MALCOLM PIRNIE

Technical Basis Document on Classifying Areas, Release Criteria And Final Status Surveys

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1.0 Introduction

Molycorp, Inc. (Molycorp) is designing an integrated closure plan for its Washington, Pennsylvania manufacturing facility, which operated between 1916 and early 2002. This integrated plan will address the spectrum of environmental issues existing at the site, both radiological and non-radiological.

Molycorp's goal is to restore the site to a condition where it can be used in the future for purposes consistent with current zoning and physical constraints. To achieve this goal, the site will be remediated in accordance with the approved Decommissioning Plan so that an unrestricted radiological release can be achieved and Source Materials License SMB-1393 can be terminated. In addition, non-radiological issues will be addressed under Pennsylvania's Land Recycling and Environmental Remediation Standards Act (Act 2) so that this brownfield site can be returned to beneficial use.

Manufacturing operations at this facility produced byproduct slags, some of which contained low level naturally occurring radiological materials, and some of which did not. Slags of both kinds were used as fill materials on portions of the plant and are commingled in some of the manufacturing areas of the plant. Therefore, in these areas, remedial activities must address both the Decommissioning Plan and Act 2 requirements.

Although detailed design of the remediation is not yet complete, it is known that radiological remediation will require large excavations and shipment of above criteria soil/slag to an offsite disposal facility. When radiological remediation excavations are complete, areas will be graded, and clean backfill and topsoil will be imported and placed to restore the pre-excavation grade. As a consequence, the entire former manufacturing area will be covered with a minimum thickness of two feet of clean fill/topsoil. This surface layer will be needed for two purposes: 1) to restore the site to original grade and 2) to meet Pennsylvania Act 2 brownfield release requirements.

Industrial activities took place in other portions of the property prior to Molycorp's ownership. The southeastern portion of the site received tar-containing residuals believed to have been generated by a manufactured gas plant located on property to the east of the site. These tar related issues are being addressed under Pennsylvania Act 2 requirements and are not discussed further in this document, which focuses on remediation in radiologically impacted portions of the property.

The purpose of this document is to address several important issues critical to design and execution of remedial activities in the radiologically impacted areas of the site: classification of areas, release criteria and final status survey approach. Subsequent sections describe the site background, classification of areas, derivation and application of AAR subsurface soil averaging guidelines, and the final status survey.

2.0 Site Background

2.1 Site Location and Description

Molycorp's Washington Facility is located in Canton Township, Washington County, Pennsylvania, approximately 35 miles southwest of Pittsburgh, Pennsylvania. The site consists of approximately 73 acres ranging from woodlands to industrial areas. Molycorp actively utilized approximately 20 acres for manufacturing operations. The main processing areas were bounded to the north by a fence line with Findlay Refractories Company and to the south by Caldwell Avenue. Employee vehicle parking, equipment and miscellaneous storage were located south of Caldwell Avenue. The eastern boundary is the former CSX and Baltimore and Ohio (B&O) railway line adjacent to Green Street. Chartiers Creek serves as the western boundary of the former manufacturing areas. Interstate 70 (I-70) runs along the southeastern area of the site.

The Molycorp site was divided into ten study areas for purposes of design and conduct of a Supplemental Site Investigation carried out by Malcolm Pirnie in 2003–2004 (Malcolm Pirnie, 2004). Figure 2-1, an aerial photograph of the site taken in 2003 after completion of building demolition, depicts the ten areas. Much of the site is relatively flat and located within the floodplain of the northward-flowing Chartiers Creek. This lowland area is where most of the site investigations and remedial activities have occurred.

The southwestern section of the site consists of a steep hillside with elevations ranging from 1020 feet above mean sea level (MSL) up to 1125 feet above MSL.

Wetlands are found in small areas in both the lowland and hillside areas of the site, with the largest wetland comprising 1.1 acres.

2.2 Site History

The main plant area was purchased by The Railway Spring and Manufacturing Company in 1902. This parcel was owned by the Railway Spring and Manufacturing Company (later known as the Railway Spring Company or the Car Springs Company) until it was sold to the Electric Reduction Company in 1920. The Molybdenum Corporation of America (in 1974 the name was changed to Molycorp, Incorporated) was formed from the Electric Reduction Company. Manufacturing operations by the Electric Reduction Company (and successors) originally were conducted in buildings constructed prior to the 1920 purchase of the site. The original building configuration is depicted in Figure 2-2. These buildings survived until the late 1970's.

Over time, the plant expanded westward as low lying areas were filled with byproduct slags and new buildings were constructed. Construction activities to support facility upgrading were performed over the years as needed. A total of 42 buildings were constructed on the facility property; however, not all of the buildings were present at the same time as obsolete buildings were replaced by newer buildings. Profiles of the buildings, including date of construction and major activities carried out, are provided in Appendix A of the Supplemental Site Characterization Report (Malcolm Pirnie, 2004). The final plant configuration circa 1995 also is depicted in Figure 2-2. Plant operations ceased in early 2002, and all of the main plant site buildings were demolished later that year, with only the guard house and truck scales remaining in place.

Additional properties were acquired by Molycorp from time to time throughout the lifetime of the operating facility in anticipation of future expansion. Properties acquired after 1973 were not impacted by licensed materials.

