1( 29) |
| A-1 | U-238 (Source: FGR 12) | 1.031E-04 | 1.031E-04 | DCF1( 30) |
| | | | | |
| B-1 | Dose conversion factors for inhalation, mrem/pCi: | | | |
| B-1 | Ac-227+D | 2.109E+00 | 2.035E+00 | DCF2( 1) |
| B-1 | Pa-231 | 5.180E-01 | 5.180E-01 | DCF2( 2) |
| B-1 | Pb-210+D | 3.694E-02 | 2.072E-02 | DCF2( 3) |
| B-1 | Ra-226+D | 3.531E-02 | 3.515E-02 | DCF2( 4) |
| B-1 | Th-230 | 3.700E-01 | 3.700E-01 | DCF2( 5) |
| B-1 | U-234 | 3.480E-02 | 3.478E-02 | DCF2( 6) |
| B-1 | U-235+D | 3.150E-02 | 3.145E-02 | DCF2( 7) |
| B-1 | U-238 | 2.960E-02 | 2.960E-02 | DCF2( 8) |
| B-1 | U-238+D | 2.963E-02 | 2.960E-02 | DCF2( 9) |
| | | | | |
| D-1 | Dose conversion factors for ingestion, mrem/pCi: | | | |
| D-1 | Ac-227+D | 4.473E-03 | 4.070E-03 | DCF3( 1) |
| D-1 | Pa-231 | 2.630E-03 | 2.627E-03 | DCF3( 2) |
| D-1 | Pb-210+D | 6.995E-03 | 2.553E-03 | DCF3( 3) |
| D-1 | Ra-226+D | 1.041E-03 | 1.036E-03 | DCF3( 4) |
| D-1 | Th-230 | 7.770E-04 | 7.770E-04 | DCF3( 5) |
| D-1 | U-234 | 1.810E-04 | 1.813E-04 | DCF3( 6) |

Dose Conversion Factor (and Related) Parameter Summary (continued)
Dose Library: ICRP 72 Plus FGR 12 & ICRP 72 (Adult)

| 0 Menu | Parameter | Current Value# | Base Case* | Parameter Name |
|---|---|---|---|---|
| D-1 | U-235+D | 1.753E-04 | 1.739E-04 | DCF3( 7) |
| D-1 | U-238 | 1.670E-04 | 1.665E-04 | DCF3( 8) |
| D-1 | U-238+D | 1.796E-04 | 1.665E-04 | DCF3( 9) |
| | | | | |
| D-34 | Food transfer factors: | | | |
| D-34 | Ac-227+D , plant/soil concentration ratio, dimensionless | 2.500E-03 | 2.500E-03 | RTF( 1,1) |
| D-34 | Ac-227+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d) | 2.000E-05 | 2.000E-05 | RTF( 1,2) |
| D-34 | Ac-227+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d) | 2.000E-05 | 2.000E-05 | RTF( 1,3) |
| D-34 | | | | |
| D-34 | Pa-231 , plant/soil concentration ratio, dimensionless | 1.000E-02 | 1.000E-02 | RTF( 2,1) |
| D-34 | Pa-231 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d) | 5.000E-03 | 5.000E-03 | RTF( 2,2) |
| D-34 | Pa-231 , milk/livestock-intake ratio, (pCi/L)/(pCi/d) | 5.000E-06 | 5.000E-06 | RTF( 2,3) |
| D-34 | | | | |
| D-34 | Pb-210+D , plant/soil concentration ratio, dimensionless | 1.000E-02 | 1.000E-02 | RTF( 3,1) |
| D-34 | Pb-210+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d) | 8.000E-04 | 8.000E-04 | RTF( 3,2) |
| D-34 | Pb-210+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d) | 3.000E-04 | 3.000E-04 | RTF( 3,3) |
| D-34 | | | | |
| D-34 | Ra-226+D , plant/soil concentration ratio, dimensionless | 4.000E-02 | 4.000E-02 | RTF( 4,1) |
| D-34 | Ra-226+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d) | 1.000E-03 | 1.000E-03 | RTF( 4,2) |
| D-34 | Ra-226+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d) | 1.000E-03 | 1.000E-03 | RTF( 4,3) |
| D-34 | | | | |
| D-34 | Th-230 , plant/soil concentration ratio, dimensionless | 1.000E-03 | 1.000E-03 | RTF( 5,1) |
| D-34 | Th-230 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d) | 1.000E-04 | 1.000E-04 | RTF( 5,2) |
| D-34 | Th-230 , milk/livestock-intake ratio, (pCi/L)/(pCi/d) | 5.000E-06 | 5.000E-06 | RTF( 5,3) |
| D-34 | | | | |
| D-34 | U-234 , plant/soil concentration ratio, dimensionless | 2.500E-03 | 2.500E-03 | RTF( 6,1) |
| D-34 | U-234 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d) | 3.400E-04 | 3.400E-04 | RTF( 6,2) |
| D-34 | U-234 , milk/livestock-intake ratio, (pCi/L)/(pCi/d) | 6.000E-04 | 6.000E-04 | RTF( 6,3) |
| D-34 | | | | |
| D-34 | U-235+D , plant/soil concentration ratio, dimensionless | 2.500E-03 | 2.500E-03 | RTF( 7,1) |
| D-34 | U-235+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d) | 3.400E-04 | 3.400E-04 | RTF( 7,2) |
| D-34 | U-235+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d) | 6.000E-04 | 6.000E-04 | RTF( 7,3) |
| D-34 | | | | |
| D-34 | U-238 , plant/soil concentration ratio, dimensionless | 2.500E-03 | 2.500E-03 | RTF( 8,1) |
| D-34 | U-238 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d) | 3.400E-04 | 3.400E-04 | RTF( 8,2) |
| D-34 | U-238 , milk/livestock-intake ratio, (pCi/L)/(pCi/d) | 6.000E-04 | 6.000E-04 | RTF( 8,3) |
| D-34 | | | | |
| D-34 | U-238+D , plant/soil concentration ratio, dimensionless | 2.500E-03 | 2.500E-03 | RTF( 9,1) |
| D-34 | U-238+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d) | 3.400E-04 | 3.400E-04 | RTF( 9,2) |
| D-34 | U-238+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d) | 6.000E-04 | 6.000E-04 | RTF( 9,3) |
| | | | | |
| D-5 | Bioaccumulation factors, fresh water, L/kg: | | | |
| D-5 | Ac-227+D , fish | 1.500E+01 | 1.500E+01 | BIOFAC( 1,1) |
| D-5 | Ac-227+D , crustacea and mollusks | 1.000E+03 | 1.000E+03 | BIOFAC( 1,2) |
| D-5 | | | | |
| D-5 | Pa-231 , fish | 1.000E+01 | 1.000E+01 | BIOFAC( 2,1) |
| D-5 | Pa-231 , crustacea and mollusks | 1.100E+02 | 1.100E+02 | BIOFAC( 2,2) |
| D-5 | | | | |
| D-5 | Pb-210+D , fish | 3.000E+02 | 3.000E+02 | BIOFAC( 3,1) |
| D-5 | Pb-210+D , crustacea and mollusks | 1.000E+02 | 1.000E+02 | BIOFAC( 3,2) |

Dose Conversion Factor (and Related) Parameter Summary (continued)
Dose Library: ICRP 72 Plus FGR 12 & ICRP 72 (Adult)

| 0 Menu | Parameter | Current Value# | Base Case* | Parameter Name |
|---|---|---|---|---|
| D-5 | Ra-226+D , fish | 5.000E+01 | 5.000E+01 | BIOFAC( 4,1) |
| D-5 | Ra-226+D , crustacea and mollusks | 2.500E+02 | 2.500E+02 | BIOFAC( 4,2) |
| D-5 | | | | |
| D-5 | Th-230 , fish | 1.000E+02 | 1.000E+02 | BIOFAC( 5,1) |
| D-5 | Th-230 , crustacea and mollusks | 5.000E+02 | 5.000E+02 | BIOFAC( 5,2) |
| D-5 | | | | |
| D-5 | U-234 , fish | 1.000E+01 | 1.000E+01 | BIOFAC( 6,1) |
| D-5 | U-234 , crustacea and mollusks | 6.000E+01 | 6.000E+01 | BIOFAC( 6,2) |
| D-5 | | | | |
| D-5 | U-235+D , fish | 1.000E+01 | 1.000E+01 | BIOFAC( 7,1) |
| D-5 | U-235+D , crustacea and mollusks | 6.000E+01 | 6.000E+01 | BIOFAC( 7,2) |
| D-5 | | | | |
| D-5 | U-238 , fish | 1.000E+01 | 1.000E+01 | BIOFAC( 8,1) |
| D-5 | U-238 , crustacea and mollusks | 6.000E+01 | 6.000E+01 | BIOFAC( 8,2) |
| D-5 | | | | |
| D-5 | U-238+D , fish | 1.000E+01 | 1.000E+01 | BIOFAC( 9,1) |
| D-5 | U-238+D , crustacea and mollusks | 6.000E+01 | 6.000E+01 | BIOFAC( 9,2) |

#For DCF1(xxx) only, factors are for infinite depth & area. See ETFG table in Ground Pathway of Detailed Report.
*Base Case means Default.Lib w/o Associate Nuclide contributions.

Site-Specific Parameter Summary

| 0 Menu | Parameter | User Input | Default | Used by RESRAD (If different from user input) | Parameter Name |
|---|---|---|---|---|---|
| R011 | Area of contaminated zone (m**2) | 1.000E+05 | 1.000E+04 | --- | AREA |
| R011 | Thickness of contaminated zone (m) | 2.000E+00 | 2.000E+00 | --- | THICK0 |
| R011 | Fraction of contamination that is submerged | 0.000E+00 | 0.000E+00 | --- | SUBMFRACT |
| R011 | Length parallel to aquifer flow (m) | 5.810E+02 | 1.000E+02 | --- | LCZPAQ |
| R011 | Basic radiation dose limit (mrem/yr) | 2.500E+01 | 3.000E+01 | --- | BRDL |
| R011 | Time since placement of material (yr) | 0.000E+00 | 0.000E+00 | --- | TI |
| R011 | Times for calculations (yr) | 1.000E+00 | 1.000E+00 | --- | T( 2) |
| R011 | Times for calculations (yr) | 3.000E+00 | 3.000E+00 | --- | T( 3) |
| R011 | Times for calculations (yr) | 1.000E+01 | 1.000E+01 | --- | T( 4) |
| R011 | Times for calculations (yr) | 3.000E+01 | 3.000E+01 | --- | T( 5) |
| R011 | Times for calculations (yr) | 1.000E+02 | 1.000E+02 | --- | T( 6) |
| R011 | Times for calculations (yr) | 3.000E+02 | 3.000E+02 | --- | T( 7) |
| R011 | Times for calculations (yr) | 1.000E+03 | 1.000E+03 | --- | T( 8) |
| R011 | Times for calculations (yr) | not used | 0.000E+00 | --- | T( 9) |
| R011 | Times for calculations (yr) | not used | 0.000E+00 | --- | T(10) |
| | | | | | |
| R012 | Initial principal radionuclide (pCi/g): Pb-210 | 1.000E+00 | 0.000E+00 | --- | S1(3) |
| R012 | Initial principal radionuclide (pCi/g): Ra-226 | 1.000E+00 | 0.000E+00 | --- | S1(4) |
| R012 | Initial principal radionuclide (pCi/g): Th-230 | 2.650E+01 | 0.000E+00 | --- | S1(5) |
| R012 | Initial principal radionuclide (pCi/g): U-234 | 1.400E+00 | 0.000E+00 | --- | S1(6) |
| R012 | Initial principal radionuclide (pCi/g): U-235 | 1.300E-02 | 0.000E+00 | --- | S1(7) |
| R012 | Initial principal radionuclide (pCi/g): U-238 | 1.400E+00 | 0.000E+00 | --- | S1(8) |
| R012 | Concentration in groundwater (pCi/L): Pb-210 | not used | 0.000E+00 | --- | W1( 3) |
| R012 | Concentration in groundwater (pCi/L): Ra-226 | not used | 0.000E+00 | --- | W1( 4) |
| R012 | Concentration in groundwater (pCi/L): Th-230 | not used | 0.000E+00 | --- | W1( 5) |
| R012 | Concentration in groundwater (pCi/L): U-234 | not used | 0.000E+00 | --- | W1( 6) |
| R012 | Concentration in groundwater (pCi/L): U-235 | not used | 0.000E+00 | --- | W1( 7) |
| R012 | Concentration in groundwater (pCi/L): U-238 | not used | 0.000E+00 | --- | W1( 8) |
| | | | | | |
| R013 | Cover depth (m) | 3.000E-01 | 0.000E+00 | --- | COVER0 |
| R013 | Density of cover material (g/cm**3) | 1.500E+00 | 1.500E+00 | --- | DENSCV |
| R013 | Cover depth erosion rate (m/yr) | 1.000E-05 | 1.000E-03 | --- | VCV |
| R013 | Density of contaminated zone (g/cm**3) | 1.500E+00 | 1.500E+00 | --- | DENSCZ |
| R013 | Contaminated zone erosion rate (m/yr) | 1.000E-05 | 1.000E-03 | --- | VCZ |
| R013 | Contaminated zone total porosity | 2.000E-01 | 4.000E-01 | --- | TPCZ |
| R013 | Contaminated zone field capacity | 5.000E-02 | 2.000E-01 | --- | FCCZ |
| R013 | Contaminated zone hydraulic conductivity (m/yr) | 2.002E+03 | 1.000E+01 | --- | HCCZ |
| R013 | Contaminated zone b parameter | 1.000E+00 | 5.300E+00 | --- | BCZ |
| R013 | Average annual wind speed (m/sec) | 3.900E+00 | 2.000E+00 | --- | WIND |
| R013 | Humidity in air (g/m**3) | not used | 8.000E+00 | --- | HUMID |
| R013 | Evapotranspiration coefficient | 9.000E-01 | 5.000E-01 | --- | EVAPTR |
| R013 | Precipitation (m/yr) | 2.660E-01 | 1.000E+00 | --- | PRECIP |
| R013 | Irrigation (m/yr) | 0.000E+00 | 2.000E-01 | --- | RI |
| R013 | Irrigation mode | overhead | overhead | --- | IDITCH |
| R013 | Runoff coefficient | 4.000E-01 | 2.000E-01 | --- | RUNOFF |
| R013 | Watershed area for nearby stream or pond (m**2) | 1.560E+08 | 1.000E+06 | --- | WAREA |
| R013 | Accuracy for water/soil computations | 1.000E-03 | 1.000E-03 | --- | EPS |
| | | | | | |
| R014 | Density of saturated zone (g/cm**3) | 2.400E+00 | 1.500E+00 | --- | DENSAQ |
| R014 | Saturated zone total porosity | 8.000E-02 | 4.000E-01 | --- | TPSZ |

Site-Specific Parameter Summary (continued)

| 0 Menu | Parameter | User Input | Default | Used by RESRAD (If different from user input) | Parameter Name |
|---|---|---|---|---|---|
| R014 | Saturated zone effective porosity | 4.000E-02 | 2.000E-01 | --- | EPSZ |
| R014 | Saturated zone field capacity | 4.000E-02 | 2.000E-01 | --- | FCSZ |
| R014 | Saturated zone hydraulic conductivity (m/yr) | 6.700E+01 | 1.000E+02 | --- | HCSZ |
| R014 | Saturated zone hydraulic gradient | 4.000E-02 | 2.000E-02 | --- | HGWT |
| R014 | Saturated zone b parameter | 1.000E+00 | 5.300E+00 | --- | BSZ |
| R014 | Water table drop rate (m/yr) | 1.000E+00 | 1.000E-03 | --- | VWT |
| R014 | Well pump intake depth (m below water table) | 1.000E-05 | 1.000E+01 | --- | DWIBWT |
| R014 | Model: Nondispersion (ND) or Mass-Balance (MB) | ND | ND | --- | MODEL |
| R014 | Well pumping rate (m**3/yr) | 0.000E+00 | 2.500E+02 | --- | UW |
| | | | | | |
| R015 | Number of unsaturated zone strata | 1 | 1 | --- | NS |
| R015 | Unsat. zone 1, thickness (m) | 6.000E+00 | 4.000E+00 | --- | H(1) |
| R015 | Unsat. zone 1, soil density (g/cm**3) | 1.500E+00 | 1.500E+00 | --- | DENSUZ(1) |
| R015 | Unsat. zone 1, total porosity | 2.000E-01 | 4.000E-01 | --- | TPUZ(1) |
| R015 | Unsat. zone 1, effective porosity | 1.500E-01 | 2.000E-01 | --- | EPUZ(1) |
| R015 | Unsat. zone 1, field capacity | 5.000E-02 | 2.000E-01 | --- | FCUZ(1) |
| R015 | Unsat. zone 1, soil-specific b parameter | 1.000E+00 | 5.300E+00 | --- | BUZ(1) |
| R015 | Unsat. zone 1, hydraulic conductivity (m/yr) | 2.002E+03 | 1.000E+01 | --- | HCUZ(1) |
| | | | | | |
| R016 | Distribution coefficients for Pb-210 | | | | |
| R016 | Contaminated zone (cm**3/g) | 1.000E+00 | 1.000E+02 | --- | DCNUCC( 3) |
| R016 | Unsaturated zone 1 (cm**3/g) | 1.000E+00 | 1.000E+02 | --- | DCNUCU( 3,1) |
| R016 | Saturated zone (cm**3/g) | 9.000E+01 | 1.000E+02 | --- | DCNUCS( 3) |
| R016 | Leach rate (/yr) | 0.000E+00 | 0.000E+00 | 5.148E-03 | ALEACH( 3) |
| R016 | Solubility constant | 0.000E+00 | 0.000E+00 | not used | SOLUBK( 3) |
| | | | | | |
| R016 | Distribution coefficients for Ra-226 | | | | |
| R016 | Contaminated zone (cm**3/g) | 1.000E+00 | 7.000E+01 | --- | DCNUCC( 4) |
| R016 | Unsaturated zone 1 (cm**3/g) | 1.000E+00 | 7.000E+01 | --- | DCNUCU( 4,1) |
| R016 | Saturated zone (cm**3/g) | 9.000E+01 | 7.000E+01 | --- | DCNUCS( 4) |
| R016 | Leach rate (/yr) | 0.000E+00 | 0.000E+00 | 5.148E-03 | ALEACH( 4) |
| R016 | Solubility constant | 0.000E+00 | 0.000E+00 | not used | SOLUBK( 4) |
| | | | | | |
| R016 | Distribution coefficients for Th-230 | | | | |
| R016 | Contaminated zone (cm**3/g) | 1.000E+00 | 6.000E+04 | --- | DCNUCC( 5) |
| R016 | Unsaturated zone 1 (cm**3/g) | 1.000E+00 | 6.000E+04 | --- | DCNUCU( 5,1) |
| R016 | Saturated zone (cm**3/g) | 9.000E+01 | 6.000E+04 | --- | DCNUCS( 5) |
| R016 | Leach rate (/yr) | 0.000E+00 | 0.000E+00 | 5.148E-03 | ALEACH( 5) |
| R016 | Solubility constant | 0.000E+00 | 0.000E+00 | not used | SOLUBK( 5) |
| | | | | | |
| R016 | Distribution coefficients for U-234 | | | | |
| R016 | Contaminated zone (cm**3/g) | 1.000E+00 | 5.000E+01 | --- | DCNUCC( 6) |
| R016 | Unsaturated zone 1 (cm**3/g) | 1.000E+00 | 5.000E+01 | --- | DCNUCU( 6,1) |
| R016 | Saturated zone (cm**3/g) | 9.000E+01 | 5.000E+01 | --- | DCNUCS( 6) |
| R016 | Leach rate (/yr) | 0.000E+00 | 0.000E+00 | 5.148E-03 | ALEACH( 6) |
| R016 | Solubility constant | 0.000E+00 | 0.000E+00 | not used | SOLUBK( 6) |