To better understand this complex site and to facilitate characterization and ultimately remediation activities, the site has been divided into ten main areas of interest:

Area 1	Process Plant Area (Subdivided into 1A and1B)
Area 2	North Slag Area
Area 3	South Slag Area
Area 4	Tylerdale Connecting Railroad
Area 5	MGP Tar Pond Area (Subdivided into 5A-5E)
Area 6	Streams
Area 7	Hill Area (Subdivided into 7A and 7B)
Area 8	Cox Plus
Area 9	Green Street
Area 10	Offsite Areas (subdivided into 10A and 10B)

As described in the Supplemental Site Characterization Report, only Areas 1B, 2 and 3, and a portion of 10A have been impacted by licensed materials.

Area 1A Description: The original manufacturing buildings were located in the eastern area and remained intact until approximately 1979. At that time, they were demolished, and new structures were constructed atop the same locations. These original buildings predate Molycorp (and predecessors) and existed throughout the time period when radioactive slags were produced at the facility. Little or no fill was placed in Area 1A. Previous investigations have discovered no radiological contamination in this area.

Area 1B Description: Historical information does not support the absence of contamination in Area 1B. Previous investigations detected radiological contamination in this section of the process plant.

Area 2 Description: This area, west of the original process plant area (Areas 1A and 1B), was a lowland containing ponds of various configurations throughout much of the operating history of the facility. Over the years, this area was filled with various slag byproducts of the manufacturing operations. As the plant expanded westward, buildings were erected above the fill in this area. Eight surface impoundments were constructed along the western boundary near Chartiers Creek in 1968. These impoundments were closed in 1995 and backfilled with clean soils.

Given the historical development of this portion of the plant, radiological contamination would be expected in this area. This has been confirmed by previous radiological surveys, including the extensive characterization study carried out by Foster Wheeler in 1994 (Foster Wheeler Environmental Corporation, 1995) and the Supplemental Site Characterization Study carried out by Malcolm Pirnie in 2003–2004 (Malcolm Pirnie, 2004).

Area 3 Description: This area south of Caldwell Avenue was the site of a former pile containing thoriated slag. The pile was located in the western part of the area adjacent to Chartiers Creek. To the east of the former pile location is the site of a former pond that received ball milled slag in the form of a slurry. Thus, the area has been affected by licensed materials as confirmed by radiological surveys.

Area 10A Description: Area located just adjacent to the northeast corner of Area 3 where a temporary rail spur was located in the 1979-1981 time period to allow receipt of raw materials during demolition and reconstruction activities in the main plant area. A portion of this area was found to be impacted by licensed material.

2.2.1 Manufacturing Operations (Areas 1, 2 and 3)

Molycorp manufactured several product types at the site over its operating history, including:

- Molybdenum trioxide powder
- Ferromolybdenum metal

- Ferrotungsten metal
- Ferrocolumbium metal
- Calcium boride
- Other rare earth and transition elements

The majority of the products generated consisted of molybdenum trioxide powder, ferromolybdenum metal, and ferrotungsten metal, with smaller quantities of the remaining products. Primary processes that were used to manufacture these products included roasters for converting molybdenum disulfide concentrates to molybdenum trioxide powder and electric arc furnaces to produce ferromolybdenum, ferrotungsten and ferrocolumbium. Supplemental processes were used to enhance product recovery and/or to control offgases/reduce waste. Eight former Resource Conservation and Recovery Act (RCRA) impoundments along the west side of the property were utilized for these supplemental processes.

Ferrotungsten was produced at the site from the 1920's into the 1970's. During this time several mines provided concentrates as feed material. Although the exact quantities in the various feed concentrates are unknown, it is expected that some byproduct slags resulting from ferrotungsten production contained uranium.

In 1963, the Molybdenum Corporation of America obtained a Source Materials License from the Atomic Energy Commission (AEC - later the Nuclear Regulatory Commission) because of the processing of concentrates that contained 0.05 percent (or higher) of uranium and/or thorium. Between 1964 and 1970, Molycorp produced ferrocolumbium alloy from concentrate produced from ore mined in Araxa, Brazil. Slag from the production of the ferrocolumbium alloy was in the form of refractory glass/ceramic slag containing thorium.

Waste slags from the ferroalloy operations were utilized on site to fill in low-lying areas and as a subbase in some building construction. Although the largest quantity of fill consisted of non-radioactive ferromolybdenum slags, thoriated slags associated with ferrocolumbium production and ferrotungsten slags possibly containing uranium also were deposited on the property.

2.3 Regulatory Highlights (Licensed Materials)

In 1963, the Molybdenum Corporation of America obtained a Source Materials License from the AEC because of the processing of ores that contained 0.05 percent (or higher) of uranium and/or thorium. Between 1964 and 1970, Molycorp produced ferrocolumbium alloy from concentrates derived from ore mined in Araxa, Brazil that was delivered to the Washington Facility. Slag from the production of the ferrocoloumbium alloy was in the form of a refractory glass/ceramic containing thorium.