Site-Specific Parameter Summary (continued)

| 0 Menu | Parameter | User Input | Default | Used by RESRAD (If different from user input) | Parameter Name |
|---|---|---|---|---|---|
| R016 | Distribution coefficients for U-235 | | | | |
| R016 | Contaminated zone (cm**3/g) | 1.000E+00 | 5.000E+01 | --- | DCNUCC( 7) |
| R016 | Unsaturated zone 1 (cm**3/g) | 1.000E+00 | 5.000E+01 | --- | DCNUCU( 7,1) |
| R016 | Saturated zone (cm**3/g) | 9.000E+01 | 5.000E+01 | --- | DCNUCS( 7) |
| R016 | Leach rate (/yr) | 0.000E+00 | 0.000E+00 | 5.148E-03 | ALEACH( 7) |
| R016 | Solubility constant | 0.000E+00 | 0.000E+00 | not used | SOLUBK( 7) |
| | | | | | |
| R016 | Distribution coefficients for U-238 | | | | |
| R016 | Contaminated zone (cm**3/g) | 1.000E+00 | 5.000E+01 | --- | DCNUCC( 8) |
| R016 | Unsaturated zone 1 (cm**3/g) | 1.000E+00 | 5.000E+01 | --- | DCNUCU( 8,1) |
| R016 | Saturated zone (cm**3/g) | 9.000E+01 | 5.000E+01 | --- | DCNUCS( 8) |
| R016 | Leach rate (/yr) | 0.000E+00 | 0.000E+00 | 5.148E-03 | ALEACH( 8) |
| R016 | Solubility constant | 0.000E+00 | 0.000E+00 | not used | SOLUBK( 8) |
| | | | | | |
| R016 | Distribution coefficients for daughter Ac-227 | | | | |
| R016 | Contaminated zone (cm**3/g) | 2.000E+01 | 2.000E+01 | --- | DCNUCC( 1) |
| R016 | Unsaturated zone 1 (cm**3/g) | 2.000E+01 | 2.000E+01 | --- | DCNUCU( 1,1) |
| R016 | Saturated zone (cm**3/g) | 2.000E+01 | 2.000E+01 | --- | DCNUCS( 1) |
| R016 | Leach rate (/yr) | 0.000E+00 | 0.000E+00 | 2.656E-04 | ALEACH( 1) |
| R016 | Solubility constant | 0.000E+00 | 0.000E+00 | not used | SOLUBK( 1) |
| | | | | | |
| R016 | Distribution coefficients for daughter Pa-231 | | | | |
| R016 | Contaminated zone (cm**3/g) | 5.000E+01 | 5.000E+01 | --- | DCNUCC( 2) |
| R016 | Unsaturated zone 1 (cm**3/g) | 5.000E+01 | 5.000E+01 | --- | DCNUCU( 2,1) |
| R016 | Saturated zone (cm**3/g) | 5.000E+01 | 5.000E+01 | --- | DCNUCS( 2) |
| R016 | Leach rate (/yr) | 0.000E+00 | 0.000E+00 | 1.063E-04 | ALEACH( 2) |
| R016 | Solubility constant | 0.000E+00 | 0.000E+00 | not used | SOLUBK( 2) |
| | | | | | |
| R017 | Inhalation rate (m**3/yr) | 8.400E+03 | 8.400E+03 | --- | INHALR |
| R017 | Mass loading for inhalation (g/m**3) | 1.000E-04 | 1.000E-04 | --- | MLINH |
| R017 | Exposure duration | 1.000E+00 | 3.000E+01 | --- | ED |
| R017 | Shielding factor, inhalation | 5.600E-01 | 4.000E-01 | --- | SHF3 |
| R017 | Shielding factor, external gamma | 2.100E-01 | 7.000E-01 | --- | SHF1 |
| R017 | Fraction of time spent indoors | 4.500E-01 | 5.000E-01 | --- | FIND |
| R017 | Fraction of time spent outdoors (on site) | 2.100E-01 | 2.500E-01 | --- | FOTD |
| R017 | Shape factor flag, external gamma | 1.000E+00 | 1.000E+00 | >0 shows circular AREA. | FS |
| R017 | Radii of shape factor array (used if FS = -1): | | | | |
| R017 | Outer annular radius (m), ring 1: | not used | 5.000E+01 | --- | RAD_SHAPE( 1) |
| R017 | Outer annular radius (m), ring 2: | not used | 7.071E+01 | --- | RAD_SHAPE( 2) |
| R017 | Outer annular radius (m), ring 3: | not used | 0.000E+00 | --- | RAD_SHAPE( 3) |
| R017 | Outer annular radius (m), ring 4: | not used | 0.000E+00 | --- | RAD_SHAPE( 4) |
| R017 | Outer annular radius (m), ring 5: | not used | 0.000E+00 | --- | RAD_SHAPE( 5) |
| R017 | Outer annular radius (m), ring 6: | not used | 0.000E+00 | --- | RAD_SHAPE( 6) |
| R017 | Outer annular radius (m), ring 7: | not used | 0.000E+00 | --- | RAD_SHAPE( 7) |
| R017 | Outer annular radius (m), ring 8: | not used | 0.000E+00 | --- | RAD_SHAPE( 8) |
| R017 | Outer annular radius (m), ring 9: | not used | 0.000E+00 | --- | RAD_SHAPE( 9) |
| R017 | Outer annular radius (m), ring 10: | not used | 0.000E+00 | --- | RAD_SHAPE(10) |
| R017 | Outer annular radius (m), ring 11: | not used | 0.000E+00 | --- | RAD_SHAPE(11) |
| R017 | Outer annular radius (m), ring 12: | not used | 0.000E+00 | --- | RAD_SHAPE(12) |

Site-Specific Parameter Summary (continued)

| Menu | Parameter | User Input | Default | Used by RESRAD (If different from user input) | Parameter Name |
|---|---|---|---|---|---|
| R017 | Fractions of annular areas within AREA: | | | | |
| R017 | Ring 1 | not used | 1.000E+00 | --- | FRACA( 1) |
| R017 | Ring 2 | not used | 2.732E-01 | --- | FRACA( 2) |
| R017 | Ring 3 | not used | 0.000E+00 | --- | FRACA( 3) |
| R017 | Ring 4 | not used | 0.000E+00 | --- | FRACA( 4) |
| R017 | Ring 5 | not used | 0.000E+00 | --- | FRACA( 5) |
| R017 | Ring 6 | not used | 0.000E+00 | --- | FRACA( 6) |
| R017 | Ring 7 | not used | 0.000E+00 | --- | FRACA( 7) |
| R017 | Ring 8 | not used | 0.000E+00 | --- | FRACA( 8) |
| R017 | Ring 9 | not used | 0.000E+00 | --- | FRACA( 9) |
| R017 | Ring 10 | not used | 0.000E+00 | --- | FRACA(10) |
| R017 | Ring 11 | not used | 0.000E+00 | --- | FRACA(11) |
| R017 | Ring 12 | not used | 0.000E+00 | --- | FRACA(12) |
| | | | | | |
| R018 | Fruits, vegetables and grain consumption (kg/yr) | 1.780E+02 | 1.600E+02 | --- | DIET(1) |
| R018 | Leafy vegetable consumption (kg/yr) | 2.500E+01 | 1.400E+01 | --- | DIET(2) |
| R018 | Milk consumption (L/yr) | not used | 9.200E+01 | --- | DIET(3) |
| R018 | Meat and poultry consumption (kg/yr) | 6.300E+01 | 6.300E+01 | --- | DIET(4) |
| R018 | Fish consumption (kg/yr) | not used | 5.400E+00 | --- | DIET(5) |
| R018 | Other seafood consumption (kg/yr) | not used | 9.000E-01 | --- | DIET(6) |
| R018 | Soil ingestion rate (g/yr) | 3.650E+01 | 3.650E+01 | --- | SOIL |
| R018 | Drinking water intake (L/yr) | not used | 5.100E+02 | --- | DWI |
| R018 | Contamination fraction of drinking water | not used | 1.000E+00 | --- | FDW |
| R018 | Contamination fraction of household water | not used | 1.000E+00 | --- | FHHW |
| R018 | Contamination fraction of livestock water | 1.000E+00 | 1.000E+00 | --- | FLW |
| R018 | Contamination fraction of irrigation water | 0.000E+00 | 1.000E+00 | --- | FIRW |
| R018 | Contamination fraction of aquatic food | not used | 5.000E-01 | --- | FR9 |
| R018 | Contamination fraction of plant food | 5.000E-02 | -1 | --- | FPLANT |
| R018 | Contamination fraction of meat | 5.000E-02 | -1 | --- | FMEAT |
| R018 | Contamination fraction of milk | not used | -1 | --- | FMILK |
| | | | | | |
| R019 | Livestock fodder intake for meat (kg/day) | 6.800E+01 | 6.800E+01 | --- | LFI5 |
| R019 | Livestock fodder intake for milk (kg/day) | not used | 5.500E+01 | --- | LFI6 |
| R019 | Livestock water intake for meat (L/day) | 5.000E+01 | 5.000E+01 | --- | LWI5 |
| R019 | Livestock water intake for milk (L/day) | not used | 1.600E+02 | --- | LWI6 |
| R019 | Livestock soil intake (kg/day) | 5.000E-01 | 5.000E-01 | --- | LSI |
| R019 | Mass loading for foliar deposition (g/m**3) | 1.000E-04 | 1.000E-04 | --- | MLFD |
| R019 | Depth of soil mixing layer (m) | 1.500E-01 | 1.500E-01 | --- | DM |
| R019 | Depth of roots (m) | 3.000E-01 | 9.000E-01 | --- | DROOT |
| R019 | Drinking water fraction from ground water | not used | 1.000E+00 | --- | FGWDW |
| R019 | Household water fraction from ground water | not used | 1.000E+00 | --- | FGWHH |
| R019 | Livestock water fraction from ground water | 0.000E+00 | 1.000E+00 | --- | FGWLW |
| R019 | Irrigation fraction from ground water | 0.000E+00 | 1.000E+00 | --- | FGWIR |
| | | | | | |
| R19B | Wet weight crop yield for Non-Leafy (kg/m**2) | 7.000E-01 | 7.000E-01 | --- | YV(1) |
| R19B | Wet weight crop yield for Leafy (kg/m**2) | 1.500E+00 | 1.500E+00 | --- | YV(2) |
| R19B | Wet weight crop yield for Fodder (kg/m**2) | 1.100E+00 | 1.100E+00 | --- | YV(3) |
| R19B | Growing Season for Non-Leafy (years) | 1.700E-01 | 1.700E-01 | --- | TE(1) |
| R19B | Growing Season for Leafy (years) | 2.500E-01 | 2.500E-01 | --- | TE(2) |
| R19B | Growing Season for Fodder (years) | 8.000E-02 | 8.000E-02 | --- | TE(3) |

Site-Specific Parameter Summary (continued)

| Menu | Parameter | User Input | Default | Used by RESRAD (If different from user input) | Parameter Name |
|---|---|---|---|---|---|
| R19B | Translocation Factor for Non-Leafy | 1.000E-01 | 1.000E-01 | --- | TIV(1) |
| R19B | Translocation Factor for Leafy | 1.000E+00 | 1.000E+00 | --- | TIV(2) |
| R19B | Translocation Factor for Fodder | 1.000E+00 | 1.000E+00 | --- | TIV(3) |
| R19B | Dry Foliar Interception Fraction for Non-Leafy | 2.500E-01 | 2.500E-01 | --- | RDRY(1) |
| R19B | Dry Foliar Interception Fraction for Leafy | 2.500E-01 | 2.500E-01 | --- | RDRY(2) |
| R19B | Dry Foliar Interception Fraction for Fodder | 2.500E-01 | 2.500E-01 | --- | RDRY(3) |
| R19B | Wet Foliar Interception Fraction for Non-Leafy | 2.500E-01 | 2.500E-01 | --- | RWET(1) |
| R19B | Wet Foliar Interception Fraction for Leafy | 2.500E-01 | 2.500E-01 | --- | RWET(2) |
| R19B | Wet Foliar Interception Fraction for Fodder | 2.500E-01 | 2.500E-01 | --- | RWET(3) |
| R19B | Weathering Removal Constant for Vegetation | 2.000E+01 | 2.000E+01 | --- | WLAM |
| | | | | | |
| C14 | C-12 concentration in water (g/cm**3) | not used | 2.000E-05 | --- | C12WTR |
| C14 | C-12 concentration in contaminated soil (g/g) | not used | 3.000E-02 | --- | C12CZ |
| C14 | Fraction of vegetation carbon from soil | not used | 2.000E-02 | --- | CSOIL |
| C14 | Fraction of vegetation carbon from air | not used | 9.800E-01 | --- | CAIR |
| C14 | C-14 evasion layer thickness in soil (m) | not used | 3.000E-01 | --- | DMC |
| C14 | C-14 evasion flux rate from soil (1/sec) | not used | 7.000E-07 | --- | EVSN |
| C14 | C-12 evasion flux rate from soil (1/sec) | not used | 1.000E-10 | --- | REVSN |
| C14 | Fraction of grain in beef cattle feed | not used | 8.000E-01 | --- | AVFG4 |
| C14 | Fraction of grain in milk cow feed | not used | 2.000E-01 | --- | AVFG5 |
| | | | | | |
| STOR | Storage times of contaminated foodstuffs (days): | | | | |
| STOR | Fruits, non-leafy vegetables, and grain | 1.400E+01 | 1.400E+01 | --- | STOR_T(1) |
| STOR | Leafy vegetables | 1.000E+00 | 1.000E+00 | --- | STOR_T(2) |
| STOR | Milk | 1.000E+00 | 1.000E+00 | --- | STOR_T(3) |
| STOR | Meat and poultry | 2.000E+01 | 2.000E+01 | --- | STOR_T(4) |
| STOR | Fish | 7.000E+00 | 7.000E+00 | --- | STOR_T(5) |
| STOR | Crustacea and mollusks | 7.000E+00 | 7.000E+00 | --- | STOR_T(6) |
| STOR | Well water | 1.000E+00 | 1.000E+00 | --- | STOR_T(7) |
| STOR | Surface water | 1.000E+00 | 1.000E+00 | --- | STOR_T(8) |
| STOR | Livestock fodder | 4.500E+01 | 4.500E+01 | --- | STOR_T(9) |
| | | | | | |
| R021 | Thickness of building foundation (m) | not used | 1.500E-01 | --- | FLOOR1 |
| R021 | Bulk density of building foundation (g/cm**3) | not used | 2.400E+00 | --- | DENSFL |
| R021 | Total porosity of the cover material | not used | 4.000E-01 | --- | TPCV |
| R021 | Total porosity of the building foundation | not used | 1.000E-01 | --- | TPFL |
| R021 | Volumetric water content of the cover material | not used | 5.000E-02 | --- | PH2OCV |
| R021 | Volumetric water content of the foundation | not used | 3.000E-02 | --- | PH2OFL |
| R021 | Diffusion coefficient for radon gas (m/sec): | | | | |
| R021 | in cover material | not used | 2.000E-06 | --- | DIFCV |
| R021 | in foundation material | not used | 3.000E-07 | --- | DIFFL |
| R021 | in contaminated zone soil | not used | 2.000E-06 | --- | DIFCZ |
| R021 | Radon vertical dimension of mixing (m) | not used | 2.000E+00 | --- | HMIX |
| R021 | Average building air exchange rate (1/hr) | not used | 5.000E-01 | --- | REXG |
| R021 | Height of the building (room) (m) | not used | 2.500E+00 | --- | HRM |
| R021 | Building interior area factor | not used | 0.000E+00 | --- | FAI |
| R021 | Building depth below ground surface (m) | not used | -1.000E+00 | --- | DMFL |
| R021 | Emanating power of Rn-222 gas | not used | 2.500E-01 | --- | EMANA(1) |
| R021 | Emanating power of Rn-220 gas | not used | 1.500E-01 | --- | EMANA(2) |
| | | | | | |
| TITL | Number of graphical time points | 32 | --- | --- | NPTS |

Site-Specific Parameter Summary (continued)

| 0 Menu | Parameter | User Input | Default | Used by RESRAD (If different from user input) | Parameter Name |
|---|---|---|---|---|---|
| TITL | Maximum number of integration points for dose | 17 | --- | --- | LYMAX |
| TITL | Maximum number of integration points for risk | 257 | --- | --- | KYMAX |

Summary of Pathway Selections

| Pathway | User Selection |
|---|---|
| 1 -- external gamma | active |
| 2 -- inhalation (w/o radon) | active |
| 3 -- plant ingestion | active |
| 4 -- meat ingestion | active |
| 5 -- milk ingestion | suppressed |
| 6 -- aquatic foods | suppressed |
| 7 -- drinking water | suppressed |
| 8 -- soil ingestion | active |
| 9 -- radon | suppressed |
| Find peak pathway doses | active |

Summary :  Mill Area with 1 pCi/g and proportational amounts of Th and U
File    : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\RAM MILL AREA 1 PCI-G.RAD

**Contaminated Zone Dimensions**

Area: 100000.00 square meters
Thickness: 2.00 meters
Cover Depth: 0.30 meters

**Initial Soil Concentrations, pCi/g**

| | |
|---|---|
| Pb-210 | 1.000E+00 |
| Ra-226 | 1.000E+00 |
| Th-230 | 2.650E+01 |
| U-234 | 1.400E+00 |
| U-235 | 1.300E-02 |
| U-238 | 1.400E+00 |

0

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 2.500E+01 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

| t (years): | 0.000E+00 | 1.000E+00 | 3.000E+00 | 1.000E+01 | 3.000E+01 | 1.000E+02 | 3.000E+02 | 1.000E+03 |
|---|---|---|---|---|---|---|---|---|
| TDOSE(t): | 9.706E-02 | 9.767E-02 | 9.886E-02 | 1.028E-01 | 1.119E-01 | 1.259E-01 | 9.708E-02 | 8.415E-03 |
| M(t): | 3.883E-03 | 3.907E-03 | 3.955E-03 | 4.111E-03 | 4.476E-03 | 5.036E-03 | 3.883E-03 | 3.366E-04 |

0Maximum TDOSE(t):  1.262E-01 mrem/yr   at t =   114.9 ñ 0.2 years
0

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.149E+02 years
0 Water Independent Pathways (Inhalation excludes radon)
0

| Radio-Nuclide | Ground | | Inhalation | | Radon | | Plant | | Meat | | Milk | | Soil | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Pb-210 | 4.146E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 4.170E-05 | 0.0003 | 7.037E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Ra-226 | 5.101E-02 | 0.4041 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.270E-03 | 0.0180 | 4.227E-05 | 0.0003 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Th-230 | 6.928E-02 | 0.5488 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 3.035E-03 | 0.0240 | 5.002E-05 | 0.0004 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-234 | 1.929E-06 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.374E-05 | 0.0001 | 9.917E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-235 | 3.106E-06 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.552E-07 | 0.0000 | 3.458E-09 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-238 | 4.855E-04 | 0.0038 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.355E-05 | 0.0001 | 9.720E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Total | 1.208E-01 | 0.9567 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 5.374E-03 | 0.0426 | 9.320E-05 | 0.0007 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.149E+02 years

0 Water Dependent Pathways

| Radio-Nuclide | Water mrem/yr | Water fract. | Fish mrem/yr | Fish fract. | Radon mrem/yr | Radon fract. | Plant mrem/yr | Plant fract. | Meat mrem/yr | Meat fract. | Milk mrem/yr | Milk fract. | All Pathways* mrem/yr | All Pathways* fract. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 4.245E-05 | 0.0003 |
| Ra-226 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 5.332E-02 | 0.4224 |
| Th-230 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 7.236E-02 | 0.5732 |
| U-234 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.577E-05 | 0.0001 |
| U-235 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 3.264E-06 | 0.0000 |
| U-238 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 4.991E-04 | 0.0040 |
| Total | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.262E-01 | 1.0000 |

0*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years
0 Water Independent Pathways (Inhalation excludes radon)

| Radio- | Ground | | Inhalation | | Radon | | Plant | | Meat | | Milk | | Soil | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Pb-210 | 2.608E-06 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.088E-05 | 0.0001 | 1.355E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Ra-226 | 9.562E-02 | 0.9851 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 6.877E-06 | 0.0001 | 1.085E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Th-230 | 5.503E-04 | 0.0057 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 3.321E-06 | 0.0000 | 5.763E-09 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-234 | 2.005E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.006E-07 | 0.0000 | 5.333E-10 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-235 | 5.357E-06 | 0.0001 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 9.057E-10 | 0.0000 | 4.846E-12 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-238 | 8.638E-04 | 0.0089 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 9.987E-08 | 0.0000 | 5.292E-10 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Total | 9.704E-02 | 0.9998 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.128E-05 | 0.0002 | 2.509E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |

0

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years
0 Water Dependent Pathways

| Radio- | Water | | Fish | | Radon | | Plant | | Meat | | Milk | | All Pathways* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Pb-210 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.363E-05 | 0.0001 |
| Ra-226 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 9.563E-02 | 0.9852 |
| Th-230 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 5.536E-04 | 0.0057 |
| U-234 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.212E-07 | 0.0000 |
| U-235 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 5.358E-06 | 0.0001 |
| U-238 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 8.639E-04 | 0.0089 |
| Total | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 9.706E-02 | 1.0000 |

0*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years
0 Water Independent Pathways (Inhalation excludes radon)

| Radio-Nuclide | Ground mrem/yr | Ground fract. | Inhalation mrem/yr | Inhalation fract. | Radon mrem/yr | Radon fract. | Plant mrem/yr | Plant fract. | Meat mrem/yr | Meat fract. | Milk mrem/yr | Milk fract. | Soil mrem/yr | Soil fract. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | 2.516E-06 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 3.279E-05 | 0.0003 | 4.999E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Ra-226 | 9.510E-02 | 0.9736 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.221E-05 | 0.0002 | 4.246E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Th-230 | 1.640E-03 | 0.0168 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.051E-05 | 0.0001 | 2.591E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-234 | 2.048E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 3.117E-07 | 0.0000 | 2.020E-09 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-235 | 5.331E-06 | 0.0001 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.808E-09 | 0.0000 | 1.864E-11 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-238 | 8.595E-04 | 0.0088 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 3.093E-07 | 0.0000 | 2.004E-09 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Total | 9.760E-02 | 0.9993 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 6.613E-05 | 0.0007 | 9.544E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |

0

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years
0 Water Dependent Pathways

| Radio-Nuclide | Water mrem/yr | Water fract. | Fish mrem/yr | Fish fract. | Radon mrem/yr | Radon fract. | Plant mrem/yr | Plant fract. | Meat mrem/yr | Meat fract. | Milk mrem/yr | Milk fract. | All Pathways* mrem/yr | All Pathways* fract. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 3.581E-05 | 0.0004 |
| Ra-226 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 9.512E-02 | 0.9739 |
| Th-230 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.650E-03 | 0.0169 |
| U-234 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 3.342E-07 | 0.0000 |
| U-235 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 5.334E-06 | 0.0001 |
| U-238 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 8.598E-04 | 0.0088 |
| Total | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 9.767E-02 | 1.0000 |