In 1966, Molycorp initiated discussions with the Pennsylvania Department of Health and the AEC in pursuit of an on-site burial permit. A formal application was submitted in 1967. About this time period, Applied Health Physics, Inc. conducted a series of leaching studies on the ferrocolumbium slags. These studies indicated that the radioactive materials were fixed and would not leach into the groundwater in excess of prescribed limits. No action was taken by the state or the AEC on the request for an on-site burial permit.

In June of 1971, an AEC compliance inspection revealed that thorium-bearing slags had been buried on-site. It was speculated that the burial occurred during a large scale clean-out of settling basins and regrading of the plant site by a private contractor who was unaware of restrictions on landfilling ferrocolumbium slags. Subsequently, AEC issued a Notice of Violation and requested Molycorp to excavate these materials and dispose of them in accordance with AEC regulations.

In 1972, Molycorp excavated soil containing relatively high concentrations of thorium-bearing slag, and shipped approximately 14 truckloads of this soil/slag material to a disposal facility in New York State. However, that facility later refused to accept any additional material because it was, in the facility manager's words, "of insignificant contamination and too large a volume" to bury at a site with limited disposal space. As a consequence, in 1973, the remaining thoriated slag material that was to be shipped offsite was instead consolidated into a single storage pile south of Caldwell Avenue and covered with a foot-thick layer of clean fill and vegetation.

A Nuclear Regulatory Commission (NRC) contractor, Oak Ridge Associated Universities (ORAU), conducted a radiological survey of the site in 1985, which identified elevated levels of thorium in the dikes which separated the RCRA surface impoundments and indicated the potential of subsurface thoriated slags in the western portion of the site. Subsequently, the Washington Facility was listed in NRC's 1990 Site Decommissioning Management Plan (SDMP) list.

In 1990, Radiation Surveillance Associates, Inc. (RSA, Inc.) conducted a sub-surface survey for Molycorp, Inc. to characterize the thorium contamination across the western portion of the site (i.e., the impoundment area). Thirty-two holes were drilled on the site, and radiation measurements were logged at every six inches of depth from the surface down to bedrock, both above and below the water table. Radiation levels were also logged in monitoring wells previously drilled on the site. In addition to the subsurface measurements, RSA, Inc. conducted a scintillometer survey of the radiation exposure rates inside the study area. The surface study consisted of approximately 400 measurements of the gamma radiation field at a height of one meter above ground level. Findings revealed that, in general, the subsurface concentrations of thorium were above those in the surface soils in almost every hole drilled.

Molycorp renewed its NRC license for the Washington County facility in 1992. Because the facility had appeared on the 1990 SDMP list, this license renewal included an amendment incorporating a schedule for characterizing and decommissioning the site. Since that time, a number of decommissioning reports and plans have been submitted to the NRC including:

- Plan for Site Characterization in Support of Decommissioning of the Molycorp, Inc., Washington, PA Facility (RSA, Inc. and Vail Engineering, Inc., 1993)
- Site Characterization Report for License Termination of the Washington, PA Facility (Foster Wheeler Environmental Corporation, 1995)
- Decommissioning Plan for the Washington, PA Facility (Foster Wheeler Environmental Corporation, 1995)
- Washington Facility Environmental Report (ICF Kaiser, Inc., 1997)
- Washington, PA Facility Decommissioning Plan, Part 1 Revision (Radiological Services, Inc., 1999)
- Washington, PA Facility Decommissioning Plan, Part 2 Revision (Radiological Services, Inc., 2000)
- Supplemental Site Characterization Plan for the Washington, Pennsylvania Site (Malcolm Pirnie, 2003)
- Supplemental Site Characterization Report for the Washington, Pennsylvania Site (Malcolm Pirnie, 2004)

The 1993 Site Characterization Plan (RSA, Inc. and Vail Engineering, Inc., 1993) explained how Molycorp would test and analyze the property to determine the presence and location of the thorium-bearing slag. As called for in the Site Characterization Plan, Molycorp drilled over 400 core borings and generated more than 12,000 soil measurements. Furthermore, Molycorp installed 19 groundwater wells and took 64 groundwater samples. Through this process, Molycorp created a three-dimensional picture of areas with elevated radiation levels. The findings of that study were reported in the 1995 Site Characterization Report (Foster Wheeler Environmental Corporation, 1995).

Based on the findings of the Site Characterization Report, Molycorp prepared an initial Decommissioning Plan that was submitted to the NRC in late 1995 (Foster Wheeler Environmental Corporation, 1995). This plan proposed removing any material that had a level of thorium above 30 pCi/g. The plan did not address contamination below structures.

In 1996, Molycorp excavated approximately 4,000 cubic yards of material that was located along and beyond its northern property boundary. This thorium-bearing slag and soil were stored in covered roll-off containers on Molycorp's property. In 2000, the thoriated slag in the roll-off containers as well as the slag pile south of Caldwell Avenue were transported offsite and disposed at the Envirocare facility in Utah.

In 1999, the NRC advised Molycorp of the results of its review of the 1995 decommissioning plan. As a result of the NRC's review, in June of 1999, Molycorp submitted to the NRC the Part I Revision to the Decommissioning Plan, which changed the thorium remediation goal. The plan also described how Molycorp would excavate the thorium-bearing slag in various areas of the property.