0*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years
0 Water Independent Pathways (Inhalation excludes radon)

| Radio-Nuclide | Ground mrem/yr | Ground fract. | Inhalation mrem/yr | Inhalation fract. | Radon mrem/yr | Radon fract. | Plant mrem/yr | Plant fract. | Meat mrem/yr | Meat fract. | Milk mrem/yr | Milk fract. | Soil mrem/yr | Soil fract. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | 2.341E-06 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 7.221E-05 | 0.0007 | 1.170E-06 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Ra-226 | 9.406E-02 | 0.9514 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 5.648E-05 | 0.0006 | 1.128E-06 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Th-230 | 3.784E-03 | 0.0383 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.582E-05 | 0.0003 | 8.903E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-234 | 2.285E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 7.297E-07 | 0.0000 | 5.023E-09 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-235 | 5.279E-06 | 0.0001 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 6.590E-09 | 0.0000 | 4.804E-11 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-238 | 8.509E-04 | 0.0086 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 7.240E-07 | 0.0000 | 4.984E-09 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Total | 9.871E-02 | 0.9984 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.560E-04 | 0.0016 | 2.397E-06 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |

0

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years
0 Water Dependent Pathways

| Radio-Nuclide | Water mrem/yr | Water fract. | Fish mrem/yr | Fish fract. | Radon mrem/yr | Radon fract. | Plant mrem/yr | Plant fract. | Meat mrem/yr | Meat fract. | Milk mrem/yr | Milk fract. | All Pathways* mrem/yr | All Pathways* fract. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 7.572E-05 | 0.0008 |
| Ra-226 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 9.412E-02 | 0.9520 |
| Th-230 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 3.810E-03 | 0.0385 |
| U-234 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 7.575E-07 | 0.0000 |
| U-235 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 5.285E-06 | 0.0001 |
| U-238 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 8.516E-04 | 0.0086 |
| Total | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 9.886E-02 | 1.0000 |

0*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years
0 Water Independent Pathways (Inhalation excludes radon)

| Radio-Nuclide | Ground mrem/yr | Ground fract. | Inhalation mrem/yr | Inhalation fract. | Radon mrem/yr | Radon fract. | Plant mrem/yr | Plant fract. | Meat mrem/yr | Meat fract. | Milk mrem/yr | Milk fract. | Soil mrem/yr | Soil fract. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | 1.819E-06 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.693E-04 | 0.0016 | 2.821E-06 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Ra-226 | 9.053E-02 | 0.8809 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.050E-04 | 0.0020 | 4.054E-06 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Th-230 | 1.094E-02 | 0.1064 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 9.008E-05 | 0.0009 | 5.659E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-234 | 4.638E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.126E-06 | 0.0000 | 1.505E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-235 | 5.101E-06 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.939E-08 | 0.0000 | 1.623E-10 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-238 | 8.215E-04 | 0.0080 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.109E-06 | 0.0000 | 1.494E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Total | 1.023E-01 | 0.9954 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 4.687E-04 | 0.0046 | 7.471E-06 | 0.0001 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |

0

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years
0 Water Dependent Pathways

| Radio-Nuclide | Water mrem/yr | Water fract. | Fish mrem/yr | Fish fract. | Radon mrem/yr | Radon fract. | Plant mrem/yr | Plant fract. | Meat mrem/yr | Meat fract. | Milk mrem/yr | Milk fract. | All Pathways* mrem/yr | All Pathways* fract. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.739E-04 | 0.0017 |
| Ra-226 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 9.074E-02 | 0.8829 |
| Th-230 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.103E-02 | 0.1073 |
| U-234 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.187E-06 | 0.0000 |
| U-235 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 5.121E-06 | 0.0000 |
| U-238 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 8.237E-04 | 0.0080 |
| Total | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.028E-01 | 1.0000 |

0*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

0 Water Independent Pathways (Inhalation excludes radon)

0

| Radio-Nuclide | Ground mrem/yr | Ground fract. | Inhalation mrem/yr | Inhalation fract. | Radon mrem/yr | Radon fract. | Plant mrem/yr | Plant fract. | Meat mrem/yr | Meat fract. | Milk mrem/yr | Milk fract. | Soil mrem/yr | Soil fract. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | 8.847E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.388E-04 | 0.0021 | 4.016E-06 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Ra-226 | 8.115E-02 | 0.7252 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 7.386E-04 | 0.0066 | 1.410E-05 | 0.0001 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Th-230 | 2.860E-02 | 0.2556 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 3.856E-04 | 0.0034 | 4.392E-06 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-234 | 2.252E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 5.585E-06 | 0.0000 | 3.992E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-235 | 4.631E-06 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 5.262E-08 | 0.0000 | 5.791E-10 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-238 | 7.432E-04 | 0.0066 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 5.539E-06 | 0.0000 | 3.959E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Total | 1.105E-01 | 0.9875 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.374E-03 | 0.0123 | 2.258E-05 | 0.0002 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |

0

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

0 Water Dependent Pathways

0

| Radio-Nuclide | Water mrem/yr | Water fract. | Fish mrem/yr | Fish fract. | Radon mrem/yr | Radon fract. | Plant mrem/yr | Plant fract. | Meat mrem/yr | Meat fract. | Milk mrem/yr | Milk fract. | All Pathways* mrem/yr | All Pathways* fract. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.437E-04 | 0.0022 |
| Ra-226 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 8.191E-02 | 0.7320 |
| Th-230 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.899E-02 | 0.2591 |
| U-234 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 5.851E-06 | 0.0001 |
| U-235 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 4.684E-06 | 0.0000 |
| U-238 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 7.487E-04 | 0.0067 |
| Total | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.119E-01 | 1.0000 |

0*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

0 Water Independent Pathways (Inhalation excludes radon)

| Radio-Nuclide | Ground | | Inhalation | | Radon | | Plant | | Meat | | Milk | | Soil | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Pb-210 | 7.099E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 6.235E-05 | 0.0005 | 1.052E-06 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Ra-226 | 5.535E-02 | 0.4396 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.125E-03 | 0.0169 | 3.960E-05 | 0.0003 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Th-230 | 6.524E-02 | 0.5182 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.489E-03 | 0.0198 | 4.023E-05 | 0.0003 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-234 | 1.583E-06 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.290E-05 | 0.0001 | 9.292E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-235 | 3.328E-06 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.406E-07 | 0.0000 | 2.853E-09 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-238 | 5.232E-04 | 0.0042 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.274E-05 | 0.0001 | 9.136E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Total | 1.211E-01 | 0.9620 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 4.702E-03 | 0.0373 | 8.107E-05 | 0.0006 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |

0

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

0 Water Dependent Pathways

| Radio-Nuclide | Water | | Fish | | Radon | | Plant | | Meat | | Milk | | All Pathways* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Pb-210 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 6.348E-05 | 0.0005 |
| Ra-226 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 5.751E-02 | 0.4568 |
| Th-230 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 6.777E-02 | 0.5383 |
| U-234 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.457E-05 | 0.0001 |
| U-235 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 3.472E-06 | 0.0000 |
| U-238 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 5.360E-04 | 0.0043 |
| Total | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.259E-01 | 1.0000 |

0*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

0 Water Independent Pathways (Inhalation excludes radon)

| Radio-Nuclide | Ground mrem/yr | Ground fract. | Inhalation mrem/yr | Inhalation fract. | Radon mrem/yr | Radon fract. | Plant mrem/yr | Plant fract. | Meat mrem/yr | Meat fract. | Milk mrem/yr | Milk fract. | Soil mrem/yr | Soil fract. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | 5.260E-11 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.329E-07 | 0.0000 | 2.245E-09 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Ra-226 | 1.854E-02 | 0.1910 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.143E-03 | 0.0221 | 3.987E-05 | 0.0004 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Th-230 | 6.823E-02 | 0.7028 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 7.764E-03 | 0.0800 | 1.381E-04 | 0.0014 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-234 | 4.987E-06 | 0.0001 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.427E-05 | 0.0001 | 1.079E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-235 | 1.366E-06 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.772E-07 | 0.0000 | 1.251E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-238 | 1.920E-04 | 0.0020 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.362E-05 | 0.0001 | 9.773E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Total | 8.697E-02 | 0.8958 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 9.936E-03 | 0.1023 | 1.781E-04 | 0.0018 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |

0

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

0 Water Dependent Pathways

| Radio-Nuclide | Water mrem/yr | Water fract. | Fish mrem/yr | Fish fract. | Radon mrem/yr | Radon fract. | Plant mrem/yr | Plant fract. | Meat mrem/yr | Meat fract. | Milk mrem/yr | Milk fract. | All Pathways* mrem/yr | All Pathways* fract. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.352E-07 | 0.0000 |
| Ra-226 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.073E-02 | 0.2135 |
| Th-230 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 7.613E-02 | 0.7842 |
| U-234 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.936E-05 | 0.0002 |
| U-235 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.656E-06 | 0.0000 |
| U-238 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.057E-04 | 0.0021 |
| Total | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 9.708E-02 | 1.0000 |

0*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years
0 Water Independent Pathways (Inhalation excludes radon)

| Radio-Nuclide | Ground mrem/yr | Ground fract. | Inhalation mrem/yr | Inhalation fract. | Radon mrem/yr | Radon fract. | Plant mrem/yr | Plant fract. | Meat mrem/yr | Meat fract. | Milk mrem/yr | Milk fract. | Soil mrem/yr | Soil fract. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | 5.825E-22 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 4.281E-18 | 0.0000 | 7.232E-20 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Ra-226 | 4.037E-04 | 0.0480 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.434E-04 | 0.0170 | 2.669E-06 | 0.0003 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Th-230 | 5.776E-03 | 0.6863 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.041E-03 | 0.2426 | 3.741E-05 | 0.0044 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-234 | 1.474E-06 | 0.0002 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.758E-06 | 0.0002 | 1.828E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-235 | 2.438E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 6.185E-07 | 0.0001 | 4.528E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| U-238 | 5.745E-06 | 0.0007 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.237E-06 | 0.0001 | 8.887E-09 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Total | 6.187E-03 | 0.7352 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.188E-03 | 0.2600 | 4.015E-05 | 0.0048 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |

0

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years
0 Water Dependent Pathways

| Radio-Nuclide | Water mrem/yr | Water fract. | Fish mrem/yr | Fish fract. | Radon mrem/yr | Radon fract. | Plant mrem/yr | Plant fract. | Meat mrem/yr | Meat fract. | Milk mrem/yr | Milk fract. | All Pathways* mrem/yr | All Pathways* fract. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 4.354E-18 | 0.0000 |
| Ra-226 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 5.497E-04 | 0.0653 |
| Th-230 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 7.854E-03 | 0.9333 |
| U-234 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 3.251E-06 | 0.0004 |
| U-235 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 9.076E-07 | 0.0001 |
| U-238 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 6.991E-06 | 0.0008 |
| Total | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 8.415E-03 | 1.0000 |

0*Sum of all water independent and dependent pathways.

Dose/Source Ratios Summed Over All Pathways
Parent and Progeny Principal Radionuclide Contributions Indicated

| 0 Parent (i) | Product (j) | Thread Fraction | DSR(j,t) At Time in Years (mrem/yr)/(pCi/g) 0.000E+00 | 1.000E+00 | 3.000E+00 | 1.000E+01 | 3.000E+01 | 1.000E+02 | 3.000E+02 | 1.000E+03 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210+D | Pb-210+D | 1.000E+00 | 1.363E-05 | 3.581E-05 | 7.572E-05 | 1.739E-04 | 2.437E-04 | 6.348E-05 | 1.352E-07 | 4.354E-18 |
| 0Ra-226+D | Ra-226+D | 1.000E+00 | 9.563E-02 | 9.512E-02 | 9.411E-02 | 9.067E-02 | 8.152E-02 | 5.617E-02 | 1.935E-02 | 4.577E-04 |
| Ra-226+D | Pb-210+D | 1.000E+00 | 3.098E-07 | 1.887E-06 | 9.030E-06 | 6.782E-05 | 3.844E-04 | 1.341E-03 | 1.376E-03 | 9.205E-05 |
| Ra-226+D | =DSR(j) | | 9.563E-02 | 9.512E-02 | 9.412E-02 | 9.074E-02 | 8.191E-02 | 5.751E-02 | 2.073E-02 | 5.497E-04 |
| 0Th-230 | Th-230 | 1.000E+00 | 1.938E-07 | 4.529E-07 | 9.659E-07 | 2.679E-06 | 6.920E-06 | 1.581E-05 | 1.682E-05 | 1.514E-06 |
| Th-230 | Ra-226+D | 1.000E+00 | 2.070E-05 | 6.181E-05 | 1.428E-04 | 4.134E-04 | 1.084E-03 | 2.498E-03 | 2.687E-03 | 2.471E-04 |
| Th-230 | Pb-210+D | 1.000E+00 | 5.407E-11 | 6.964E-10 | 7.265E-09 | 1.647E-07 | 2.956E-06 | 4.304E-05 | 1.693E-04 | 4.774E-05 |
| Th-230 | =DSR(j) | | 2.089E-05 | 6.227E-05 | 1.438E-04 | 4.162E-04 | 1.094E-03 | 2.557E-03 | 2.873E-03 | 2.964E-04 |
| 0U-234 | U-234 | 1.000E+00 | 8.653E-08 | 2.383E-07 | 5.388E-07 | 1.542E-06 | 4.028E-06 | 9.241E-06 | 9.859E-06 | 8.915E-07 |
| U-234 | Th-230 | 1.000E+00 | 1.120E-12 | 6.489E-12 | 3.104E-11 | 2.546E-10 | 1.903E-09 | 1.431E-08 | 4.556E-08 | 1.368E-08 |
| U-234 | Ra-226+D | 1.000E+00 | 6.208E-11 | 4.327E-10 | 2.265E-09 | 1.956E-08 | 1.492E-07 | 1.138E-06 | 3.713E-06 | 1.194E-06 |
| U-234 | Pb-210+D | 1.000E+00 | 1.375E-16 | 3.621E-15 | 8.057E-14 | 5.396E-12 | 2.920E-10 | 1.569E-08 | 2.115E-07 | 2.230E-07 |
| U-234 | =DSR(j) | | 8.660E-08 | 2.387E-07 | 5.411E-07 | 1.562E-06 | 4.179E-06 | 1.041E-05 | 1.383E-05 | 2.322E-06 |
| 0U-235+D | U-235+D | 1.000E+00 | 4.122E-04 | 4.103E-04 | 4.065E-04 | 3.937E-04 | 3.592E-04 | 2.604E-04 | 1.031E-04 | 3.811E-06 |
| U-235+D | Pa-231 | 1.000E+00 | 3.144E-09 | 9.686E-09 | 2.391E-08 | 8.535E-08 | 3.532E-07 | 2.118E-06 | 1.031E-05 | 3.755E-05 |
| U-235+D | Ac-227+D | 1.000E+00 | 3.740E-10 | 2.593E-09 | 1.342E-08 | 1.113E-07 | 7.649E-07 | 4.582E-06 | 1.392E-05 | 2.846E-05 |
| U-235+D | =DSR(j) | | 4.122E-04 | 4.103E-04 | 4.066E-04 | 3.939E-04 | 3.603E-04 | 2.671E-04 | 1.274E-04 | 6.982E-05 |
| 0U-238 | U-238 | 5.400E-05 | 3.601E-12 | 1.117E-11 | 2.614E-11 | 7.618E-11 | 2.001E-10 | 4.601E-10 | 4.915E-10 | 4.454E-11 |
| 0U-238+D | U-238+D | 9.999E-01 | 6.171E-04 | 6.141E-04 | 6.083E-04 | 5.883E-04 | 5.348E-04 | 3.829E-04 | 1.469E-04 | 4.990E-06 |
| U-238+D | U-234 | 9.999E-01 | 1.580E-13 | 1.049E-12 | 5.381E-12 | 4.595E-11 | 3.483E-10 | 2.633E-09 | 8.402E-09 | 2.532E-09 |
| U-238+D | Th-230 | 9.999E-01 | 1.204E-18 | 1.509E-17 | 1.581E-16 | 3.813E-15 | 8.244E-14 | 2.040E-12 | 1.942E-11 | 1.944E-11 |
| U-238+D | Ra-226+D | 9.999E-01 | 4.399E-17 | 6.570E-16 | 7.592E-15 | 1.945E-13 | 4.305E-12 | 1.085E-10 | 1.066E-09 | 1.169E-09 |
| U-238+D | Pb-210+D | 9.999E-01 | 8.518E-23 | 4.522E-21 | 2.112E-19 | 4.132E-17 | 6.618E-15 | 1.256E-12 | 5.553E-11 | 2.117E-10 |
| U-238+D | =DSR(j) | | 6.171E-04 | 6.141E-04 | 6.083E-04 | 5.883E-04 | 5.348E-04 | 3.829E-04 | 1.469E-04 | 4.994E-06 |

The DSR includes contributions from associated (half-life ó 180 days) daughters.

0

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 2.500E+01 mrem/yr

| 0Nuclide (i) | t= 0.000E+00 | 1.000E+00 | 3.000E+00 | 1.000E+01 | 3.000E+01 | 1.000E+02 | 3.000E+02 | 1.000E+03 |
|---|---|---|---|---|---|---|---|---|
| Pb-210 | 1.835E+06 | 6.981E+05 | 3.302E+05 | 1.437E+05 | 1.026E+05 | 3.939E+05 | 1.849E+08 | *7.634E+13 |
| Ra-226 | 2.614E+02 | 2.628E+02 | 2.656E+02 | 2.755E+02 | 3.052E+02 | 4.347E+02 | 1.206E+03 | 4.548E+04 |
| Th-230 | 1.197E+06 | 4.015E+05 | 1.739E+05 | 6.007E+04 | 2.285E+04 | 9.776E+03 | 8.702E+03 | 8.435E+04 |
| U-234 | 2.887E+08 | 1.047E+08 | 4.620E+07 | 1.600E+07 | 5.982E+06 | 2.402E+06 | 1.808E+06 | 1.077E+07 |
| U-235 | 6.066E+04 | 6.093E+04 | 6.149E+04 | 6.347E+04 | 6.938E+04 | 9.361E+04 | 1.963E+05 | 3.581E+05 |
| U-238 | 4.051E+04 | 4.071E+04 | 4.110E+04 | 4.249E+04 | 4.674E+04 | 6.529E+04 | 1.702E+05 | *3.361E+05 |

*At specific activity limit

Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
at tmin = time of minimum single radionuclide soil guideline
and at tmax = time of maximum total dose = 114.9 ñ 0.2 years

| 0Nuclide (i) | Initial (pCi/g) | tmin (years) | DSR(i,tmin) | G(i,tmin) (pCi/g) | DSR(i,tmax) | G(i,tmax) (pCi/g) |
|---|---|---|---|---|---|---|
| Pb-210 | 1.000E+00 | 27.05 ñ 0.05 | 2.450E-04 | 1.020E+05 | 4.245E-05 | 5.890E+05 |
| Ra-226 | 1.000E+00 | 0.000E+00 | 9.563E-02 | 2.614E+02 | 5.332E-02 | 4.688E+02 |
| Th-230 | 2.650E+01 | 203.8 ñ 0.4 | 3.130E-03 | 7.986E+03 | 2.731E-03 | 9.155E+03 |
| U-234 | 1.400E+00 | 244.5 ñ 0.5 | 1.415E-05 | 1.767E+06 | 1.126E-05 | 2.220E+06 |
| U-235 | 1.300E-02 | 0.000E+00 | 4.122E-04 | 6.066E+04 | 2.511E-04 | 9.956E+04 |
| U-238 | 1.400E+00 | 0.000E+00 | 6.171E-04 | 4.051E+04 | 3.565E-04 | 7.012E+04 |

Summary : Mill Area with 1 pCi/g and proportional amounts of Th and U
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\RAM MILL AREA 1 PCI-G.RAD

Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated

| 0Nuclide (j) | Parent (i) | THF(i) | DOSE(j,t), mrem/yr t= 0.000E+00 | 1.000E+00 | 3.000E+00 | 1.000E+01 | 3.000E+01 | 1.000E+02 | 3.000E+02 | 1.000E+03 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | Pb-210 | 1.000E+00 | 1.363E-05 | 3.581E-05 | 7.572E-05 | 1.739E-04 | 2.437E-04 | 6.348E-05 | 1.352E-07 | 4.354E-18 |
| Pb-210 | Ra-226 | 1.000E+00 | 3.098E-07 | 1.887E-06 | 9.030E-06 | 6.782E-05 | 3.844E-04 | 1.341E-03 | 1.376E-03 | 9.205E-05 |
| Pb-210 | Th-230 | 1.000E+00 | 1.433E-09 | 1.846E-08 | 1.925E-07 | 4.365E-06 | 7.833E-05 | 1.141E-03 | 4.487E-03 | 1.265E-03 |
| Pb-210 | U-234 | 1.000E+00 | 1.925E-16 | 5.069E-15 | 1.128E-13 | 7.554E-12 | 4.088E-10 | 2.197E-08 | 2.961E-07 | 3.122E-07 |
| Pb-210 | U-238 | 9.999E-01 | 1.193E-22 | 6.330E-21 | 2.957E-19 | 5.785E-17 | 9.266E-15 | 1.758E-12 | 7.775E-11 | 2.963E-10 |
| Pb-210 | =DOSE(j) | | 1.394E-05 | 3.771E-05 | 8.494E-05 | 2.461E-04 | 7.065E-04 | 2.545E-03 | 5.863E-03 | 1.358E-03 |
| 0Ra-226 | Ra-226 | 1.000E+00 | 9.563E-02 | 9.512E-02 | 9.411E-02 | 9.067E-02 | 8.152E-02 | 5.617E-02 | 1.935E-02 | 4.577E-04 |
| Ra-226 | Th-230 | 1.000E+00 | 5.485E-04 | 1.638E-03 | 3.784E-03 | 1.095E-02 | 2.873E-02 | 6.621E-02 | 7.120E-02 | 6.549E-03 |
| Ra-226 | U-234 | 1.000E+00 | 8.692E-11 | 6.058E-10 | 3.171E-09 | 2.739E-08 | 2.088E-07 | 1.594E-06 | 5.199E-06 | 1.671E-06 |
| Ra-226 | U-238 | 9.999E-01 | 6.158E-17 | 9.198E-16 | 1.063E-14 | 2.723E-13 | 6.027E-12 | 1.519E-10 | 1.492E-09 | 1.637E-09 |
| Ra-226 | =DOSE(j) | | 9.617E-02 | 9.676E-02 | 9.790E-02 | 1.016E-01 | 1.103E-01 | 1.224E-01 | 9.055E-02 | 7.008E-03 |
| 0Th-230 | Th-230 | 1.000E+00 | 5.137E-06 | 1.200E-05 | 2.560E-05 | 7.099E-05 | 1.834E-04 | 4.189E-04 | 4.458E-04 | 4.012E-05 |
| Th-230 | U-234 | 1.000E+00 | 1.568E-12 | 9.085E-12 | 4.346E-11 | 3.565E-10 | 2.665E-09 | 2.004E-08 | 6.378E-08 | 1.915E-08 |
| Th-230 | U-238 | 9.999E-01 | 1.685E-18 | 2.113E-17 | 2.213E-16 | 5.339E-15 | 1.154E-13 | 2.856E-12 | 2.719E-11 | 2.721E-11 |
| Th-230 | =DOSE(j) | | 5.137E-06 | 1.200E-05 | 2.560E-05 | 7.099E-05 | 1.834E-04 | 4.189E-04 | 4.459E-04 | 4.014E-05 |
| 0U-234 | U-234 | 1.000E+00 | 1.211E-07 | 3.336E-07 | 7.543E-07 | 2.159E-06 | 5.639E-06 | 1.294E-05 | 1.380E-05 | 1.248E-06 |
| U-234 | U-238 | 9.999E-01 | 2.212E-13 | 1.469E-12 | 7.534E-12 | 6.432E-11 | 4.876E-10 | 3.687E-09 | 1.176E-08 | 3.545E-09 |
| U-234 | =DOSE(j) | | 1.211E-07 | 3.336E-07 | 7.543E-07 | 2.160E-06 | 5.639E-06 | 1.294E-05 | 1.381E-05 | 1.252E-06 |
| 0U-235 | U-235 | 1.000E+00 | 5.358E-06 | 5.334E-06 | 5.285E-06 | 5.118E-06 | 4.670E-06 | 3.385E-06 | 1.341E-06 | 4.954E-08 |
| 0Pa-231 | U-235 | 1.000E+00 | 4.087E-11 | 1.259E-10 | 3.108E-10 | 1.110E-09 | 4.592E-09 | 2.754E-08 | 1.340E-07 | 4.881E-07 |
| 0Ac-227 | U-235 | 1.000E+00 | 4.862E-12 | 3.371E-11 | 1.744E-10 | 1.447E-09 | 9.944E-09 | 5.956E-08 | 1.809E-07 | 3.700E-07 |
| 0U-238 | U-238 | 5.400E-05 | 5.041E-12 | 1.563E-11 | 3.660E-11 | 1.066E-10 | 2.801E-10 | 6.442E-10 | 6.880E-10 | 6.236E-11 |
| U-238 | U-238 | 9.999E-01 | 8.639E-04 | 8.598E-04 | 8.516E-04 | 8.237E-04 | 7.487E-04 | 5.360E-04 | 2.057E-04 | 6.986E-06 |
| U-238 | =DOSE(j) | | 8.639E-04 | 8.598E-04 | 8.516E-04 | 8.237E-04 | 7.487E-04 | 5.360E-04 | 2.057E-04 | 6.986E-06 |

THF(i) is the thread fraction of the parent nuclide.

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

| 0Nuclide (j) | Parent (i) | THF(i) | S(j,t), pCi/g t= 0.000E+00 | 1.000E+00 | 3.000E+00 | 1.000E+01 | 3.000E+01 | 1.000E+02 | 3.000E+02 | 1.000E+03 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pb-210 | Pb-210 | 1.000E+00 | 1.000E+00 | 9.644E-01 | 8.970E-01 | 6.961E-01 | 3.372E-01 | 2.670E-02 | 1.903E-05 | 1.841E-16 |
| Pb-210 | Ra-226 | 1.000E+00 | 0.000E+00 | 3.044E-02 | 8.761E-02 | 2.532E-01 | 5.158E-01 | 5.533E-01 | 1.900E-01 | 3.820E-03 |
| Pb-210 | Th-230 | 1.000E+00 | 0.000E+00 | 1.757E-04 | 1.532E-03 | 1.530E-02 | 1.027E-01 | 4.669E-01 | 6.183E-01 | 5.246E-02 |
| Pb-210 | U-234 | 1.000E+00 | 0.000E+00 | 2.792E-11 | 7.345E-10 | 2.487E-08 | 5.246E-07 | 8.931E-06 | 4.072E-05 | 1.294E-05 |
| Pb-210 | U-238 | 9.999E-01 | 0.000E+00 | 1.982E-17 | 1.569E-15 | 1.790E-13 | 1.164E-11 | 7.100E-10 | 1.067E-08 | 1.227E-08 |
| Pb-210 | =S(j): | | 1.000E+00 | 9.950E-01 | 9.861E-01 | 9.645E-01 | 9.557E-01 | 1.047E+00 | 8.084E-01 | 5.630E-02 |
| 0Ra-226 | Ra-226 | 1.000E+00 | 1.000E+00 | 9.944E-01 | 9.834E-01 | 9.457E-01 | 8.458E-01 | 5.723E-01 | 1.874E-01 | 3.767E-03 |
| Ra-226 | Th-230 | 1.000E+00 | 0.000E+00 | 1.142E-02 | 3.389E-02 | 1.088E-01 | 2.932E-01 | 6.711E-01 | 6.883E-01 | 5.386E-02 |
| Ra-226 | U-234 | 1.000E+00 | 0.000E+00 | 2.715E-09 | 2.418E-08 | 2.589E-07 | 2.096E-06 | 1.607E-05 | 5.017E-05 | 1.374E-05 |
| Ra-226 | U-238 | 9.999E-01 | 0.000E+00 | 2.566E-15 | 6.856E-14 | 2.447E-12 | 5.948E-11 | 1.525E-09 | 1.438E-08 | 1.345E-08 |
| Ra-226 | =S(j): | | 1.000E+00 | 1.006E+00 | 1.017E+00 | 1.055E+00 | 1.139E+00 | 1.243E+00 | 8.758E-01 | 5.764E-02 |
| 0Th-230 | Th-230 | 1.000E+00 | 2.650E+01 | 2.636E+01 | 2.609E+01 | 2.517E+01 | 2.270E+01 | 1.582E+01 | 5.640E+00 | 1.526E-01 |
| Th-230 | U-234 | 1.000E+00 | 0.000E+00 | 1.254E-05 | 3.723E-05 | 1.197E-04 | 3.239E-04 | 7.527E-04 | 8.054E-04 | 7.277E-05 |
| Th-230 | U-238 | 9.999E-01 | 0.000E+00 | 1.777E-11 | 1.583E-10 | 1.697E-09 | 1.377E-08 | 1.067E-07 | 3.427E-07 | 1.034E-07 |
| Th-230 | =S(j): | | 2.650E+01 | 2.636E+01 | 2.609E+01 | 2.517E+01 | 2.270E+01 | 1.582E+01 | 5.641E+00 | 1.526E-01 |
| 0U-234 | U-234 | 1.000E+00 | 1.400E+00 | 1.393E+00 | 1.379E+00 | 1.330E+00 | 1.200E+00 | 8.364E-01 | 2.985E-01 | 8.109E-03 |
| U-234 | U-238 | 9.999E-01 | 0.000E+00 | 3.948E-06 | 1.172E-05 | 3.770E-05 | 1.020E-04 | 2.371E-04 | 2.540E-04 | 2.302E-05 |
| U-234 | =S(j): | | 1.400E+00 | 1.393E+00 | 1.379E+00 | 1.330E+00 | 1.200E+00 | 8.366E-01 | 2.988E-01 | 8.132E-03 |
| 0U-235 | U-235 | 1.000E+00 | 1.300E-02 | 1.293E-02 | 1.280E-02 | 1.235E-02 | 1.114E-02 | 7.769E-03 | 2.774E-03 | 7.551E-05 |
| 0Pa-231 | U-235 | 1.000E+00 | 0.000E+00 | 2.743E-07 | 8.187E-07 | 2.679E-06 | 7.631E-06 | 2.135E-05 | 4.104E-05 | 4.791E-05 |
| 0Ac-227 | U-235 | 1.000E+00 | 0.000E+00 | 4.324E-09 | 3.797E-08 | 3.875E-07 | 2.770E-06 | 1.560E-05 | 3.869E-05 | 4.764E-05 |
| 0U-238 | U-238 | 5.400E-05 | 7.560E-05 | 7.521E-05 | 7.444E-05 | 7.181E-05 | 6.478E-05 | 4.518E-05 | 1.613E-05 | 4.391E-07 |
| U-238 | U-238 | 9.999E-01 | 1.400E+00 | 1.393E+00 | 1.378E+00 | 1.330E+00 | 1.200E+00 | 8.366E-01 | 2.988E-01 | 8.132E-03 |
| U-238 | =S(j): | | 1.400E+00 | 1.393E+00 | 1.379E+00 | 1.330E+00 | 1.200E+00 | 8.366E-01 | 2.988E-01 | 8.132E-03 |

THF(i) is the thread fraction of the parent nuclide.
0RESCALC.EXE execution time =    1.83 seconds

## ATTACHMENT A

# DATA RECOVERY PLAN FOR ARCHEAOLOGICAL RESOURCES

# Rio Algom Mining LLC

December 20, 2005

Via email

ADDRESSEE ONLY
Mr. Michael Raddatz
U.S. Nuclear Regulatory Commission
11555 Rockville Pike
Rockville, MD 20852-2738

Re: **License SUA-1473, Docket 40-8905**
**Response to Outstanding RAI Questions on Pond 10 and Cultural Resources**

Dear Mr.Raddatz,

Rio Algom Mining LLC (RAM) provides the attached information to address the outstanding questions that were discussed with your staff during the October 27, 2005 public meeting.

This submittal provides information associated with additional laboratory analysis of Pond 10 samples and the data recovery plan proposed to the State of New Mexico to address the cultural resource site previously identified within the affected area.

Please contact me if you have any questions or are in need of additional information related to this modification request.

Regards,

Peter Luthiger
Manager, Radiation Safety
and Environmental Affairs

Attachment: As stated

xc: T. Fletcher
R. Jones (KM)
B. Lewis (Komex)
File

CULTURAL RESOURCES

DATA RECOVERY PLAN

*Data Recovery Plan*

**For LA 82534 and LA 82635 at Rio Algom Mine, Near Ambrosia Lake, McKinley County, New Mexico**

Prepared by
**Richard Burleson and Robert Phippen**

Under

**BLM Permit Number 157-2920-04-L**
New Mexico State Land Permit Number NM-05-107

NMCRIS NO. 95014

Organization
**Ecosystem Management, Inc.**
**4004 Carlisle NE, Suite C1**
**Albuquerque, New Mexico 87107**
(505) 884-8300
FAX (505) 884-8305

For

**Rio Algom Mining, LLC.**

**EMI Report Number 675**

December 2005

## ABSTRACT

The data recovery treatment plan presented herein has been developed in response to a request by Rio Algom Mining, LLC to address proposed adverse effects to archaeological sites LA 82634 and LA 82635. The sites are located at the Rio Algom Mine, near Ambrosia Lake, in McKinley County, New Mexico. LA 82634 and LA 82635 are situated within Township 14N Range 9W of Section 32 on the USGS 7.5 minute Ambrosia Lake quadrangle.

Rio Algom Mining, LLC intends to initiate a remediation plan to deal with contaminated soils related to previous mining activities. Implementation of the remediation plan may have an adverse effect on archaeological sites LA 82634 and LA 82635 resulting from ground disturbing activities that will disturb both sites. As a result, all data potential present at both sites will be diminished.

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## PROJECT DESCRIPTION and PURPOSE OF THE STUDY

The data recovery treatment plan presented herein has been developed in response to a request by Rio Algom Mining, LLC to address proposed adverse effects to archaeological sites LA 82634 and LA 82635. The sites are located at the Rio Algom Mine, near Ambrosia Lake, in McKinley County, New Mexico. LA 82634 and LA 82635 are situated within Township 14N Range 9W of Section 32 on the USGS 7.5 minute Ambrosia Lake quadrangle. The sites were originally recorded by Southwest Archaeological Consultants in October 1990 (Viklund 1990). Survey assessment of the sites identified them both as an Anasazi lithic and ceramic scatters with no clearly identified features.

Rio Algom Mining, LLC intends to initiate a remediation plan to deal with contaminated soils related to previous mining activities. Implementation of the remediation plan may have an adverse effect on archaeological sites LA 82634 and LA 82635 resulting from ground disturbing activities that will disturb both sites. As a result, all data potential present at both sites will be diminished.

The purpose of the Plan is to remediate the windblown tailings, effluent contaminated soils, and soils contaminated by license activities that originated from the milling operation and disposal area, and to demonstrate that the clean up plan was successful in remediating the contaminated soils to comply with the proposed release criteria and achieve appropriate closure to allow for the transfer of these areas to the U.S. Department of Energy. A comprehensive description of proposed remediation activities is provided below.

### *Remediation Strategy*

Remediation of affected areas involves excavation of the surface soils followed by verification of remediation through instrument surveys and laboratory analysis. Following successful remediation, the area will be revegetated.

#### Excavation

The technique that will be considered for remediation of surface soils is excavation. Excavation will consist of picking up contaminated soil and transporting it to the disposal cell. Excavation of contaminated material is expected to be limited to the top six inches of surface soil. Excavation techniques for larger areas will include grading and/or scraping. The contaminated area may be graded to form windrows of surface soil that are subsequently picked up by scraper. Otherwise, the surface soil may be picked up directly by scraper. The excavated area will be contoured by grading as necessary after excavation to facilitate survey activities. Excavation techniques for small areas will include grading and/or scraping. The surface soil of the contaminated area may be pushed into a pile that is subsequently picked up by bucket loader. Otherwise, the surface soil may be picked up directly by bucket loader. The excavated area will be contoured by grading or backfill with clean soil as necessary after excavation and successful surveys.

#### Verification - Surveys

The objective of the verification phase is to demonstrate that the final condition of the site satisfies the requirements of 10 CFR 40 Appendix A Criterion 6(6). Scanning surveys will be completed using a NaI(Tl) radiation detector coupled to a handheld scaler/ratemeter. Measurements will be collected by keeping the detector approximately eighteen (18) inches off ground surface while walking or driving over the area at a rate comparable to a casual walk. The

## LA 82635/SW 260-3

**Site Type: Artifact Scatter**
**No. of Components: 1**
**UTM Coordinates: 244200 E; 3920840 N, Z 13**
**Cultural Affiliation: Anasazi**
**Elevation: 6930 feet above mean sea level**
**Topographic Location: Alluvial flat**
**Vegetation Community: Desert Scrub**

Site LA 82635 is a lithic and ceramic scatter that is located on an alluvial flat, just to the west of New Mexico State Highway 509 (NM 509). The site was originally recorded in September of 1990 by Lonyta Vicklund of Southwest Archaeological Consultants (Vicklund 1990). The site measures approximately 39 m x 35 m, has a site area of 1,365 square meters, and is at an elevation of 6930 feet above mean sea level. It is situated within a desert scrub vegetation community comprised of chamisa, four-wig saltbush, sage, Russian thistle, and various grasses. A total of 4 flakes were identified during the original recording and are dispersed across the site boundary. They are defined as primary and secondary flakes manufactured from chert and quartzite. A trough metate and three small pieces of unmodified vesicular basalt were also noted. Ceramics on the site include 55 sherds. Types represented within the assemblage include Red Mesa Black-on-white, indeterminate pinchpot fragment, indeterminate grayware, and corrugated indented sherds representing both bowl and jar remnants. Sandstone spalls and unmodified blocks were noted in limited quantities on the site, however no formal feature designation was given. The site condition was determined to be intact. The site was determined to have possible subsurface deposits present. The site was interpreted to represent a field gathering/processing location and possible habitation dating from the Late Pueblo I to Pueblo III period (A.D. 800-1000) based on the presence of several different types of ceramic vessels and possible remnants of a subsurface structure or eroded jacal structure. The ceramic types present more accurately date to the Pueblo II to Pueblo III period (A.D. 900-1050). The site was recommended as eligible for inclusion to the National Register of Historic Places under criterion D, information potential.

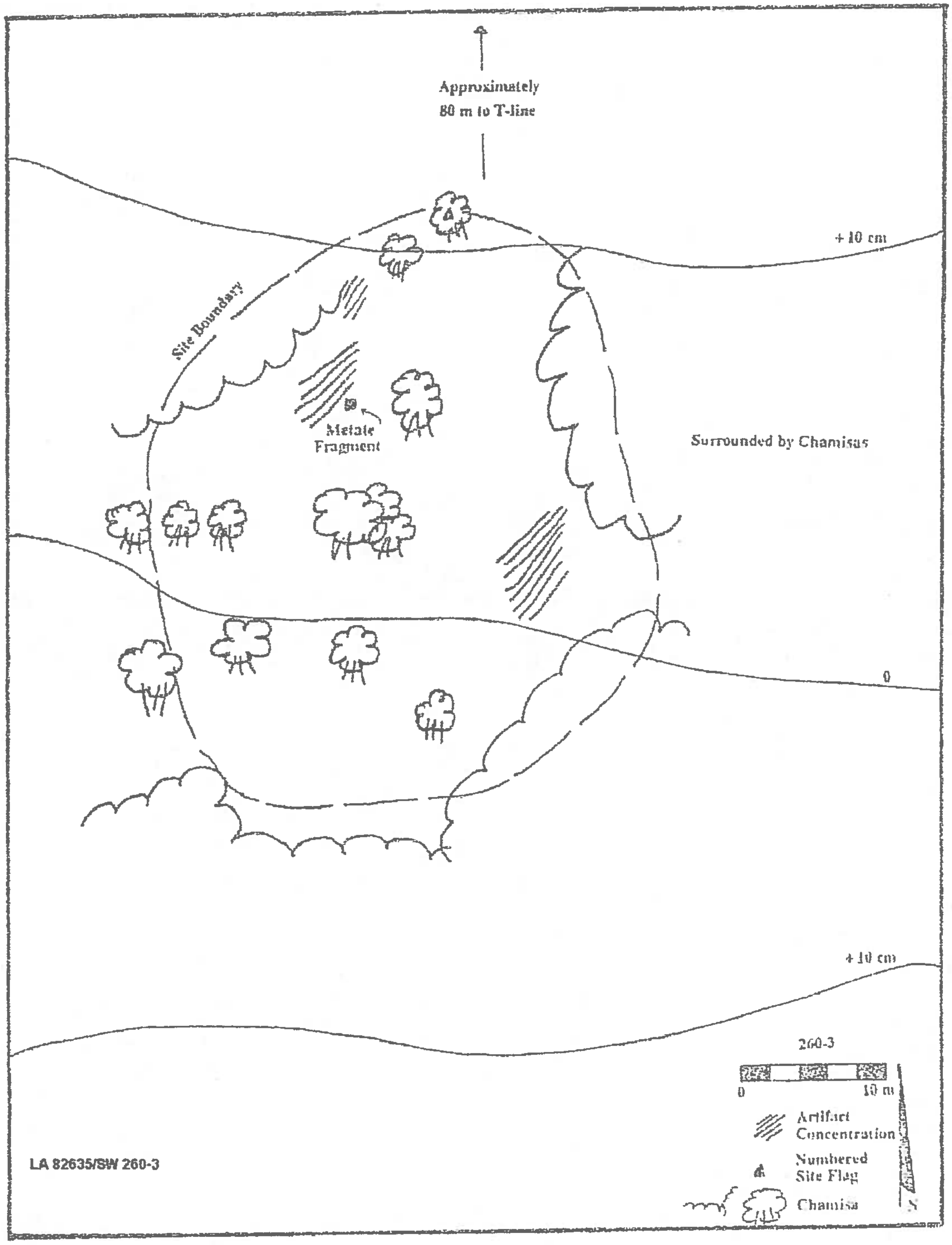


Figure 4. Site map for LA 82635/SW 260-3.

## PROPOSED TREATMENT

To adequately address the concerns of the site owner (Rio Algom Mining, LLC) and the New Mexico State Historic Preservation Office (SHPO), a data collection and synthesis proposal/plan is required. The plan must address technical and logistical guidelines for the physical collection, as well as research orientation for the synthesis of information gathered.