In July of 2000, Molycorp submitted the Part 2 Revision to the Decommissioning Plan that addressed a proposal to construct an onsite disposal cell for material that exceeded SDMP Action Criteria (10 pCi/g). The Decommissioning Plan Part 2 Revision was never approved. Molycorp has since abandoned its plans to construct the onsite cell and now intends to close the site in a manner that results in unrestricted release with respect to radiological issues.

NRC has issued a series of amendments to Molycorp's Materials License (No. SMB-1393). The most recent amendment is No. 6, which was issued on May 1, 2002. The amendment specifies conditions that must be met as part of decommissioning the site.

In September 2003, Molycorp undertook a Supplemental Site Characterization to address both radiological and non-radiological issues at the site. Radiological characterization included a 100% coverage walkover survey for detection of gross gamma radiation in areas that were used by Molycorp for manufacturing operations and other selected areas of the site. More than 108,000 gamma measurements were collected. A total of 235 soil borings were completed utilizing split spoon sampling techniques. More than 1,600 2-foot core segments from soil borings were scanned for radioactivity with a 2-inch-by-2-inch NaI scintillation detector. In addition, more than 200 soil samples were analyzed by gamma spectroscopy, and 25 soil samples were analyzed by alpha spectroscopy for Th and U. Areas of uranium contamination which were not addressed in previous investigations were defined in the Supplemental Site Characterization.

2.4 Remedial Actions

Five principal remedial actions have occurred in the affected areas of the site:

- Excavation of Buried Thorium-bearing Slag
- Impoundments Closure
- Northern Property Boundary Remediation
- Slag Pile Removal
- Building Demolition

Each of these remedial actions is described in the 2004 Supplemental Site Characterization Report (Malcolm Pirnie, 2004).

3.0 Classification of Areas

3.1 Basis

Post-remediation radiological surveys (final status surveys) will be conducted to demonstrate that release goals have been met. Classification is a critical step in design of those surveys, because it determines the level of survey coverage necessary to achieve an acceptable level of confidence that the site satisfies the established release criteria based upon the potential for residual contamination.

The Washington, PA Facility Decommissioning Plan, Part 1, Revision 1 (Radiological Services, Inc., 1999) contemplates dividing the Molycorp site into Affected and Unaffected areas in accordance with guidance provided in Manual for Conducting Radiological Surveys in Support of License Termination, NUREG/CR-5849. These classifications are defined in the approved Decommissioning Plan as follows:

Affected Areas: Areas that have potential radioactive contamination (based on plant operating history) or known radioactive contamination (based on actual radiological surveys).

Unaffected Areas: All areas not classified as Affected Areas. These areas are not expected to contain residual radioactivity based upon survey information. These are areas where characterization and decontamination surveys detected no residual activity in excess of guideline values.

The large body of available survey data and historical information have been carefully analyzed and evaluated to develop the area classification boundaries delineated herein. The evaluation process as well as the area classifications is described below.

3.2 Classification Process

Based upon historical knowledge alone, the northwestern (Areas 1B and 2) and southern (Areas 3 and 10A) portions of the former manufacturing areas would be classified as affected. Because the original manufacturing buildings predated Molycorp's presence on the site and remained intact throughout the time period when radioactive slags were produced, and no fill is believed to have been placed in this northeastern portion of the site, Area 1A would be classified as unaffected.

Historical classification conclusions have been reinforced and refined by several radiological surveys conducted between 1985 and 2004. Based upon the body of knowledge available at that time, in an April 3, 2000 letter to NRC, Molycorp classified areas in the eastern portion of the site as unaffected and other portions of the site as affected. This letter is referenced in License Condition 13 of Amendment No. 6 of Molycorp's Materials License SMB-1393. Open land areas classified as unaffected were areas east of buildings 25, 22 and 1. In addition, land under buildings 2, 2W, 13, 14, acid plant and storage tanks, and rail siding in this eastern area also were classified as unaffected. This unaffected eastern area, shown in Figure 3-1, roughly corresponds to Area 1A. Land beneath certain buildings to the west also was classified as unaffected: land beneath buildings 19, 21, 22, 23, 25, 26, 29, 31, 37 and possibly building 1.

Subsequent to the classification detailed in the April 3, 2000 letter, Molycorp demolished and removed the existing buildings, except for the guard station. Molycorp then engaged the services of Malcolm Pirnie to conduct a supplemental site characterization to better define the nature (Th, U, Ra) and limits of radiological contamination.

This investigation included installation of some 235 soil borings across the site utilizing split spoon sampling techniques in conjunction with hollow-stem auger drilling. Split spoon sampling consisted of progressively extracting a series of 2-inch diameter by 24-inch length soil core samples at each location until refusal (up to 26 feet). Each core segment was scanned with a 2 inch x 2 inch NaI scintillator detector, Ludlum Model 44-

10, linked to a Ludlum Model 221 scaler to develop a gamma radiation profile of each boring. More than 1600 core segments were scanned. More than 200 of the core segments were analyzed by high resolution gamma spectroscopy in a commercial laboratory and 24 soil samples were analyzed by alpha spectroscopy. The laboratory results subsequently were correlated with core scanning results. Locations of borings installed by Malcolm Pirnie are shown in Figure 3-2.