## SPECIFIC RESEARCH QUESTIONS

General research issues that may be applicable to the investigation of LA 82634 and 82635 are related mainly to settlement and subsistence strategy patterns and how they relate to regional data bases. Research questions that may be answered by the excavation of small, presumably seasonal loci include cultural, economic, technological and possibly seasonal and longevity of site use. Sampling of feature deposits may recovery evidence of dietary and perishable economic products, as well as other technological items. Interpretation of attributes derived from macrobotanical or artifactual evidence may lead to a better understanding of prehistoric strategies of resource production/procurement for subsistence products, as well as raw materials for tool production, related processing methods, and the determination of regional cultural affiliation as defined through lithic tool forms, raw materials, groundstone, and ceramic analysis. Considerable emphasis has been placed on the value of ceramic typology when interpreting temporal and cultural affiliations of various Southwestern cultures. Additional artifact classes and the information potential that they provide are often overlooked. Every attempt to derive interpretive data from the analysis of ceramics and other artifact classes i.e. flaked lithic, groundstone, bone, mineral etc. may insure an enhanced understanding of prehistoric economies at the sites.

The importance of determining site function can help to clarify the directing environmental factors of settlement patterns. Identifying small site function is necessary for determining exactly how people were utilizing their environment and how these sites fit into the overall cultural landscape. This is especially true of Anasazi settlement patterns and site function whether residential, agricultural, resource procurement or ceremonial. Regardless of site function economic activities occur both on and off specific site types. Sites are typically a conglomeration of features and artifacts indicative of occupation or economic activity. It seems logical to state that many transient activities relevant to prehistoric subsistence occur away from the permanent or longer-term residential sites. Numerous reasons may be presented, however the most logical one is the scattered distribution of natural resources across the landscape. Modern analogy may be used to infer analyzing past human behavior. Most people have a primary residence at which many activities take place, resulting in material remains that are indicators of those domestic activities. On the contrary, many other activities take place away from that primary residence that also leave material remains behind. These material remains, however, are evidence that is more difficult to relate back to a specific primary residence. As such, a regional approach must be employed, analyzing both on and off site data, to understand landscape utilization during a typical year or throughout a specific prehistoric period. In order to accomplish such a task, an analysis of all sites within a given region, as well as areas interstitial to those sites must be conducted before an adequate assessment of landscape utilization can be developed. An undertaking of that magnitude is clearly beyond the scope of this data recovery project. However an analysis of artifacts and specialized features and their role in Anasazi site function can contribute to regional data from survey and excavation contexts. Excavated contexts retaining chronological, economic or other cultural data are investigated at a far lesser frequency than those provided by survey data. With the accentuated quality of preservation found in buried contexts and their ability to provide data, interpretation of discrete feature or activity areas found at small sites is preferable to surface indications used to interpret buried or disrupted features/assemblages during survey interpretation.

LITHIC ARTIFACTS

Determination of flaked lithic artifact type and function is critical for understanding specific elements of resource processing and identifying similar or differential activity loci within a site. Research issues related to lithic tool type and function as they relate to the inference of site function include, but are not limited to: (1) can artifact type, raw material and function be reliably ascertained? (2) can stages of, or type of manufacture (i.e. hard hammer vs. soft hammer) represented in the assemblage be reliably ascertained from the assemblage data (3) can differential activity loci be determined by the identification of artifact type or attribute analysis data?; and (4) are lithic artifact type, lithic artifact functions (as determined through use wear analysis and tool form), stages of manufacture, and relation to activity loci primary indicators of site function? and (5) does the presence of certain raw material types or stages of manufacture relate to local or imported sources and therefore cultural interaction through trade; or additional transience in resource acquisition strategies.

Lithic artifact analysis should occur on a variety of levels. First, determination of artifact type and raw material is critical for understanding what types of activities associated with lithics were taking place at the site. This determination of an artifacts introduction to the site and the identification of its disposition whether being a functional entity or the by-product of producing a functional entity is the initial typing of the individual artifact. Specific artifacts are often temporally diagnostic in form (arrowpoints vs dart points) or morphologically indicative of distinct types of activities (e.g. scraping, cutting, planning etc.). The attributes of physical morphology both natural and human imparted, can provide information about the procession or trajectory of lithic acquisition and reduction possibly providing inferences to the cultural or economic strategies.

The determination of the process of manufacture is crucial in identifying the role of the artifact and possibly cultural relation to the assemblage data. Whole artifacts, particularly flakes, are crucial for the discussion of reduction trajectories or stages. Attributes such as the type and percentage of cortex on debitage may be a primary indicator of reduction stage or stages performed at the site. For example, assemblages that exhibit flakes with a high percentage of cortex may be categorized as the product of primary core preparation or tool production from a cortical piece of raw material. Conversely, exterior flakes that exhibit large percentages of cortex may have been selected for the specific properties that cortical surfaces impart to use edges, or for backing purposes. Therefore, the identification of an artifact as specifically debitage, the by-product of tool manufacture or an item produced specifically for use as a tool is critical to the identification of the act that produced the artifact and therefore one of the site functions inferred by the assemblage. Therefore the presence or absence of certain types of debitage is crucial to activities being employed or sources of raw materials.

Identification of platform types on individual flakes may further enable determination of flake type or origination. An essential attribute for inferring whether a flake was produced from a core for a specific use, produced during the manufacture of a biface or in other tool manufacture or maintenance activities such as retouching may be inferred by platform or other dimensional flake attributes. Individual artifacts identified by single, or multiple attributes may then be compared or contrasted with groups of artifacts recovered from the site, further enabling confidence of function at the assemblage level. By viewing an assemblage as a whole, it may be possible to identify procurement and transportation strategies of raw material, stages or trajectories of lithic reduction or tool production, and inferred function of stone tools and therefore, activities being performed at the site. This last distinction is important to note. Any mention of site function can only be discussed in terms of lithics and the role they played in the prehistoric procurement and subsistence strategies. Other artifact types such as those used for manufacture and maintaining stone tools may or may not be present must also be considered. At a minimum the artifact assemblage may provide an overview of some of the activities that bring the artifact to, as well as those being performed at the site. At a higher level, site data can then be incorporated into a regional perspective of Anasazi behavior.

Raw material sourcing also has implications concerning Anasazi populations and possible interaction with other entities. Questions that may be answered through raw material analysis include, but are not limited to: (1) is the selection of a specific raw material type such as Chinle chert for multiple uses typical of local Anasazi sites?; (2) is the selection of multiple raw material types for single or multiple uses typified on Anasazi sites?; (3) are specific raw material types preferred for the specific processing activities or the product of expedient acquisition or tool production?; and (4) can mobility and/or trade patterns of seasonally inhabited areas be determined through raw material analysis?

Most non-local materials identified on seasonally inhabited Anasazi sites are assumed to be a product of trade. Trade of raw material across great distances is commonplace in the southwest during the Pueblo periods. The presence of usable pieces of debitage or formal tools without the presence of waste or shatter from reduction processes is the most obvious or provable relationship that may be qualified through analysis.

## GROUNDSTONE ARTIFACTS

The use of groundstone to identify economic activities is more obvious in nature given the inferred function of an implement i.e. mano, metate, lapstone etc. Specialized artifacts such as a tsamajilla, or corn maiden may be culturally significant.

Mano form and size are generally accepted to relate to product being processed and therefore possibly useful in determining presence or absence of certain dietary produce. One-hand manos and basin or slab metates are generally associated with processing wild foods such as seeds. Two-hand manos and trough metates are generally seen to relate to corn processing. The former types are generally smaller and portable and typical of a more mobile economic strategy. The latter are generally much larger and heavier due to the processing needs of dried maize. The presence or absence of these types of artifacts may be helpful in determining subsistence products and longevity of site use.

Specialized activities or possessions may be identified by the presence of artifacts such as grooved abraders, pecked and ground implements, ground mineral pigments or jewelry such as pendants.

## CERAMIC ARTIFACTS

Ceramic artifacts are probably the most obvious component of Anasazi artifact assemblages. The project area is located at the confluence of several Anasazi provinces within the Mount Taylor region. It is on the eastern periphery of the Red Mesa areas, south of Chaco Canyon and west of the Puerco/Salado area. The San Mateo and Cebolleta regions are most proximate to the Ambrosia Lake area. All of these provinces exhibit similar ceramic wares relating to the widespread use of Cibola Whitewares during the Pueblo II and Pueblo III periods. There are however differential frequencies of whitewares and several intrusive wares that relate to one district or the other.

Relatively high frequencies of ceramic artifacts or the presence of a predominant ware are usually necessary to assign discrete differences to an assemblage. If a sufficient number of sherds is recovered these discrete regional assignations may be deduced. Differences in occupation may also be determined within the Pueblo II period and the later portion of that period and the early portion of the Pueblo III.

The influence of the Chaco system on local Anasazi populations in the Mount Taylor Region during the A.D. 950 to A.D 1150 accounts for rapid increases in local populations, and therefore site densities, Stuart and Gauthier (1981) also relate a widespread trade network in the region. Therefore, ceramic evidence

should relate to this phenomenon. Any deviation from this pattern would be evident in the ceramic assemblage.

Mineral painted Black-on-White wares such as Red Mesa, Gallup, Puerco, Escavada and Chaco, are the predominant types found throughout the Pueblo II period and early Pueblo III period. The presence of Red Mesa Black-on-White is reduced from the middle to the end of the period. Carbon painted Black-on-White such as Chaco McElmo and redwares such as Puerco Black-on-Red and Wingate Black-on-Red are indicative of the latter portion of the period and the early portion of the Pueblo III period.

All of these wares are found across the region at Anasazi sites of this period. If less prevalent or intrusive wares such as Socorro or Casa Salazar Black-on-White occur, a relation to the Cebolleta group may be inferred. The presence of brownware ceramics within the Mount Taylor region is generally accepted as evidence of Anasazi and Mogollon contact. Cibola Whitewares are expected to comprise the bulk of the assemblage. The overall ceramic assemblage will be documented as to type of ware concentrating on the identification of wares divergent to the Cibola Whiteware types mentioned.

## SITE STRUCTURE AND ARTIFACT/FEATURE RELATIONSHIPS

How may the site type be determined by site structure and artifact distribution? The presence or absence of certain features and densities of artifact assemblages are the most obvious characteristics observed during survey documentation. Specialized Anasazi locations relating to agricultural activities will exhibit artifacts and features similar to those at extended occupations (ramadas, single masonry rooms) but at lower frequencies and reduced sizes. Substantial or multi-roomed masonry structures or large pitrooms are generally absent. Because of the seasonal or short-term occupation at specialized sites, temporary, and therefore expedient feature types are used. The ephemeral nature of these locations subjects them to more substantial degradation through erosion. Discrete features such as postholes or hearth pits are often obliterated in surface contexts, therefore the artifact scatters/concentrations are the only remaining evidence.

Small or specialized Anasazi sites such as field houses or ramadas will exhibit a more expedient assemblage of both lithic and groundstone artifacts and lack the densities and varieties observed at residential centers. Exotic lithic raw materials may be present, but the tools are generally representative of more limited activities than at longer-term residential loci. Ceramic artifacts may be represented by higher frequencies of utilitarian wares at specialized locations and decorated wares may be represented by multiple types, but in lower frequencies than residential locales.

The formerly discussed differences at both site types are considered obvious. What is not usually obvious at the ephemeral locales is the presence of discrete features. If artifacts are the only cultural evidence observed during survey documentation the site is considered non-structural. A variety of open site exhibiting artifact scatters have been found to produce features when excavated (Phippen, personal observation). To compare similar site structure and use patterns albeit bimodal from residential to specialized site the use of artifact scatters may be used as a guide for excavation. Both site types exhibit similar patterning in site structure. Midden areas and residential areas are set at generally west to east or northwest to east/southeast with the residences on the west to north sides. Therefore the excavation strategies employed during the project will use this relationship to investigate the possibility for features, and therefore deposits containing intact carbon or macrobotanical materials valuable for interpretation of time frames and economic attributes of the occupation.

The presumed assemblage of artifacts, and association to site areas or features that may be encountered, is the predominant tool that a researcher possesses to propose and initiate excavation strategies. The presence of an open site that has been variously affected by a variety of climactic and depositional/erosional sequences directs to some degree the progression of excavation. Minimally this

includes identification of areas retaining cultural horizons and therefore artifacts and/or features, and the expansion of these areas through excavation to recover as much artifactual or other data present as possible. These goals may be reached by first attaining a cross section of the subsurface characteristics of the site to gain insight into the areas retaining the highest potential. Following the identification of positive subsurface areas, excavations following the levels of cultural materials observed are expanded to attain the highest degree of artifact and feature deposits as possible. The expanded excavation of positive areas and the artifacts that they may yield will provide a chance for the assemblage to provide similar or differential artifact functions, and therefore uses of the site. Specifically, artifacts from both screened and excavated contexts, as well as features, should provide information concerning artifact and site function, raw material procurement and preferences, settlement patterns, and how this site relates to others previously identified in the area.

In summary, the analyses of individual artifacts resulting from the proposed data recovery will serve as the bridging mechanism between the research orientation and the field methods. In this specific situation, the damaged area of the site dictates to a large degree the methods of fieldwork to be employed during the data recovery. Other areas on the site may produce more suitable data for understanding site function, settlement, and the site's relationship to others in the region; however, these undisturbed areas of the site are not subject to the proposed data recovery. The proposed data recovery will allow the researcher to exhaust the data potential in the damaged areas by incorporating a systematic process of excavation and analysis. The fieldwork is primarily guided by the damaged area requiring treatment, while the analysis of any materials that result from the fieldwork operates to directly address the research orientation of the project. Hence, the research orientation, fieldwork, and analysis should be viewed as tightly integrated entities.

## SPECIFIC PROCEDURES TO TEST/EXCAVATE THE SITES

The duties of Principal Investigator and Project Director will be performed by Richard Burleson of Ecosystem Management, Inc. (EMI). The basic organizational unit for excavation will be a five person crew consisting of the Field Supervisor (Robert Phippen) and four archaeological technicians.

The limits of each site have previously been determined during the initial documentation of the sites. These site boundaries will be reassessed in the field to determine whether or not any significant changes have occurred. No features were delineated during the initial recordation, however sandstone slab spalls were noted that may be remnants of features. These areas will be assessed in the field thoroughly prior to initiating excavation/shovel testing. Previously defined artifact distributions and densities will be re assessed in an attempt to define any intrasite activity areas.

Different strategies will be employed at each site. The current level of site documentation suggests that there are likely significant subsurface cultural deposits that may yield important subsistence, settlement, and chronological data at LA 82634 as evidenced by the presence of a relatively high frequency, spatial distribution, and type of ceramics on the present ground surface. It is believed that a probable subsurface feature may be present. On the contrary, LA 82635 likely contains a lesser degree of potential to yield such information. The current assemblage is a low density, dispersed scatter of lithics and corrugated indented utility ceramics with no defined concentrations that suggest possible subsurface feature areas.

LA 82634:

Prior to the initiation of excavation, the site area will be included within a metric grid system. The datum will be assigned the designation 100 N x 100 E. This will provide each excavation unit a unique number and avoid the possibility of error when having repeated numbers in adjacent grids (e.g., 1N x 1E, 1N x 1W etc.). All excavation will be tied horizontally and vertically to a main site datum and sub-datums as necessary. The main horizontal control unit is the 1 m x 1 m grid square. Initial excavations will consist of single units, with blocks of contiguous 1 m x 1 m units being the anticipated result of ongoing and completed excavation. The basic vertical control unit will be the 10 centimeter (cm) in depth level. Excavations within individual grid units will proceed in flat, arbitrary, 10 cm levels until cultural strata are encountered. Cultural strata will be excavated in 10 cm levels unless they do not reach that thickness and are removed as a unit.

Vertical documentation will relate to the ground surface at the datum of 100 m elevation. This will avoid using any negative numbers across a site with differing topography. All elevations will either be less than 100.00 (99.99 down or 100.01 and up). Prior to excavation, ground surface elevations will be determined for X and Y baselines, as well as individual unit and block excavations. Subsequent elevation readings will be taken using the transit rather than line levels. This convention will be used because occupation levels may be thin, and the deviation in elevations taken with line levels is too large.

Documentation of the excavations will be recorded using standard excavation grid unit level forms, grouped grid unit forms, and feature forms. All features will be assigned an individual number. A plan and profile drawing of the completed excavation will be produced showing all relevant sediment or cultural characteristics. Instrument mapping of the entire site area will be performed following delineation of the area through excavation. Photographic documentation will be used to coincide with feature forms, plan and profile view drawings, and architectural characteristics.

All soil fill will be screened through ¼ inch (in) mesh. Fill in sensitive areas such as features may be screened using 1/8 in mesh if appropriate. Lithic, bone, and ceramic artifacts will be bagged by specimen type and provenience (grid, level, stratum, and feature association as appropriate), and assigned a unique field specimen (FS) number. Specialized non-artifactual samples will also be assigned an FS number. The field specimen numbers will be kept in numerological order by grid unit. Each unit will be assigned a unique number when cultural material is first collected. Each successive field specimen or sample collected will be listed as a decimal following the unique grid number. For example, for grid number 100N/100E, the field specimen is assigned the number 100.0. Each field specimen or sample recovered will be numbered in progression as encountered (e.g. 100.1, 100.2, 100.3 etc.).

Standard methods of collection and appropriate storage containers will be used for sample collection. Bulk soil macrobotanical samples will be collected, in total, from feature fill, and other special contexts as necessary, and placed in ziplock bags. Radiocarbon samples may be collected from burned contexts and stored in aluminum foil. An effort will be made to collect all burned wood or other carbonized material if it is the only datable material encountered. If possible an effort will be made to collect samples of single, (rather than bulk) large, intact pieces of charcoal from burned contexts. If large enough, the individual samples may provide a more reliable date range than bulk charcoal. As a general rule, pollen samples will not be collected from burned or open site contexts. If groundstone is encountered in well preserved contexts, it will be protected during collection in anticipation of pollen washing. Collection and storage of

samples and artifacts will be achieved using the greatest care to protect against contamination of samples and damage to individual artifacts.

Excavation will proceed in a two phase approach. The present artifact assemblage will be collected from its surface context, noting locations of high frequency and distribution. This will be followed by surface stripping the site boundary using shovels. An estimated 5-7 centimeters of aeolian overburden will be removed in an attempt to identify potential subsurface feature elements. Initial excavations after surface stripping the site will center on establishing the character of the natural strata across the site. This will be performed by excavating control units across the site in an attempt to identify any undulation, inclusion, or consistency of the natural stratigraphic profile of the substrate. Determination of the profile is necessary for subsequent subsurface analogy in potentially cultural, as well as negative strata.

Following the definition of the stratigraphic profile across the site, excavations will concentrate on determining the extent of subsurface cultural horizons. This may be evident following the excavation of the control pits. If no cultural material is encountered in the control pits, additional single excavation units and blocks of units will be installed across the site in an effort to identify any buried artifact concentration, feature, or horizon. Block excavation units may be excavated by stripping similar amounts of sediment from groups of 1 m x 1 m units, or by vertical excavation of single units.

If and when subsurface cultural material is encountered, the excavation units surrounding the unit in which the material was encountered will be opened to expose the full extent of the buried artifact horizon. Any subsurface discovery or continuous artifact horizon will be excavated in total in an effort to retrieve as much artifactual and/or feature data available.

LA 82635:

Due to the dispersed nature of the artifact assemblage, it is recommended that the site undergo shovel testing at a predetermined interval along an established grid system in an attempt to identify any potential subsurface archaeological deposits. Prior to the initiation of shovel testing, the site area will be included within a metric grid system. The datum will be assigned the designation 100 N x 100 E. This will provide each excavation unit a unique number and avoid the possibility of error when having repeated numbers in adjacent grids (e.g., 1N x 1E, 1N x 1W etc.). All shovel testing will be tied horizontally and vertically to a main site datum. The main horizontal control unit will be a 50 cm x 50 cm shovel test unit. Initial testing will consist of shovel test units excavated at 2 m intervals across the site boundary. The basic vertical control unit will be the 10 centimeter (cm) in depth level. Excavations within individual shovel test units will proceed in arbitrary, 10 cm levels.

Vertical documentation will relate to the ground surface at the datum of 100 m elevation. This will avoid using any negative numbers across a site with differing topography. All elevations will either be less than 100.00 (99.99 down or 100.01 and up). Prior to excavation, ground surface elevations will be determined for X and Y baselines, as well as individual unit and block excavations. Subsequent elevation readings will be taken using the transit rather than line levels. This convention will be used because occupation levels may be thin, and the deviation in elevations taken with line levels is too large.

Documentation of the shovel testing will be recorded using standard shovel test level forms. All features will be assigned an individual number if encountered. A plan and profile drawing of the completed units will be produced showing all relevant sediment or cultural characteristics should

features be identified. Instrument mapping of the entire site area will be performed following delineation of the area through excavation. Photographic documentation will be used to coincide with forms, plan and profile view drawings, and architectural characteristics.

All soil fill will be screened through ¼ inch (in) mesh. Fill in sensitive areas such as features may be screened using 1/8 in mesh if appropriate. Lithic, bone, and ceramic artifacts will be bagged by specimen type and provenience (grid, level, stratum, and feature association as appropriate), and assigned a unique field specimen (FS) number. Specialized non-artifactual samples will also be assigned an FS number. The field specimen numbers will be kept in numerological order by grid unit. Each unit will be assigned a unique number when cultural material is first collected. Each successive field specimen or sample collected will be listed as a decimal following the unique grid number. For example, for grid number 100N/100E, the field specimen is assigned the number 100.0. Each field specimen or sample recovered will be numbered in progression as encountered (e.g. 100.1, 100.2, 100.3 etc.).