In addition to the borings, near surface gamma radiation levels were measured using a 2 x 2 inch NAI detector liked to a Trimble Pro XRS Global Positioning System (GPS). Radiation detection measurements were collected continuously and data recorded approximately every 4 to 5 seconds. The Trimble Pro XRS was integrated with a Ludlum 2221 ratemeter with a 44-10 detector. More than 108,000 discrete measurements were recorded.

Results of Malcolm Pirnie's radiological surveys (surface and subsurface) carried out during that investigation are fully described in the Supplemental Site Characterization Report (Malcolm Pirnie, 2004). Survey information obtained in this supplemental investigation then was utilized to refine the previously defined boundaries of affected and unaffected areas via several steps.

Subsurface radiological characterization consisted of a combination of core scans of each 2-foot segment of each boring and radiological laboratory gamma and alpha spectroscopy determinations on selected core segments. Subsequently, laboratory data were correlated with core scan data.

Based on the correlations developed between analytical data and core scan values in each Area (1, 2, 3 and 10A), a core scan value was determined which represented the sum of fractions (SOF)* at that depth increment†. The core scan values at each depth increment

* Sum of Fractions in this instance is defined as: $\frac{Th^{232}}{GL_{Th}^{232}} + \frac{U^{238}}{GL_{U}^{238}} + \frac{\text{excess } Ra^{226}}{GL_{Ra}^{226}}$

were then processed in ArcView 8.3 using Spatial Analyst to develop site-wide SOF contours.

Utilizing the SOF contours, zones of contamination were generalized by drawing bounds around the areas which had core scan values exceeding a SOF of unity at that depth. This bound delineated material that was greater than or less than release criteria at that depth, assuming all layers above were clean.

Actual core scan values from the site borings then were plotted with the bounds developed from the correlation and kriging. The bounds were adjusted based on the actual core scan values from borings at each depth increment. SOF values then were calculated based on the laboratory analytical data and plotted at the depth interval from which the material was sampled. As necessary, the bounds were further adjusted to account for gamma spectrometry data.

The adjusted bounds were overlaid for each depth interval to define the extent of contamination requiring excavation.

As a further refinement, contamination limits developed from this process were overlaid with down-hole gamma data collected by Foster-Wheeler during a previous investigation of the site. The Foster Wheeler gamma survey used a borehole gamma logging technique and gamma ray spectroscopy to identify thoriated materials in the subsurface soil and fill. The survey was conducted by drilling soil borings at selected locations on the site using a hollow stem auger. Soil samples were collected continuously throughout the soil column using split spoon sampling techniques to approximately 20 feet below grade.

Where GL=the AAR guideline value for the individual radionuclide series.

† AAR Soil Averaging guidelines are described in Section 4 of this document.

A total of 418 borings were completed by Foster Wheeler. In the borehole logging survey, a NaI scintillator was lowered into the completed boreholes and count rate measurements were taken at six-inch intervals to the bottom of the soil boring. Each count rate measurement was converted to a Th-232 concentration. Approximately 12,500 data points were obtained in this manner. A subset of the soil boring samples collected during drilling were analyzed by gamma ray spectroscopy. The gamma spectroscopy was conducted on six-inch intervals in the split spoon samples to measure thorium concentration. These samples were considered primarily as a quality assurance measurement for the borehole gamma logging technique. Foster Wheeler's boring locations are shown in Figure 3-2.

Foster Wheeler borings which were outside the defined contamination limits were identified, and the total thorium data obtained by the down-hole gamma method were reviewed to determine if any of the Foster-Wheeler data indicated that significant contamination was present outside of the defined limits. The boundaries then were readjusted to capture areas indicated by the Foster-Wheeler data as affected.

Results of this process are shown in Figure 3-2, which also shows all of the Foster Wheeler and Malcolm Pirnie sampling points used in this analysis. All of the extensive subsurface survey data outside of the shaded areas indicate these areas are unaffected by licensed material in excess of the AAR release criteria. Surface contamination indicated in the Malcolm Pirnie walkover survey data also is captured in the shaded areas.

3.3 Area Classification Boundaries

Based upon the evaluation process described above, three distinct types of areas have been delineated:

Affected Areas: Areas where contamination exists in excess of guideline values and which must be remediated.

Unaffected Areas: Areas not containing residual radioactivity above background levels based upon historical knowledge and radiological surveys.

Areas Affected Below Guidelines: Areas impacted by licensed materials but which extensive characterization data demonstrate to be within the AAR Guideline release criteria.

The boundaries of each area type are delineated in Figure 3-3. Molycorp believes that no additional radiological surveys are necessary in either Unaffected Areas or those Areas Affected Below Guidelines. The possible exception to this would be if an area otherwise compliant with decommissioning criteria inadvertently became contaminated during decommissioning activities. In that case, it would become subject to a final status survey.

4.0 AAR Method for Developing Site-Specific Soil Averaging Limits for the Washington Site

As stated in the Washington, PA Facility Decommissioning Plan, Part 1 Revision (Radiological Services, Inc., 1999) Molycorp plans to demonstrate compliance with subsurface unrestricted use limits by applying NRC guidance contained in the February 13, 1997 letter from John T. Buckley, NRC to Howard A. Pulsifer, AAR Corporation. A copy of this letter, often referred to as the AAR method, is attached in Appendix A.