Standard methods of collection and appropriate storage containers will be used for sample collection. Bulk soil macrobotanical samples will be collected, in total, from feature fill, and other special contexts as necessary, and placed in ziplock bags. Radiocarbon samples may be collected from burned contexts and stored in aluminum foil. An effort will be made to collect all burned wood or other carbonized material if it is the only datable material encountered. If possible an effort will be made to collect samples of single, (rather than bulk) large, intact pieces of charcoal from burned contexts. If large enough, the individual samples may provide a more reliable date range than bulk charcoal. As a general rule, pollen samples will not be collected from burned or open site contexts. If groundstone is encountered in well preserved contexts, it will be protected during collection in anticipation of pollen washing. Collection and storage of samples and artifacts will be achieved using the greatest care to protect against contamination of samples and damage to individual artifacts.

*Photographic Documentation:*

All phases of excavation, as well as before and after documentation, will be photographed using 35 mm single lens reflex and digital cameras.

## PROCEDURES TO OPERATIONALIZE THE PLAN

*Mapping:*

Initially, an instrument map of each site area as it relates to the central datum will be generated. This map will function as an indicator of the extent of the sites' cultural surface indications. A mapping log will be generated to document all stages of site treatment. This will enable the production of final maps showing the extent of damage, as well as archaeologically investigated areas. An ongoing instrument map will be generated for the entire area included in the excavations. This map will document all areas excavated. Any subsurface manifestation will be documented on the excavation plan view.

Maps of individual grids and blocks of grids will be generated during excavation. Planviews and profiles will be drawn for any positive result. Profiles of individual pits will be produced to relate local stratigraphy as it relates to the site wide profile.

*Hand Excavation Units and Sampling:*

measurements will be made along straight line paths between opposite borders of the area being surveyed. The distance between the paths will be approximately six (6) feet. The scaler/ratemeter will be coupled to global positioning system (GPS) equipment and a data logger. A gamma measurement from the scaler/ratemeter and a location from the GPS will be recorded approximately every two seconds. The gamma measurement will be recorded as counts per minute. The location will be recorded with respect to a reference coordinate system. The scanning measurements will be averaged for each 100 $m^2$ grid. If the scanning average value is less than or equal to the gamma guideline value, no further scanning survey will be made of the grid. If the scanning average value is greater than the gamma guideline value, the failed grid and each surrounding grid will be remediated and another gamma scan performed.

Verification – Soil Sampling

Soil samples will be collected in a known and consistent fashion, and with respect to the location reference system used for the scanning survey in grids selected for sampling. Soil plugs will be collected from five evenly spaced locations across a 100$m^2$ grid. The soil plugs will be collected from the top six inches of soil. The five plugs from a six inch layer will be combined to create one composite soil sample. Sample collection activities will also include documentation of sampling activities on a field log, decontamination of equipment between sample locations, and collection of replicate samples at a rate of one per 10. Chain-of-custody procedures will be applied beginning at the time of sample collection. The composite soil samples will be prepared in a known and consistent manner for laboratory analysis. The preparation will include removing rocks and vegetation, drying (if needed), crushing, and mixing/blending. The preparation concludes with placement of the prepared soil in a container and labeling the container.

The soil sample result will be compared to clean up levels such that the sum of the ratios for the concentration of each radionuclide of concern to the respective concentration limit will not exceed "1" (unity). If the sum of ratios is less than or equal to one, no further measurement or evaluation will be made of the 100 $m^2$ grid. If the sum of the ratios exceeds unity, the grid and every adjacent grid will be remediated and re-sampled. Results of characterization sampling and remediation control sampling of soils may be incorporated into to the final status survey data set. If the number of failed 100 $m^2$ grids is greater than five per 100 the gamma guideline value will be re-evaluated and adjusted downward.

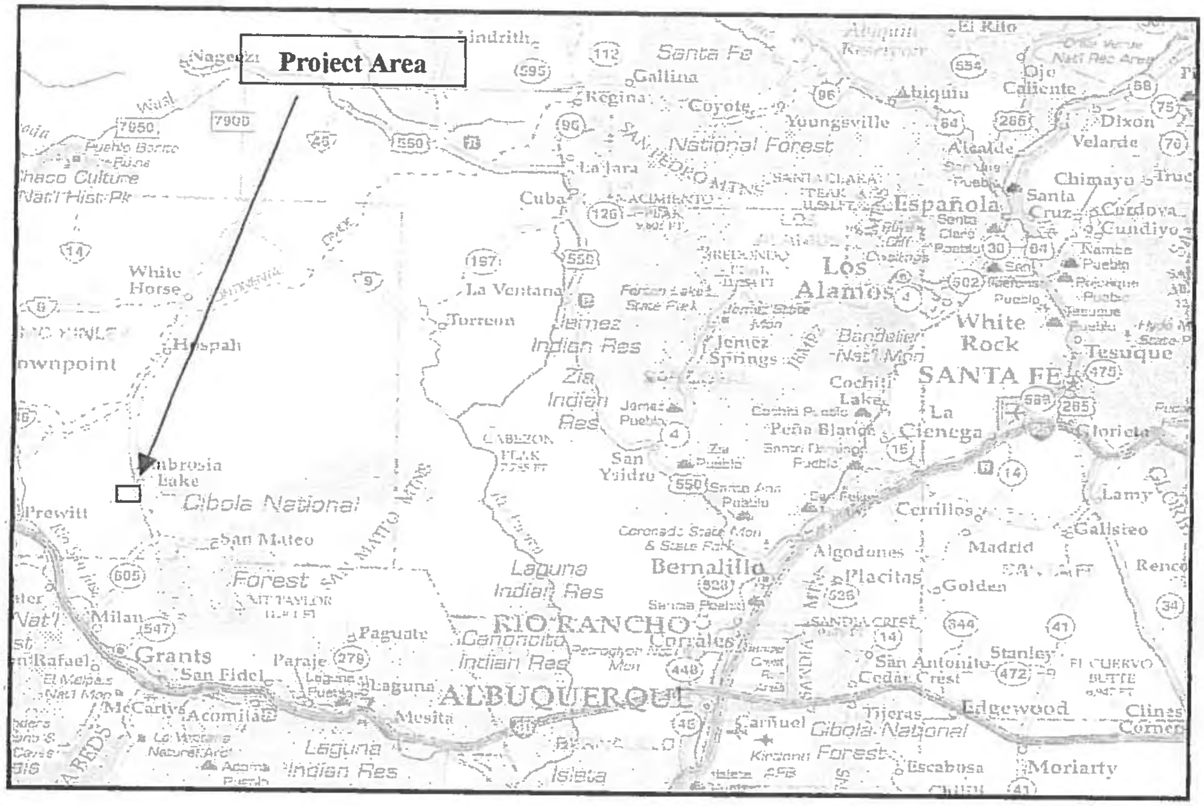


**Figure 1.** Project Location.
Source: Recreational Map of New Mexico, GTR Mapping (2000 Edition).

# TREATMENT PLAN ORGANIZATION AND CONTENT

The treatment plan consists of ten basic elements: (1) research context; (2) resource description/current knowledge of the sites; (3) specific research questions; (4) specific procedures to excavate the sites; (5) procedures to operationalize the plan; (6) backfill; (7) analytical procedures; (8) schedule; (9) personnel; and (10) curation. The intent of the research orientation section is to identify basic research themes that apply to the project area as a whole, and to the kinds of sites that are known to occur.

## RESEARCH CONTEXT

**Sites LA 82634 and LA 82635 are Anasazi lithic and ceramic scatters with possible subsurface features dating to the Pueblo II to Early Pueblo III period (A.D. 900-1150) based on diagnostic ceramics identified at each site. As such, the research context shall emphasize these time periods in terms of a comprehensive culture history based on current research.**

The following discussion of the prehistory and history of the area is taken from the Farmington Proposed Resource Management Plan and Final Environmental Impact Statement (2003). This information provides a thorough backdrop for the types of resources expected and highlighting developmental sequences identified within the project area. The discussion is at a regional level, however, is tempered with information with regard to local phases and settlement/subsistence patterns likely seen within the project area.

*Pueblo II (ca. A.D. 900 to 1050)*

The Pueblo II (PII) period is characterized by an increase in the number of sites, an increase in average site size, a shift toward above-ground coursed masonry architecture, the appearance of larger numbers and larger sizes of storage facilities, and the appearance of formal kivas. Sites typically contain between 6 and 9 rooms per site, most arranged in a linear fashion. Larger sites containing more numerous rooms are often laid out in a quadrilateral pattern around central plazas. It is during PII times that the Chaco phenomenon truly flourishes, accompanied by the establishment of very large towns, the appearance of multistoried room blocks, increasingly complex architectural elaboration of kivas, the advent of field systems in an effort to boost agricultural production, and the development of road systems to facilitate trade and exchange. These changes seem to signal a return to accelerating population growth in response to dramatically improved climatic conditions. Unlike the PI period, climatic reconstructions for A.D. 900 to 1050 indicate a return to higher rainfall levels, although this was accompanied by episodic droughts whose intensity varied from place to place. In areas less affected by droughts, settlements were pushed into areas that would have been marginal in PI times. It is suspected that differential spatial distributions of critical resources probably became more pronounced in PII times over much of the San Juan Basin. In short, current theories suggest that much of the PII period is typified by imbalances between people and resources, both temporally and geographically. Such imbalances necessitated the introduction of various buffering mechanisms in an effort to offset these imbalances. Among the buffering mechanisms inferred from the archaeological record were improved storage facilities, expansion of regional exchange networks, and more frequent abandonment and reestablishment of large villages in areas better suited for agriculture. One consequence is that PII sites often were occupied for relatively short periods of time. Subsistence practices indicate greater reliance on cultivated plants, although evidence of use of wild resources persists at most PII sites. Maize, beans, and squash are quite common at both large and small sites. Evidence of agricultural intensification derives from the identification and dating of the first water control structures in the San Juan Basin. These structures were designed to augment rainfall, thereby increasing overall productivity of given plots of land. Many of these water control devices seem to provide water to outwash fans, areas that are often marginal for direct rainfall agriculture. Earlier dissimilarities between sites in the southern San Juan Basin and

those in the northern basin largely disappear during PII times. The emergence of region-wide (relative) homogeneity in ceramics, architecture, subsistence practices, and settlement patterns has been interpreted as evidence supporting the inference that region-wide trade and exchange systems emerge in full force during PII times. One notable exception to this homogeneity is found in the Chaco Canyon region, where settlement in the Chaco heartland is typified by numerous small habitation sites distributed around fewer, but very much larger and more complex towns (central places) containing kivas, great kivas, reservoirs, dams, and roads. Sourcing studies suggest that non-local materials were being imported from far-flung parts of the Southwest. These facts, combined with the panregional distribution of ceramics that are virtually identical, suggests that Chaco Canyon may have been the primary focal point for trade and exchange networks whose limits extended into northeastern Arizona, southern Colorado, and west-central New Mexico. Analyses of ceramics and chipped stone indicate that source areas for such critical resources gradually shifted over time from the southeastern part of the area (Zuni) to the western (Chuska) region and, finally, to the northern portion of the San Juan Basin. It is likely that these regions approximate the outer limits of this exchange and trading network. There is some evidence suggesting that turkeys and perhaps corn were among the crucial subsistence resources being imported into the Chaco region. If such inferences are accurate, reliance on imported foodstuffs underscores the tenuous agricultural conditions that prevailed across the central San Juan Basin during PII times. Chaco Canyon, and the outlying sites related to it, is unique in Southwestern prehistory. The Chaco phenomenon is defined on the basis of multiple attributes. There are two alternating site types, great houses and villages viewed by many as indicative of economic and political differences inherent in the Chaco system. Multistoried great houses, usually consisting of upwards of 200 rooms, typically were constructed as a series of temporally discrete units (Kantner and Mahoney 2000, Saitta 1997). In contrast, surrounding villages usually consist of single story structures ranging from 20-40 rooms in extent. Obvious differences in site construction characteristics are underscored by the recovery of exotic goods in great house sites and the virtual absence of such goods in villages. Among these goods are copper bells, turquoise, shell jewelry, and macaws from Central America (Mathien and McGuire 1986, Toll 2001). Finally, great houses appear to be nodes for upwards of 70 constructed roads or road segments, often interpreted as remnants of transportation/communication routes (Renfrew 2001; Vivian 1997a, b). Because the "Chaco phenomenon" is one of the most well-documented archaeological manifestations in the Southwest, it is no surprise that it provides a basis for widespread discussion of the factors that contributed to its appearance, operation, and eventual collapse. The phenomenon of "Chaco" has been viewed by different scholars as either (1) largely a local geographic phenomena that appears in response to generally favorable climatic conditions and is typified by redistributive activities or (2) as one component of a much larger Mexican-Southwestern interaction network founded largely on ideational factors. The characteristics of inferences necessarily vary considerably between these perspectives.

*Chaco as a Regional System*

Those who view Chaco as a somewhat localized Southwestern phenomenon underlain by redistributive activities assume that Chaco exhibits attenuated links to other regions (e.g., Mexico). Researchers of this perspective generally focus on the occurrence of two alternating site types, great houses and villages, as well as the presence of exotic goods and constructed roads as consistent with strategies to control access to and redistribution of goods—both subsistence resources and trade items—across the San Juan Basin (Renfrew 2001). Those advocating the presence of religicopolitical elites cite the presence of large proportions of non-residential rooms at great house sites as evidence for storage of surplus foodstuffs, which were then redistributed by elites residing in great house communities. There are differences of opinion on this theme primarily with respect to inferred degrees of political centralization, ranging from egalitarian (Vivian 1990) or ranked (Grebinger 1973) to chiefdoms (Earle 2001, Lekson 1999, Saitta 1997).

Others, however, find insufficient evidence to conclude that hierarchical elites were present (Feinman et al. 2000, Saitta 1997, Sebastian 1992, Vivian 1997b, Windes and Ford 1996). The presence of upwards of 70 constructed road segments, possibly built through some form of non-coerced or coerced communal labor (Saitta 1997), is viewed by some as reinforcing the notion of politico-religious authorities coordinating road construction to facilitate transport and communication across the San Juan Basin (Cameron and Toll 2001, Nelson 1995, Vivian 1997b). Among the activities inferred for Chacoan roads are transport of beams into great house communities for use in roof construction (Snygg and Windes 1998), as access routes for pilgrims to ceremonies and periodic markets centered in great house communities (Judge 1989, Malville and Malville 2001, Renfrew 2001, Roney 1992, Vivian 1997b), as routes for the movement of turquoise, much of which seems to have been used within Chacoan communities (Mathien 2001), or as routes for military activities undertaken to forcibly integrate outlying communities into the Chaco system (Wilcox 1994). Others, however, have concluded that these roads were too wide to have been designed simply as transportation routes, regardless of what might or might not have been transported (Roney 1992, Kantner 1997, Vivian 1997b). Similarly, while exotic items of Mexican origin (e.g., copper bells, macaws) are known from Chacoan sites, those subscribing to the notion that Chaco was a regional network note that the overall quantity of such remains is too small to reflect widespread trade or exchange with Mexico (Renfrew 2001). At the same time, some have suggested that the value, not quantity, of exotic items from Mexico may be a far more important factor in evaluating the presence of such items at Chaco (Reyman 1995). Finally, some see Chaco's settlement system as based largely on cosmology (Stein and Lekson 1992). Specifically, the Chaco phenomenon is argued to have been predicated on shared ritual ideology linked to cosmological events (e.g., solstices, equinoxes) which, in turn, were manifested in the structured spatial arrangement of archaeological sites (e.g., kivas, shrines, rock art, water control features, and roads) across Chacoan landscapes (see also Sofaer 1997).

*Chaco as a Pan-Regional System*

Most recently, Lekson has proposed that Chaco may be part of a much larger Mexican-Southwest settlement system. Lekson (1999) focuses on the supposed alignment of structures found at the New Mexico sites of Aztec Ruins and Chaco Canyon, along with the site of Paquimé in northern Mexico, on a north-south axis running from nearly Colorado into northern Chihuahua. These complexes are suggested to be time-sequent residences of religico-political elites that moved in response to a succession of deteriorated environmental intervals. Specifically, he proposes that a politico-religious elite, originally resident in Chaco Canyon, moved successively to Aztec (ca. A.D. 1125) and then Paquimé (A.D. 1275). What is perhaps most controversial about Lekson's argument is the notion that the arrangement of these three sites along a given meridian represents a deliberate effort to construct sites according to some preconceived plan by a multi-generational elite that spanned more than 200 years and 630 kilometers. Not surprisingly, there are objections to Lekson's view of Chaco. For example, Phillips (2000) demurs about this model, observing that the alignment of these three sites along a given meridian may be more apparent than real and, moreover, that the presumptive similarity of architecture across these three sites is without foundation. Further, Phillips notes that, in particular, ceramic assemblages from Paquimé are quite dissimilar from Chacoan ceramics in general, suggesting that a time- and spacetransgressive elite is not responsible for constructing these three sites.

*Pueblo III (ca. A.D. 1050 to 1300)*

The Pueblo III (PIII) period is typified by the aggregation of populations into progressively larger centers, accompanied by the gradual collapse of the Chaco phenomenon that so defines early and middle PII times. Some researchers suggest that populations began to move northward into the northern San Juan Basin near Aztec, as well as southward out of the Mesa Verde region. Concurrent with Chaco's gradual decline in importance is a seeming realignment of social interaction spheres northward toward Mesa Verde. For example, sites along the Chuska Mountains seem to evidence a period of increased building events, accompanied by the replacement of Chacoan ceramics with those more typical of Mesa Verde. As well, the appearance of bi- and tri-wall buildings, nominally characteristic of the Mesa Verde region at sites in the San Juan Basin, suggests the gradual outward expansion of Mesa Verde peoples into areas formerly containing Chaco components. Over much of this period, sites contain between 13 and 30 rooms, with larger sites exhibiting upwards of 200 rooms. These changes are attributed to the onset of a period of dramatically decreased rainfall after ca. A.D. 1220, accompanied by increased spatial variability in rainfall across the basin as a whole. Areas adversely affected by reduced rainfall, the central and southern San Juan Basin, seem to act as donor areas for population out-migration, while areas less subject to reduced rainfall, like the Mesa Verde and McElmo regions, become recipient areas for immigrants. Many parts of the Basin appear to have been abandoned toward the terminal portion of the PIII period. Further, as noted in the PII discussion, dual PII-PIII components are quite common across the region.

RESOURCE DESCRIPTION/CURRENT KNOWLEDGE OF THE SITES

**LA 82634/SW 260-2**

**Site Type: Artifact Scatter**
**No. of Components: 1**
**UTM Coordinates: 244380 E; 3920460 N, Z 13**
**Cultural Affiliation: Anasazi**
**Elevation: 6930 feet above mean sea level**
**Topographic Location: Alluvial flat**
**Vegetation Community: Desert Scrub**

Site LA 82634 is a lithic and ceramic scatter that is located on an alluvial flat, just to the west of New Mexico State Highway 509 (NM 509). The site was originally recorded in September of 1990 by Lonyta Vicklund of Southwest Archaeological Consultants (Vicklund 1990). The site measures approximately 28 m x 48 m, has a site area of 1,344 square meters, and is at an elevation of 6930 feet above mean sea level. It is situated within a desert scrub/grassland vegetation community comprised of chamisa, four-wig saltbush, sage, Russian thistle, and various grasses. A total of 15 flakes were identified during the original recording and are dispersed across the site boundary. They are defined as primary and secondary flakes manufactured from chert and quartzites. Three small pieces of unmodified vesicular basalt were also noted. Ceramics on the site include more than 100 sherds. Types represented within the assemblage include Red Mesa Black-on-white, Gallup Black-on-white, and Escavada Black-on-white sherds representing bowls and jars. Numerous sherds of indeterminate grayware, Clapboard corrugated, and corrugated indented jar sherds (with some Chuska varieties). Sandstone spalls and unmodified blocks were noted in limited concentrations on the site, however no formal feature designation was given. The site condition was determined to be intact. The site was determined to have possible subsurface deposits present. The site was interpreted to represent a field location and possible habitation dating from the Late Pueblo I to Pueblo III period (A.D. 800-1150) based on the presence of several different types of ceramic vessels and possible remnants of a subsurface structure or eroded jacal structure. The ceramic types present more accurately date to the Pueblo II to Pueblo III period (A.D. 900-1150). The site was recommended as eligible for inclusion to the National Register of Historic Places under criterion D, information potential.

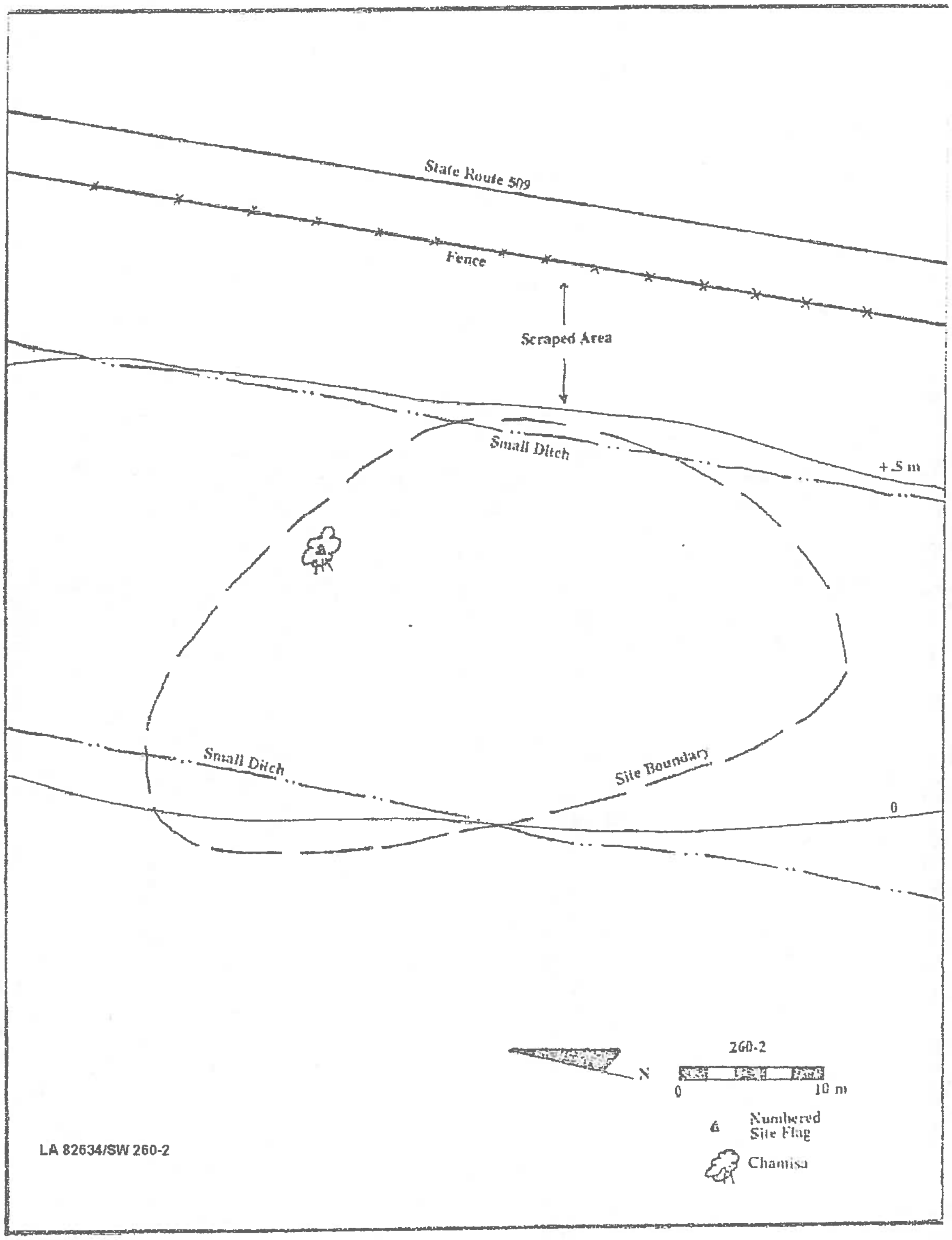


Figure 3. Site map for LA 82634/SW 260-2.

Whether or not there is potential for any intact feature deposit or cultural horizon to be present is, at this time, unknown. Excavation will concentrate on areas exhibiting surface manifestations, with sampling across other areas. Excavation will begin with the installation of control pits across the site along the N/S and E/W baselines, as well as areas that may represent differential sediment thickness or exhibit surface indications of cultural materials. Initially these pits will be placed at 2 meter and 5 meter intervals across the site. The number of control pits installed after initial testing is somewhat dependant on the results. In the event that none of the initial pits prove positive, a second round of single excavation units will be installed in areas previously untested along baseline and other areas. Control pits will be placed strategically and randomly in baseline and other site areas until a positive result is reached or the subsurface potential of the site is exhausted. Pits that prove positive will be used as the starting point for block excavations. Each positive pit area will be included within a block of grids that may be expanded or terminated depending on the results of excavation.

LA 82634:

As described above the total site area is 1344 square meters. The site will be excavated by surface stripping blocks within areas exhibiting surface manifestations. Stripped blocks will expand or be terminated depending on subsurface discovery. Subsurface discoveries will be excavated in total as described in the excavation methods discussion. One square meter control pits will be placed systematically along grid coordinates in areas exhibiting surface manifestation and at random across areas not exhibiting surface materials.

Initially five one-meter square control pits will be excavated in areas exhibiting surface materials. These will be associated with but not continuous with, three 25 square meter blocks of surface stripped area. The blocks will be placed over artifact concentrations and areas to the west and northwest in an attempt to identify any potential structure or feature areas. Standard one square meter test units will be excavated within each block. These may be continuous or dispersed depending on strata and cultural materials. Additionally, shovel width trenches will be excavated across one axis of the blocks at one-meter intervals along grid lines. An additional series of surface stripping trenches will be excavated across site areas exhibiting surface materials, as well as areas west and northwest of artifact concentrations. Site space not exhibiting surface materials will be stripped with 25 cm shovel width trenches at regular intervals. Minimum excavation totals may reach as much as 80 square meters with additional coverage as necessary. Shovel width stripped surfaces may add as much as another one meter square for every 4 meters of stripping.

LA 82635:

As described above, it is proposed that a series of shovel tests be excavated across the entire site boundary of LA 82635. The site area is approximately 1,365 square meters. The placement of shovel tests at 2 meter intervals is recommended. Therefore, a total of 290 shovel test units are proposed. Each shovel test unit shall be approximately 50 cm x 50 cm and excavated to a depth of cultural sterility. The basic vertical control unit will be the 10 centimeter (cm) in depth level. If necessary excavations within individual shovel test units will proceed in arbitrary, 10 cm levels. This equates to a total of 72.5 square meters of shovel test excavation, which equates to approximately 19% of the total site area. A random series of shovel width trenches will be installed across site areas not investigated or exhibiting cultural materials. If subsurface discovery necessitates additional excavation it will proceed as previously described in methodology sections.

*Surface Collection:*

As a result of the implementation of Rio Algom Mine's remediation plan, all site areas will be destroyed. As such, a 100% surface collection of all artifacts will be conducted. Prior to collection, artifact concentrations will be delineated in order to facilitate provenience information from surface contexts. All artifacts within each defined concentration will be collected for curation accordingly and mapped on the instrument map discussed above. After provenienced concentrations have been collected, the site-wide scatter of artifacts will then be collected. Only specific artifacts (i.e. projectile points and/or unique artifacts) will be point provenienced on the instrument map. Initial in-field analysis previously conducted appears sufficient at this time. All artifacts surface collected will under go further detailed analysis upon their return to the laboratory.

*Samples:*

Should feature deposits be encountered, appropriate samples will be collected to assist in the determination of the site's age and products used there. Deposits will be collected in total from thermal or possibly storage features. Charcoal or charcoal within carbonaceous deposits may assayed for radiocarbon dating. Economic plant/wood data whether dietary, construction or fuels may be identified. Pollen samples will not be collected from burned deposits, but groundstone found in well sealed contexts may be processed for pollen washing.

Specialized analytical studies such as macrobotanical studies, faunal analysis, and pollen analysis are handled through subcontractors. A partial list includes: Beta Analytical (for radiocarbon assay), Laboratory of Tree-Ring Research at the University of Arizona, Colorado State University Archaeomagnetic Services, Lithic Analysis & Obsidian Hydration Laboratory Cotsen Institute of Archaeology at UCLA, University of Minnesota-Duluth College of Science and Engineering Archaeometry Laboratory, National Petrographic Service, Inc. and University of Washington Luminescence Laboratory.

*Human Burials:*

In accordance with the Native American Graves Protection and Repatriation Act, section 10, the discovery of human remains will be treated in the following manner. In case of discovery of human remains all excavation at that location will cease. Immediate telephone notification of the discovery, with written confirmation, will be provided to the appropriate local law enforcement agency officials. will be These officials will then contact the medical examiner and State Historic Preservation Officer. Notification by telephone and written confirmation will be provided by the appropriate agency official to the Indian tribes likely to be affiliated with the discovery. The discovery will result in an immediate ceasing of activities in the area of the discovery along with a reasonable effort to protect the human remains, funerary objects, sacred objects, or objects of cultural patrimony. If the human remains, funerary objects, sacred objects, or objects of cultural patrimony are to be excavated or removed, the requirements and procedures in the Native American Graves Protection and Repatriation Act Section 10.3(b) will be followed. The activities that resulted in the discovery may resume 30 days after certification by the SHPO of receipt of the written confirmation of notification of the discovery if the resumption of the activity is lawful. The activity may also resume at any time that a written, binding agreement is executed between the SHPO, Rio Algom Mining LLC, and the affiliated Indian tribes that adopt a recovery plan for the excavation or removal of the human remains, funerary objects, sacred objects, or objects of cultural patrimony following the Native American Graves Protection and Repatriation Act Section 10.3(b)(1).

Excavation of human burials will be consistent with current professional archaeological standards. The Archaeological Records Management System (ARMS) forms for each burial ground (if not previously recorded), plan maps of each burial and associated funerary objects, material objects or artifacts, photographs of each burial in situ with associated funerary objects, material objects or artifacts, description of field methodology, including observations about soils and the context of each burial within the burial ground will be prepared. Analysis of human remains will include sex, age, basic measurements, pathologies, and photodocumentation. Analysis of associated funerary objects, material objects, or artifacts will include a written inventory list of all items associated with the burial and removed from the burial ground, to be submitted to the SHPO before final disposition of the remains. The list will be specific in terms of material, typology, quantity and condition of the items recovered and scaled photographs of all recovered items, to be submitted with written inventory. The photographs will be labeled with the name of the permittee, provenience of the burial, date of excavation and disposition of items.

## BACKFILL

All shovel test units and excavated units will be backfilled upon completion of the project. As previously stated in the description of the project undertaking, the overburden being removed for remediation will not be re-deposited on the sites. After data recovery, clean soil will be deposited on the site from an adjacent location. This will be accomplished manually utilizing shovels and wheelbarrows.

## ANALYTICAL PROCEDURES

Where possible the results of analysis will be applied to or used to the extent that the numbers of artifacts or materials recovered from samples allow. Radiocarbon or tree-ring data will support or negate the assessment of the ceramic assemblage. Debitage analysis may relate use by Archaic groups if biface debitage is present. Tool types and wear pattern analysis may be used to describe or postulate the actions performed and on what type(s)of materials. Presence or absence of tool types will qualify processing activities (to the extent that is possible in the event that they were not removed at abandonment). Any macrobotanical remain will provide insight into subsistence activities.

Analyses of collected materials will be completed by qualified consultants in cases where the proper expertise is not available on the EMI staff. Mr. Burleson and Mr. Phippen have extensive experience in developing and performing lithic and ceramic analysis projects. As these sites are relatively small, it is proposed that 100% of all surface cultural materials and recovered materials from excavation contexts be conducted in an attempt to extract as much data as possible from each site. All accumulated data will be processed using Microsoft Access (MCACCESS).

Lithic and groundstone artifacts will be analyzed by EMI personnel. Lithic analysis will be directed toward standard artifact attribute recording. Lithic artifacts (chipped, ground, and unmodified but utilized stone artifacts) will be entered into MCACCESS database system by logging a variety of attributes. Collection of attributes will focus on the manufacturing techniques and artifact function. The following information will be recorded:

- Artifact type: angular debris/shatter, flake and flake sub-types (core or hard hammer, biface/soft hammer, retouch, Bifaces and (biface stage i.e. I,II,III,IV), uniface and scraper type (end, transverse, spurred, combination etc.), core, core tool (chopper, pecking stone, and, scraper planes in particular), hammerstone, projectile point (sub categories to be developed), drill, etc. Flakes exhibiting use wear will be dropped from the debitage category and placed in a utilized flake type.

- Material type: specific materials found in the local area/region as well as distinctive non-local materials. Materials typically identified on archaeological sites include andesite, basalt, chalcedony, chert, jasper, limestone, metasediment, obsidian, ryholite, silicified wood, and quartzites.
- Condition of artifact: whole, proximal, distal, lateral, medial, unknown fragment, and burned artifacts.
- Percentage of cortex: estimated.
- Platform type (refers to flakes or artifacts with visible platforms): not applicable, absent, collapsed, cortical, single facet, multi-facet, stepped, ground, crushed, bipolar.
- Dimensions (measured in millimeters): length, width, and thickness. Broken artifacts especially bifaces and projectiles will be measured in terms of thickness. If any maximum dimension can be inferred it will be monitored.

Retouch will be monitored for flakes exhibiting marginal refinishing through retouch. This will be documented as to location on the flake (proximal, distal, lateral), and directionality (unidirectional, bidirectional).

Use Wear on debitage and tools will be monitored as present or absent at a minimum. If present, use retouch, rounding and polish, battering etc. will be recorded.

Analysis at the assemblage/site level will incorporate the specific data already mentioned, as well as information to assess functional, temporal, and potential spatial patterns across the site. These include:

- Component type: Paleoindian, Early Archaic, Middle Archaic, Late Archaic, etc.
- Reduction stage: primary reduction, secondary reduction, primary/secondary reduction, advanced stages of reduction, and all stages of reduction.
- Presence of tools: yes or no.
- Presence of cores: yes or no.
- Presence of groundstone: yes or no.
- Presence of fire-cracked rock: yes or no.
- Presence of non-local lithics: yes or no.
- Presence of structures or stains: yes or no.
- Topography: bench, hillslope, ridge, low rise, plain/flat, saddle, terrace, swale, and/or combinations of the above, etc.

Diagnostic projectile points, formal tools, and utilized flakes will undergo multi-attribute analysis to determine function and/or typological placement in regional seriations. Artifacts specifically mentioned in the report text will be drawn and photographed.

Ceramic analysis will be conducted by EMI archaeologists Robert Phippen and Richard Burleson. Mr. Phippen and Mr. Burleson have substantial experience with ceramic analysis in the southwest. Ceramic artifacts will be entered into MCACCESS database system by logging a variety of attributes. Collection of attributes will focus on the recordation of a series of attributes that describe the manufacturing techniques, function, ceramic type, form, temper, and interior/exterior surface treatment. Based on a visual inspection of the sites, typical Pueblo II period ceramics relating to the Cibola whiteware series are present.

Bone artifacts and faunal remains will be analyzed by EMI personnel when possible, and in the case of unknown species, a private consultant will be contracted on an hourly basis.

Macrobotanical processing and analysis will be performed by Pamela McBride, a private consultant who also is employed with the Museum of New Mexico, Office of Archaeological Studies. Any pollen sample recovered will be sent to a palynological consultant. Radiocarbon samples will be processed by Beta Analytic of Miami, Florida. All dendrochronological samples will be sent to the Tree Ring Laboratory at the University of Arizona in Tucson.

## SCHEDULE

Projected fieldwork is the total amount of hours estimated to fully excavate all proposed areas and exhaust the data potential for both sites. The total area involved at LA 82634 is 1,344 square meters and the total area involved at LA 82635 is 1,365 square meters. As it relates to LA 82634, the amount of earth moved by a crew of five will rarely exceed 2.5 cubic meters per day, especially if the incidence of cultural material is high. If the depth of fill reaches 50 cm per one meter excavation unit, a total of four units may be completed per day. This would total approximately 20 days. Therefore, the estimate of 20 days is used to account for the possibility that all pits will not have positive results, and most will not be excavated to a depth of 50 cm. Excessive discovery situations will slow progress. As it relates to LA 82635, an estimated eighty 50 cm x 50 cm shovel test pits excavated to a depth of 50 cm can be completed per day. This would total approximately 3.65 days. Therefore, the total amount of estimated time to complete all excavation and shovel testing would be approximately 24 days.

## PERSONNEL

**Richard Burleson M.A., Principal Investigator and Director of Laboratory Analysis**
*Education:* Ph.D. pending, Anthropology, University of New Mexico; M.A., Anthropology, New Mexico State University 1999; B.A., Anthropology, Appalachian State University, 1996
*Years of Experience:* 13
*Experience Summary:* Richard Burleson is EMI's Cultural Resource Program Manager and principal investigator and will be the principal point of contact for this contract. His duties include management and coordination of EMI's cultural resource projects. He prepares budgets and proposals, hires and manages crews, conducts artifact analyses, conducts record searches, conducts surveys, testing, and data recovery, Section 106 consultation, TCP and Native American consultation, report writing, and editing. His professional background includes over 13 years of experience in all phases of cultural resource management with work conducted in the Southwest (New Mexico, Colorado, Arizona, and Texas), the Great Plains (Oklahoma and Texas), the southeastern US (North Carolina), and Central America (Yucatan Peninsula of Mexico and Belize). He has authored six paper presentations at national and regional conferences, and more than 85 reports and chapters concerning prehistoric and historic resources throughout the Southwest, Southeast, Great Plains, and Mexico. Mr. Burleson holds permits with the Navajo Nation HPD, BIA, Bureau of Land Management in New Mexico (NE, NW, SE, SW), Arizona, and Colorado, and State lands in New Mexico and Arizona. Mr. Burleson is currently managing large multi-year contracts with the New Mexico Bureau of Land Management, New Mexico Department of Transportation, White Sands Missile Range, and the Federal Highway Administration. Mr. Burleson also has extensive experience running laboratory facilities at a professional/curatorial level while serving as assistant to the curator for 2.5 years at the Maxwell Museum of Anthropology. As Program Director for the Pottery Mound Project, Mr. Burleson supervised and conducted the analysis of over 90,000 artifacts from Pottery Mound, a Classic period pueblo located along the Puerco River in north-central New Mexico. While serving in this capacity, Mr. Burleson also curated materials from the Cox Ranch Land Exchange and the Mimbres Foundation excavations. Mr. Burleson's expertise is in lithic analysis, specifically microwear analysis.

**Robert Phippen, B.A., Archaeologist, Field Director/Field Supervisor and Director of Laboratory Analysis**
*Education:* B.A. Anthropology, 1976, University of New Mexico
*Years of Experience:* 29
*Experience Summary:* Robert Phippen is EMI's cultural resource field director. His duties include coordination and direction of EMI's cultural resource projects in the field. He manages field crews, conducts records searches, conducts artifact analyses, and assists in report preparation. His professional background includes 29 years of experience in all phases of cultural resource management with work conducted in the Southwest (Arizona, Colorado, Utah, Texas, and New Mexico), the Plains (Oklahoma, Kansas, and Texas), and California. He has authored more than 75 reports and chapters concerning prehistoric and historic resources throughout the Southwest, Great Basin, Great Plains, and California. Mr. Phippen holds permits with the BIA, Bureau of Land Management in New Mexico (NE, NW, SE, SW, Dinetah, Great Plains, and Southwest Culture Area), Arizona, and Colorado, State lands in New Mexico and Arizona, and Navajo Nation. Mr. Phippen has extensive experience in directing and conducting data recovery projects on Archaic, Anasazi, and Navajo archaeological sites.

## CURATION

Excavated and screened cultural materials will be stored temporarily in the contractor's office/laboratory facilities in Albuquerque, New Mexico during the period of analysis and report preparation. With the exception of human remains (if applicable), all excavated and screened materials, field records, and photographic records will be reposited permanently at the Museum of New Mexico, Laboratory of Anthropology curatorial facilities utilizing approved curation procedures.

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# ATTACHMENT B

# LONG-TERM EROSION MODELING REPORT

# PREDICTION
# OF
# EROSIONAL SOIL LOSS
# AND
# LAND SURFACE PROTECTION MEASURES

Ambrosia Lake Facility

Rio Algom Mining Company, LLC

Grants, New Mexico

CURTIS O. SEAL
NEW MEXICO
10084
LICENSED PROFESSIONAL ENGINEER
7-7-05

Prepared by:

Maxim Technologies

Albuquerque, NM

July 2005

**Introduction**

This engineering report has been prepared by Maxim Technologies (Maxim) for Rio Algom Mining Company, LLC., to evaluate the long term erosion potential for general areas at the Ambrosia Lake facility near Grants, New Mexico. The purpose was to use standard methodologies to predict soil loss potential in reclaimed areas beyond the existing reclaimed tailing ponds that could be affected by runoff and run-on from periodic and long term storm events. In addition, the erosion potential of the land surface of reclaimed holding ponds 4, 5 and 6 were evaluated both for short term periodic storm events and from a PMP event.

The following paragraphs present the accepted methodologies for predicting soil loss and present recommendations for achieving stable reclamation covers and land surfaces at the facility.

**Soil Loss Prediction Methodologies**

Several methodologies exist that are useful to predict erosion potential of reclamation covers and surrounding land surfaces. Agricultural erosion has been studied for many years resulting in the development of prediction algorithms and control procedures. Because soil erosion and sedimentation from construction and mining activities are similar, the procedures and algorithms developed are useful in predicting soil erosion from these activities.

Maxim utilized two industry accepted methods for predicting soil erosion loss at the Ambrosia Lake Facility which are presented in NUREG Documents CR-3199, CR-4620 and 1623. The methods are described as follows:

Universal Soil Loss Equation

The principal controlling factors affecting the erosional processes in the Universal Soil Loss Equation model are:

- Soil particle size, density and moisture control
- Surface roughness
- Slope angle and slope length
- Vegetation/surface protection
- Climatic Variables

Both the short and long term erosional stability of slopes at this facility can be evaluated with respect to the aforementioned variables by use of the Universal Soil Loss Equation model.

The USLE was primarily developed for agricultural purposes but has been modified to accommodate mining and construction activities in the Western United States by the Utah Water Research Laboratory. The resulting modified method (MUSLE) is a mathematical model based on coefficients determined in the field and provides the most rational approach to evaluating the potential for long term erosion on bare or vegetated land surfaces.

The modified Universal Soil Loss Equation (MUSLE) is defined as follows:

$$A=R*K*(LS)*(VM) \qquad \text{Equation 1.1}$$

Where,

A = the computed loss per unit area in tons per calculated area units per year with the units selected for K and R properly selected:

R = the rainfall factor which is the number for rainfall erosion index units plus a factor for snowmelt, if applicable:

K = the soil erodibility factor, which is the soil loss rate per erosion index unit for a specified soil as measured on a unit plot that is defined as a 72.6 ft length of uniform 9% slope continuously maintained as clean tilled fallow:

LS = the topographic factor, which is the ratio of soil loss from the field slope length to that from a 72.6 ft length under otherwise identical conditions:

VM = the dimensionless erosion control factor relating to vegetative and mechanical factors. This factor replaces the cover management factor (C) and the support factor (P) of the original USLE.