In preparation for applying the AAR method to the Washington, PA Facility, Malcolm Pirnie developed Site-Specific Subsurface Soil Averaging Limits for the Washington site. These limits were derived using the methodology documented in "Method for Surveying and Averaging Concentrations of Radioactivity in Potentially Contaminated Subsurface Soil, Molycorp's York PA Site" (Mactec Development Corporation, 2003) which is an extension of the AAR method as applied to Molycorp's York, PA Facility. A copy of the Mactec document is attached in Appendix B.

In developing AAR site specific limits for the Washington, PA facility, all of the dose modeling parameters were identical to those used in the Mactec document with the exception of soil layer thickness. The Mactec derivation was based on 1-meter thick layers of soil and developed soil averaging limits for each 1-meter depth increment below the ground surface. For the Washington site, characterization samples were composited over 2-feet depth intervals and therefore the soil averaging limits were calculated based on 2-feet thick layers of soil.

Both the Washington and York soil averaging limits are based on a resident farmer scenario. The RESRAD output report files for the Washington site baseline case (contaminated area = 10,000 m^2, volume = 3000 m^3) for U-238, Th-232 and Ra-226 are presented in Appendix C. All RESRAD runs were completed using Version 6.22 (February 6, 2004).

Table 4-1 presents the tabular data set from the RESRAD modeling runs conducted for the Washington site. Table 4-1 is analogous to Appendix B in the Mactec report.

Based upon the comparative dose modeling performed in this assessment, a tabular set of subsurface soil concentration limits was calculated. Each of the calculated concentration limits for subsurface units of soil is derived from the approved surface soil concentration limits for residual radioactivity specified in the Washington, PA Facility Decommissioning Plan (Radiological Services, Inc., 1999) using the dose-response relationship as a function of volume excavated and brought to the surface where human exposure may occur. Site-Specific Subsurface Soil Averaging Limits for the Washington site for the uranium, thorium and radium isotope series are presented in Table 4-2.

The concentration limits described in Table 4-2 were derived independent of one another. That is, there is no presumption about whether the concentrations of uranium, thorium and radium apply independently or as components of a sum of fractions. If the approved concentration limits in the Decommissioning Plan are understood as components of a sum of fractions that must be demonstrated to be less than or equal to unity, then the same application applies to the subsurface averaging limits presented in Table 4-2. In keeping with the protocol established for the York site, a sum of fractions treatment is assumed to be appropriate.

4.1 Natural Background Radioactivity in Soil

AAR soil concentration limits presented in Table 4-2 are intended to be applied after subtraction of natural background radioactivity in soil. To determine appropriate background concentrations, thirteen soil samples were taken from uncontaminated portions of the site and analyzed for the naturally occurring radionuclides of interest (MPI, 2004). The results for Ra-226, U-238, and Th-232 were reported as 1.65 ± 0.20, 1.59 ± 0.65, and 1.50 ± 0.65 pCi/g, respectively. The stated errors are one standard deviation. Another analysis of background concentrations was done (Morton, 2004)[‡] using a subset of 81 slag and soil samples from the supplemental characterization samples. The subset of samples was selected using cumulative probability plots and other statistical arguments. This work concluded that the mean Ra-226, U-238, and Th-232 background concentrations were 1.78, 1.84, and 1.65 pCi/g, respectively. These two assessments of background are in very good agreement. In addition, since the latter assessment used a mixture of slag and soil samples, it indicates that the background concentrations in the slag and in the local soils are similar in magnitude. Molycorp proposes to use the results as reported in the Supplemental Site Characterization Report (Malcolm Pirnie, 2004) as naturally occurring background concentrations.

‡ Morton, 2004. Natural Background Radioactivity in Soil on Molycorp Washington Pennsylvania Site. Unpublished report. November 10, 2004. Morton Associates, Potomac, MD 20854.

4.2 Application of Derived AAR Subsurface Soil Concentration Limits

Averaging criteria apply to any contiguous volume defined by the given number of 5 m grid samples. For averaging over a 100 m^2 area, each combination of the four "nearest neighbor" samples in a given 2 feet layer should be evaluated. This means that each 5m x 5m grid (except those on the boundary of a survey unit) would be evaluated as a part of four different 100 m^2 areas.

In addition to the areal averaging, vertical averaging criteria are also defined. These averaging criteria are intended to identify significant volumes of residual radioactivity in contiguous volumes in the vertical, as opposed to the horizontal (lateral) direction. Again, the sampling upon which the vertical averaging criteria is derived assumes a 5 meter grid size with one sample collected from each 25m^2 area and 2 feet depth increment. A vertical (columnar) average will be calculated for each contiguous combination of samples in a single vertical column starting with the ground surface.

For subsurface soil in the 0 to 2 feet depth increment below ground surface, there are two AAR Soil Averaging Limits from Table 4-2 that apply:

- Average of four "nearest neighbor" samples (61 m^3), and
- Individual sample (15 m^3).