The Rainfall and Runoff Factor (R)

The R factor is described in terms of a rainfall storm energy (E) and the maximum 30-minute rainfall intensity ($I_{30}$). Generalized R factors applicable to the interior western United States are given in Table 1.1.

Table 1.1 Generalized Rainfall and Runoff (R) Values

| State | Eastern Third | Central Third | Western Third |
|---|---|---|---|
| N. Dakota | 50-75 | 40-50 | 40 |
| S. Dakota | 75-100 | 50 | 40 |
| Montana | 30-40 | 20 | 20-50 |
| Wyoming | 30-50 | 15-30 | 15-25 |
| Colorado | 75-100 | 40-50 | 20-40 |
| Utah | 20-30 | 20-50 | 15-40 |
| New Mexico | 75-100 | 40-50 | 20-40 |
| Arizona | 20-50 | 20-50 | 25-40 |

Source: NUREG CR-4620

The Soil Erodibility Factor (K)

The soil erodibility factor (K) recognized the fact that the erodibility potential of a given soil is dependent on its compositional makeup, which in turn reflects the grain size distribution of the soil. To predict soil erodibility, five soil characteristics that include the percent silt and fine sand, percent sand greater that 0.2 mm, percent organic material, general soil structure and general permeability are determined. The K factor is then found by using the Wischmeier nomograph presented in Figure 1.1.

The Topographic Factor (LS)

Although the effects of both length and steepness of slope have been investigated separately in different research efforts, it is more convenient for analytical purposes to combine the two into one topographic factor, LS. Wischmeier and Smith (1978) developed plots correlating the topographic factor for slopes up to 500 meters in length at slope inclinations from 0.5% to 50%.

The equation to determine the LS factor is as follows:

$$LS = \frac{650 + 450 + 65s2}{10{,}000 + s2} \quad \frac{L}{72.6} \quad M \qquad \text{Equation 1.2}$$

where LS = topographic factor

L = slope length in feet

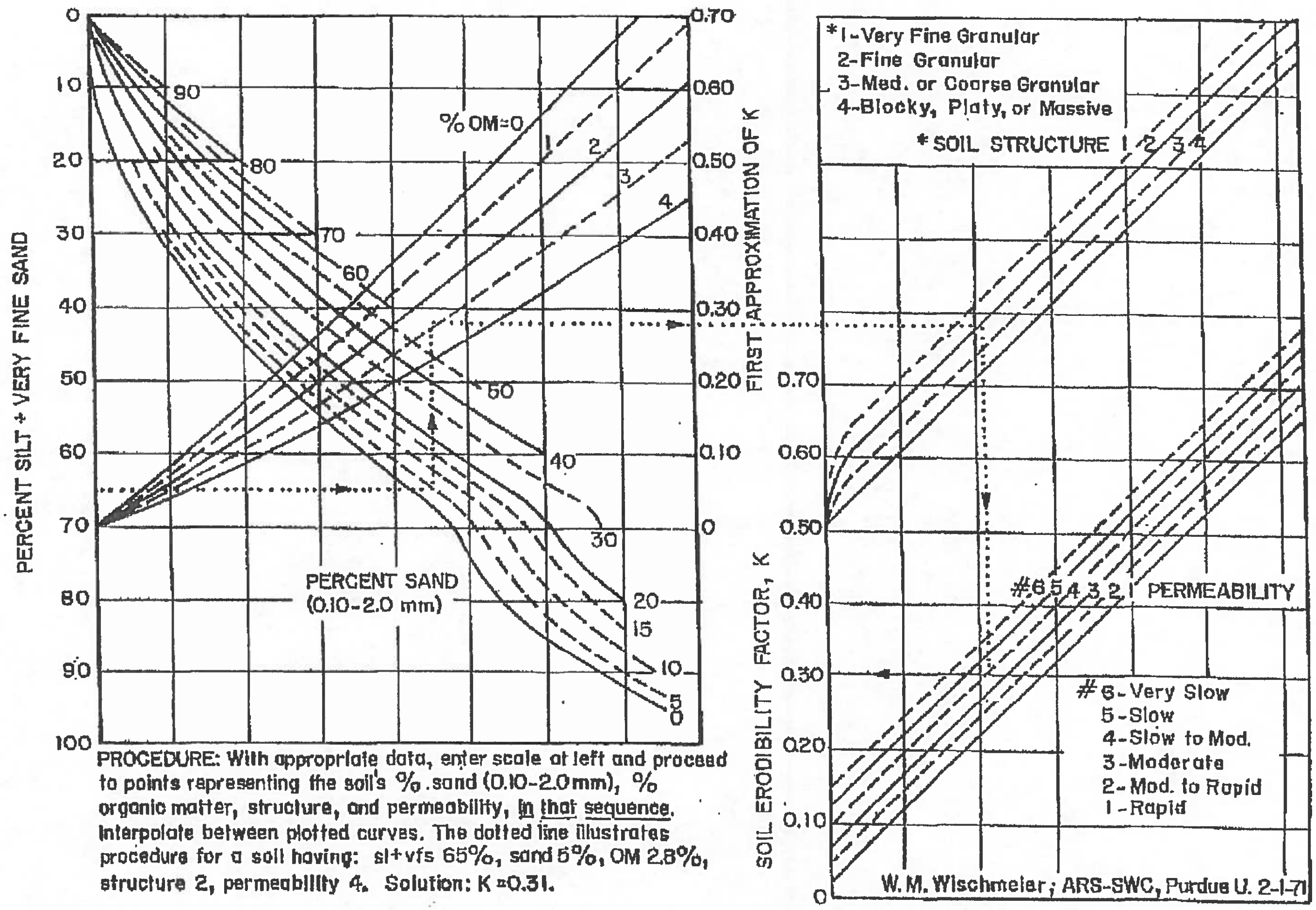


**Fig. 1.1 Nomograph for determining soil erodibility factor *K*.** *Source:* after Wischmeier et al., 1971.

S = slope steepness in percent

M = exponent dependent upon slope steepness

The slope dependent exponent m is presented in Table 1.2

Table 1.2 Slope Dependent Exponent

| Slope | m |
|---|---|
| $s \leq 1.0$ | 0.2 |
| $1.0 < s \leq 3.0$ | 0.3 |
| $3.0 < s \leq 5.0$ | 0.4 |
| $5.0 < s \leq 10.0$ | 0.5 |
| $s > 10.0$ | 0.6 |

The VM Factor

The VM factor is the erosion control factor applied in place of the cover and erosion control factors found in the USLE. The erosion control factor accounts for measures implemented at the construction site to include vegetation, mulching, chemical treatments and sprayed emulsions to impede or reduce erosion due to the overland flow of water. Values of the VM factor relative to site-specific conditions are presented in Table 1.3 The VM factor is perhaps the most sensitive factor to effect the computed erosion loss for a given site. As shown by the values presented on Table 1.3, the development of a permanent vegetative cover can have a significant impact in reducing the computed erosion loss.

Permissible Velocity Approach

The erosion potential of a soil cover or land surface can be evaluated by determining the properties of the soils and specifying a velocity criterion that will not erode the cover or land surface and will prevent scour. Studies by the U.S. Army Corps of Engineers, Universities and other organizations have developed permissible velocities for various soil types obtained from experimental studies which provide a conservative estimate for evaluating erosion potential of soil for the long term. These permissible velocity values are summarized in NUREG CR-4620 and are presented in Tables 1.4 through 1.6.

Table 1.3 Typical VM Factor Values Reported in the Literature.[a]

| Condition | VM Factor |
|---|---|
| 1. Bare soil conditions | |
| freshly disked to 6-8 inches | 1.00 |
| after one rain | 0.89 |
| loose to 12 inches smooth | 0.90 |
| loose to 12 inches rough | 0.80 |
| compacted bulldozer scraped up and down | 1.30 |
| same except root raked | 1.20 |
| compacted bulldozer scraped across slope | 1.20 |
| same except root raked across | 0.90 |
| rough irregular tracked all directions | 0.90 |
| seed and fertilizer, fresh | 0.64 |
| same after six months | 0.54 |
| seed, fertilizer, and 12 months chemical | 0.38 |
| not tilled algae crusted | 0.01 |
| tilled algae crusted | 0.02 |
| compacted fill | 1.24 - 1.71 |
| undisturbed except scraped | 0.66 - 1.30 |
| scarified only | 0.76 - 1.31 |
| sawdust 2 inches deep, disked in | 0.61 |
| 2. Asphalt emulsion on bare soil | |
| 1250 gallons/acre | 0.02 |
| 1210 gallons/acre | 0.01 - 0.019 |
| 605 gallons/acre | 0.14 - 0.57 |
| 302 gallons/acre | 0.28 - 0.60 |
| 151 gallons/acre | 0.65 - 0.70 |
| 3. Dust binder | |
| 605 gallons/acre | 1.05 |
| 1210 gallons/acre | 0.29 - 0.78 |
| 4. Other chemicals | |
| 1000 lb. fiber Glass Roving with 60-150 gallons asphalt emulsion/acre | 0.01 - 0.05 |
| Aquatain | 0.68 |
| Aerospray 70, 10 percent cover | 0.94 |
| Curasol AE | 0.30 - 0.48 |
| Petroset SB | 0.40 - 0.66 |
| PVA | 0.71 - 0.90 |
| Terra-Tack | 0.66 |
| Wood fiber slurry, 1000 lb/acre fresh[b] | 0.05 |
| Wood fiber slurry, 1400 lb/acre fresh[b] | 0.01 - 0.02 |
| Wood fiber slurry, 3500 lb/acre fresh[b] | 0.10 |
| 5. Seedings | |
| temporary, 0 to 60 days | 0.40 |
| temporary, after 60 days | 0.05 |
| permanent, 0 to 60 days | 0.40 |
| permanent, 2 to 12 months | 0.05 |
| permanent, after 12 months | 0.01 |
| 6. Brush | |
| 7. Excelsior blanket with plastic net | 0.04 - 0.10 |

[a]Note the variation in values of VM factors reported by different researchers for the same measures. References containing details of research which produced these VM values are included in NCHRP Project 16-3 report, "Erosion Control During Highway Construction. Vol. III. Bibliography of Water and Wind Erosion Control References," Transportation Research Board, 2101 Constitution Avenue, Washington, DC 20418.

[b]This material is commonly referred to as hydromulch.

Table 1.4 Maximum permissible velocities in erodible channels

| Channel Material | Water Transporting Colloidal Silts Velocity v (ft/sec) |
|---|---|
| Fine sand, colloidal | 2.50 |
| Sandy loam, non-colloidal | 2.50 |
| Silty loam, non-colloidal | 3.00 |
| Alluvial silts, non-colloidal | 3.50 |
| Firm loam | 3.50 |
| Volcanic ash | 3.50 |
| Stiff clay, colloidal | 5.00 |
| Alluvial silts, colloidal | 5.00 |
| Shales and hardpans | 6.00 |
| Fine Gravel | 5.00 |
| Graded loam to cobbles, non-colloidal | 5.00 |
| Graded Silts to cobble, colloidal | 5.50 |
| Coarse gravel, non-colloidal | 6.00 |
| Cobbles and shingles | 5.50 |

Source: NUREG CR-4620

Table 1.5 Maximum allowable velocities in sand-based material

| | Velocity (ft/sec) |
|---|---|
| Very light sand of quicksand character | 0.75 to 1.00 |
| Very light loose sand | 1.00 to 1.50 |
| Coarse sand to light sandy soil | 1.50 to 2.00 |
| Sandy soil | 2.00 to 2.50 |
| Sandy loam | 2.50 to 2.75 |
| Average loam, alluvial soil, volcanic ash | 2.75 to 3.00 |
| Firm loam, clay loam | 3.00 to 3.75 |
| Stiff clay soil, gravel soil | 4.00 to 5.00 |
| Coarse gravel, cobbles and shingles | 5.00 to 6.00 |
| Conglomerate, cemented gravel, soft slate, Tough hardpan, soft sedimentary rock | 6.00 to 8.00 |

Source: NUREG CR-4620

Table 1.6 Limiting velocities in cohesive materials

| | Compactness of Bed | | | |
|---|---|---|---|---|
| | Loose | Fairly Compact | Compact | Very Compact |
| Principle Cohesive Material | Velocity (ft/sec) | Velocity (ft/sec) | Velocity (ft/sec) | Velocity (ft/sec) |
| Sandy clay | 1.48 | 2.95 | 4.26 | 5.90 |
| Heavy clayey soils | 1.31 | 2.79 | 4.10 | 5.58 |
| Clays | 1.15 | 2.62 | 3.94 | 5.41 |
| Lean clayey soils | 1.05 | 2.30 | 3.44 | 4.43 |

Source: NUREG CR-4620

## Recommendations

### General

The surface soils at the Ambrosia Lake facility consist of alluvium/colluvium which classify primarily as very silty sands to sandy silts in the Unified Soil Classification system. The types of soils are easily erodible under storm runoff events.

Prediction of soil loss by the Modified Universal Soil Loss equation shows that unvegetated soils at this site will be relatively stable for slopes generally less than one percent and not exceeding 200 feet. Predicted soil loss for this gradient and length is on the order of one foot per 1000 years. Unvegetated slopes steeper than one percent even for short distances will experience an unacceptable erosion rate. (See Results of MUSLE Analysis in Tables A-1 and A-2 in the appendix.)

Soil surfaces that are sparingly to moderately vegetated will be stable at slopes up to 3 percent. Vegetated slopes at 3 percent will generally be stable up to a distance approaching 1000 feet.

Using the "Allowable Velocity Approach" the surface soils at this facility will erode at runoff velocities approaching or exceeding 2.5 ft/sec. This criterion is more conservative than the MUSLE model and is recommended to evaluate surface stability in sensitive areas and from significant storm events.

### Stability of Land Surface (Reclaimed Ponds 4, 5 & 6)

Ponds 4,5 & 6 are considered to be in a sensitive area because of the proximity to the Arroyo del Puerto, and the need to apply alternative release criteria to this area. The MUSLE model shows that a moderately vegetated surface will under go about 1/3 foot of soil loss over a 1000 year period. Calculations of runoff from a PMP event (see appendix) show that the runoff velocity will be on the order of 2.6 feet/sec and the flow depth will be on the order of 0.4 foot. Considering the above, it is recommended that a

rock mulch be placed over the existing reclaimed surface of Ponds 4, 5 & 6. The rock should have a median stone diameter $D_{50}$ of 0.5 inch or larger. The stone should have a minimum thickness of 1.0 inch. This will more than adequately protect the land surface in this area from the runoff originating from a PMP event.

Stability of Land Surface (Ponds 7 & 8)

The area of encompassing Ponds 7 and 8 and surrounding land is sparsely to moderately vegetated. For this area it is recommended that a gravel mulch be placed on slopes exceeding one percent. The gravel should have a median stone diameter ($D_{50}$) of 0.5 inch. The gravel may be placed in a thin layer as practicably achievable. The stone may be placed directly on the established grasses and around shrubs. The placement of this gravel mulch will enhance soil moisture retention, further promote re-establishment of the vegetative cover and enhance infiltration. Runoff velocities from storm events will also be reduced, further enhancing the stability of the land surface.

**Selected References**

Johnson, T. L., 1998, Design of Erosion Protection for Long-Term Stabilization. Draft Report for Comment, NUREG-1623. U.S. Nuclear Regulatory Commission, Washington, D.C.

Nelson, J. D., S. R. Abt, R. L. Volpe, D. van Zyl, N. E. Hinkle, W. R. Staub, 1986, Methodologies for Evaluating Long-Term Stabilization Designs for Uranium Mill Tailings Impoundments. NUREG/CR-4620, U. S. Nuclear Regulatory Commission, Washington, D. C.

Voorhees, L. D., M. J. Sale, J. W. Webb, P. J. Mulholland, 1983, Guidance for Disposal of Uranium Mill Tailings: Long-Term Stabilization of Earthen Cover materials, NUREG/CR-3199, U. S. Nuclear Regulatory Commission, Washington, D. C.

# Appendix

# Calculations

Figure A-1

## MODIFIED UNIVERSAL SOIL LOSS EQUATION (MUSLE)

**INPUT**

| | |
|---|---|
| SLOPE LENGTH (FEET) | 200 |
| SLOPE (%) | 3.00 |
| RAIN FALL EROSIVITY FACTOR-R | 30 |
| SOIL ERODIBILITY FACTOR-K | 0.55 |
| VEG MANAGEMENT FACTOR-(VM) | 0.25 |
| SOIL DENSITY (PCF) | 105 |

**COMPUTED RESULTS**

| | |
|---|---|
| TOPOGRAPHIC FACTOR | 0.35 |
| AVERAGE ANNUAL SOIL L (TONS/ACRE/YEAR) | 1.44 |
| LOSS IN DEPTH (FT/1000 YEARS) | 0.63 |

REFERENCE NUREG/CR-4620

**Table A-1**
Results of MUSLE Analysis
Predicted Soil Loss Measured in Feet/1000 years
On
Bare Land Surfaces
Ambrosia Lake Facility
Rio Algom Company, LLC

Slope Length (feet)

| Slope Percent | | 50 | 100 | 200 | 500 | 1000 | 2000 |
|---|---|---|---|---|---|---|---|
| | 3 | 1.67 | 2.05 | 2.52 | 3.32 | 4.09 | 5.04 |
| | 2 | 1.17 | 1.44 | 1.77 | 2.33 | 2.87 | 3.53 |
| | 1 | 0.78 | 0.90 | 1.03 | 1.24 | 1.42 | 1.53 |

Note: All values reported in chart are in feet/1000 years

**Table A-2**
Results of MUSLE Analysis
Predicted Soil Loss Measured in Feet/1000 Years
On
Vegetated Land Surfaces
Ambrosia Lake Facility
Rio Algom Company, LLC

Slope Length (feet)

| Slope Percent | | 50 | 100 | 200 | 500 | 1000 | 2000 |
|---|---|---|---|---|---|---|---|
| | 3 | 0.42 | 0.51 | 0.63 | 0.83 | 1.02 | 1.26 |
| | 2 | 0.29 | 0.36 | 0.44 | 0.58 | 0.72 | 0.88 |
| | 1 | 0.19 | 0.22 | 0.26 | 0.31 | 0.35 | 0.41 |

MAXIM TECHNOLOGIES
A DIVISION OF TETRA TECH, INC.

BY C SEALY DATE 7-5-05

JOB TITLE Rio Algom JOB NUMBER

SUBJECT PMP Hydrology - Ponds 4, 5 & 6 SHEET 1/2

FOR Drainage Area

MAX Length = 1780

Avg Slope = 0.66% OR 0.0066

DETERMINE $T_c$ (Time of Conc)

$$T_c = 0.0013 \frac{L^{0.77}}{S^{0.385}}$$

$$T_c = 0.0013 \frac{(1780)^{0.77}}{(0.0066)^{0.385}} = 0.286 \text{ HRS OR } 17.15 \text{ min.}$$

Calculate % of 1-HR PMP

Table 2.1 NUREG 4620

| DURATION (MIN) | % 1-HR PMP |
|---|---|
| 15 | 74 |
| 17.15 | ? → 77.4% |
| 20 | 82 |

PMP RAINFALL Depth = (0.774)(9.4) = 7.3 inches

Rainfall Intensity

$$i = \frac{(7.3)(60)}{17.15} = 25.5 \text{ inches/HR}$$

FIG A-2

MAXIM TECHNOLOGIES BY C. SEALY DATE 7-5-05

A DIVISION OF TETRA TECH, INC.

JOB TITLE Rio Algom JOB NUMBER

SUBJECT PMP Hydrology SHEET 2/2

Peak Sheet Flow Unit Discharge

Rational Formula $Q = CIA$

$q_{soil} = Q/ft = (1.0)(25.5)\left(\frac{1780}{43,560}\right) = 1.04$ cfs/ft

Calc Sheet Flow Velocity

$y$ = Flow Depth $= \left[\frac{(1.04)(.025)}{(1.486)(0.0066)^{1/2}}\right]^{3/5} = 0.4$ foot

$V_{Design\ (Soil\ Surface)} = Q/A = \frac{1.04}{0.4} = 2.6$ ft/sec $>$ 2.5 ft/sec

∴ Surface Protection from Runoff Req'd

Safety Factors Method - See Attached Spread Sheet Fig A-4

$D_{50} \sim 1/2$ inch S.F. = 1.16 ∴ OK

NUREG 1623 Sect D-8

Abt & Johnson Method

$Q_{Rock} = Q_{soil} \times 0.8 = 1.04 \times 0.8 = 0.83$ cfs

$D_{50} = (5.23)(0.0066)^{0.43}(0.83)^{.56}$

$D_{50} = (5.23)(.1155)(0.90) = 0.54$ inch

Use $D_{50} \sim 0.5$

Fig A3

**Figure A-2**

Project: Rio Algom-Ambrosia Lake

Location: Ponds 4,5,& 6

Date 7/5/05

**RIPRAP DESIGN-SAFETY FACTORS METHOD**
**FLOW OVER A PLANE SLOPING BED**

| INPUT | | COMPUTED RESULTS | |
|---|---|---|---|
| Median Rock Diameter-(D-50)-ft | 0.04 | | |
| Flow Depth-Ft | 0.40 | Design Shear-Psf | 0.16 |
| Bed Slope- Ft/Ft | 0.007 | | |
| Angle of repose-Rock-Degrees | 40.00 | Safety Factor | 1.16 |
| Unit Weight-Rock-Pcf | 160.00 | | |