For subsurface soil in the 4 to 6 feet depth increment below ground surface, the AAR Soil Averaging Limits from Table 4-2 associated with the 0 to 2 feet depth increment and 2 to 4 feet depth increment apply in addition to four other criteria from Table 4-2:

- Average of four "nearest neighbor" samples (61 m^3) in the 4 to 6 feet depth increment,
- Average of the twelve samples in a 10-m x 10-m area in the 0 to 6 feet depth increment (183 m^3),

- Individual sample (15 m^3), and

- Average of the three samples from the 0 to 6 feet depth increment (46 m^3) in each of four vertical columns.

4.3 Case Study – Applying AAR Subsurface Soil Concentration Limits to the Washington Site

Figure 4-1 illustrates the 3-step process for applying the AAR Limits in Table 4-2 to a hypothetical 10-m x 10-m excavation cell. Table 4-3 presents initial net subsurface concentrations for the example. For this example, soil concentrations are assumed to be homogeneous within individual 2-feet layers of the excavation cell.

Initial conditions are shown as Step 1 in Figure 4-1. SOF estimates for Layer A (0 – 2 feet) and Layer B (2 – 4 feet) indicate that both layers contain acceptable levels of residual radioactivity based upon the criteria associated with four samples from the subject layer. Based on prior characterization activities, it is known that unacceptable levels of radioactivity are present at depth in this excavation cell. Therefore, Layers A and B must be excavated to gain access to the deeper layers C and D.

Step 2 illustrates the excavation in progress. Table 4-4 presents isotope concentrations and SOF estimates associated with the excavation. Each is characterized, evaluated as a SOF using appropriate AAR Limits from Table 4-2 and stockpiled. Layers with SOF < 1 are stockpiled for later use as backfill. Layers with SOF > 1 are stockpiled separately for offsite disposal. Layers that are combined in a stockpile are assumed to mix completely. The excavation terminates at 8-feet because the SOF for Layer E is estimated to be less than one and prior characterization activities demonstrated that subsurface concentrations decreased at depths greater than 10-feet in the area of this excavation cell.

Before the stockpiled Layers A and B are returned to the excavation, two sets (Tables 4-4 and 4-5) of SOF calculations are made. Table 4-4 presents isotope concentrations, AAR Averaging Limits and SOF estimates associated with the excavation. Table 4-5 characterizes the post backfill conditions.

Step 3 of Figure 4-1 illustrates the excavation cell after backfilling. Table 4-5 shows that all appropriate SOF estimates (i.e., individual layer and surface to individual layer) are less than one.

5.0 Final Status Survey

Post-remediation radiological surveys (final status surveys) will be conducted to support closure of the site. As previously discussed, the remedial design will specify that subsequent to excavation and removal of above criteria soil, the entire area will be graded and a cover of uncontaminated soil will be imported and placed over all slag areas. Therefore, for final status survey purposes, the surface layer will be considered uncontaminated and the cleanup criteria of importance will be the subsurface criteria, which vary as a function of depth. These criteria will be applied to the subsurface soils within each survey unit.

Release protocols are based on the AAR method for site specific soil averaging limits. The original AAR method considered average concentrations in a soil layer of 25 m^2 area and a depth of 1 m (volume of 25 m^3). A 5-meter grid is established over the area to be released and soil samples taken within each layer. This concept has been applied to this site with the exception that the depth of each layer has been conservatively chosen as 2-feet.

All affected areas requiring remediation (shown in Figure 3-3) will be excavated to achieve the AAR release criteria. Excavated soils will be segregated into waste and non-waste piles. The non-waste piles will be made up of material where the average concentration does not exceed the concentration limits for the subject layer. This non-waste material will be used as backfill. Additional uncontaminated imported material will be applied as a final cover after excavation is complete, as described in the AAR discussion in Section 4.

As excavation proceeds, periodically a gamma scan of the entire excavated surface will be conducted and an evaluation made as to whether the survey unit meets the release criteria prior to performing the final status soil sampling. The gamma scan data will be converted to an approximate Th-232 concentration using correlations developed during excavations.

Once data suggest that the area meets release criteria, 24-inch deep soil samples will be taken from the excavation surface on a 5-m grid spacing. These samples will be analyzed and the results will be evaluated against the AAR criteria. Residual concentrations of constituents in the backfill (non-waste piles) will be considered in the evaluation. Non-waste piles will be characterized prior to evaluation using the sampling strategy given in 5.3 below.

The steps for conducting the final status survey are discussed below. All major activities will be performed using Standard Operating Procedures.

5.1 Site Coordinate System

The data will be managed using ArcView GIS, a geographical information system. The coordinate system used for the site will be UTM zone 17. The site will be divided into 100-m by 100-m grid blocks. These "major grid blocks" will be subdivided into one hundred equal grid blocks of 10-m by 10-m dimensions. These 10-m by 10-m grid blocks then will be further divided into 5-m by 5-m grid blocks. Each of these smaller grid blocks corresponds to an area equal to 25 m^2, the basis of the cleanup standard.

The grid block nomenclature is best understood by looking at Figure 5-1. In the figure, the 100-m by 100-m major grid block F5 is subdivided into 100 smaller 10-m by 10-m grid blocks. One of these smaller grid blocks, g04, is further subdivided into 4 smaller grid blocks, each being 5-m by 5-m and lettered from A to D. The name of the example 5-m by 5-m grid block is F5g04D. For ease in sample management, soil samples taken from each grid block will be identified using the corresponding 5-m by 5-m grid block number as the sample number.

5.2 Soil Sampling

A 5-m by 5-m grid will be established over the excavated area to be sampled using the coordinate system discussed in 5.1. In order to be unbiased, the points will follow the natural divisions of the coordinate system (i.e. fall on UTM East and West coordinates that are divisible by 5). Areas greater than 25 percent of a grid block will be considered a grid block. Areas less than 25 percent of a grid block will be ignored providing that the gamma scan data indicate that the area contains no unusually high gamma count rates for that depth interval.

A soil sample will be taken from the bottom of the excavation to a depth of 24 inches at each grid node using a geoprobe or alternative sampling device. The sample will be labeled the same as the coordinate using a V1 suffix. Should further remediation be required at that grid node, and the area sampled a second time, the second sample will have a V2 suffix, etc. Sampling equipment will be washed thoroughly with water after each sample. A sample record will be maintained. These requirements will be included in the Standard Operating Procedure for Soil Sampling.

5.3 Non-Waste Pile

Overburden and other slag soil that does not require off-site disposal will be removed and placed in stockpiles for use as backfill. The material is expected to slightly exceed natural background concentrations but will be below the AAR release criteria. The spatial variability of radionuclide concentrations in the pile will be small since there will be considerable mixing due to handling.

A minimum of 20 samples will be taken from the loader bucket during excavation as a stockpile is built. These samples will be analyzed to estimate the average concentration for each pile. The samples will be taken at approximately the same intervals so that each sample represents approximately the same volume of material. Alternatively, 20 representative samples will be obtained from a completed stockpile to characterize the material.

Upon completion of the final status survey of the excavation as described in 5.2, material from the characterized backfill pile will be returned to the excavation in a manner that will achieve the AAR criteria set forth in Section 4.0. This determination will be made via calculations based upon the known concentrations in the backfill and the excavation.

5.4 Sample Analysis

An on-site laboratory will be established to support the excavation control function and final status survey. A Multichannel Analyzer(s) (MCA) employing an HPGe detector will be used to analyze for Th-232, Ra-226, and U-238. Samples will be mixed and dried prior to analyses. A slag/soil matrix NIST traceable standard or alternative method will be used to calibrate the spectrometer. Archived samples from characterization work will be analyzed and used as a secondary method for detector calibration. The detectors will have an upward looking cryostat so that 1-liter Marinelli beakers can be used. The detectors will be shielded with lead to reduce the minimum detectable concentration. Standard Operating Procedures will be used.

Samples used for developing correlations will be analyzed on site without splits sent to a vendor laboratory. Final Status Survey samples and samples used for backfill characterization will be analyzed on site, and every 10^{th} sample will be sent to a vendor laboratory for analysis for QC purposes.

5.5 Surface Surveys

Following site restoration (backfilling excavations and placement of a layer of imported fill and topsoil), an exposure rate survey will be performed to assure that an average exposure rate of 10 µR/hr above background at 1 meter from the ground surface is achieved and that no discrete location exceeds 20 µR/hr above background at 1 meter.

In addition, surface surveys consistent with criteria set forth in the Decommissioning Plan will be performed in any affected area not covered with imported fill/topsoil. Any unaffected area or area affected below guidelines which inadvertently became contaminated (as defined by scoping surveys) during decommissioning activities and not covered with clean fill also would be subject to remedial action and subsequently a surface final status survey.

6.0 References

Plan for Site Characterization in Support of Decommissioning of the Molycorp, Inc., Washington, PA Facility (RSA, Inc. and Vail Engineering, Inc., 1993)

Site Characterization Report for License Termination of the Washington, PA Facility (Foster Wheeler Environmental Corporation, 1995)

Decommissioning Plan for the Washington, PA Facility (Foster Wheeler Environmental Corporation, 1995)

Washington Facility Environmental Report (ICF Kaiser, Inc., 1997)

Molycorp's Materials License SMB-1393, Amendment No. 6, License Condition 13

Washington, PA Facility Decommissioning Plan, Part 1 Revision (Radiological Services, Inc., 1999)

Washington, PA Facility Decommissioning Plan, Part 2 Revision (Radiological Services, Inc., 2000)

Method for Surveying and Averaging Concentrations of Radioactivity in Potentially Contaminated Subsurface Soil, Molycorp's York PA Site (Mactec Development Corporation, 2003)

Supplemental Site Characterization Plan for the Washington, Pennsylvania Site (Malcolm Pirnie, 2003)

Supplemental Site Characterization Report for the Washington, Pennsylvania Site (Malcolm Pirnie, 2004)

Appendix A of the Supplemental Site Characterization Report (Malcolm Pirnie, 2004)

Final Status Survey Report for Installation Restoration Program Site OT-10, Kirtland Air Force Base, prepared by MWH Americas for HQAFCEE/ERD, Brooks City Base, Texas, 78253 (MWH, 2005)

Manual for Conducting Radiological Surveys in Support of License Termination, NUREG/CR-5849

NUREG–1575, Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)

NUREG-1507, Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions (NRC, 1997)

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FIGURES

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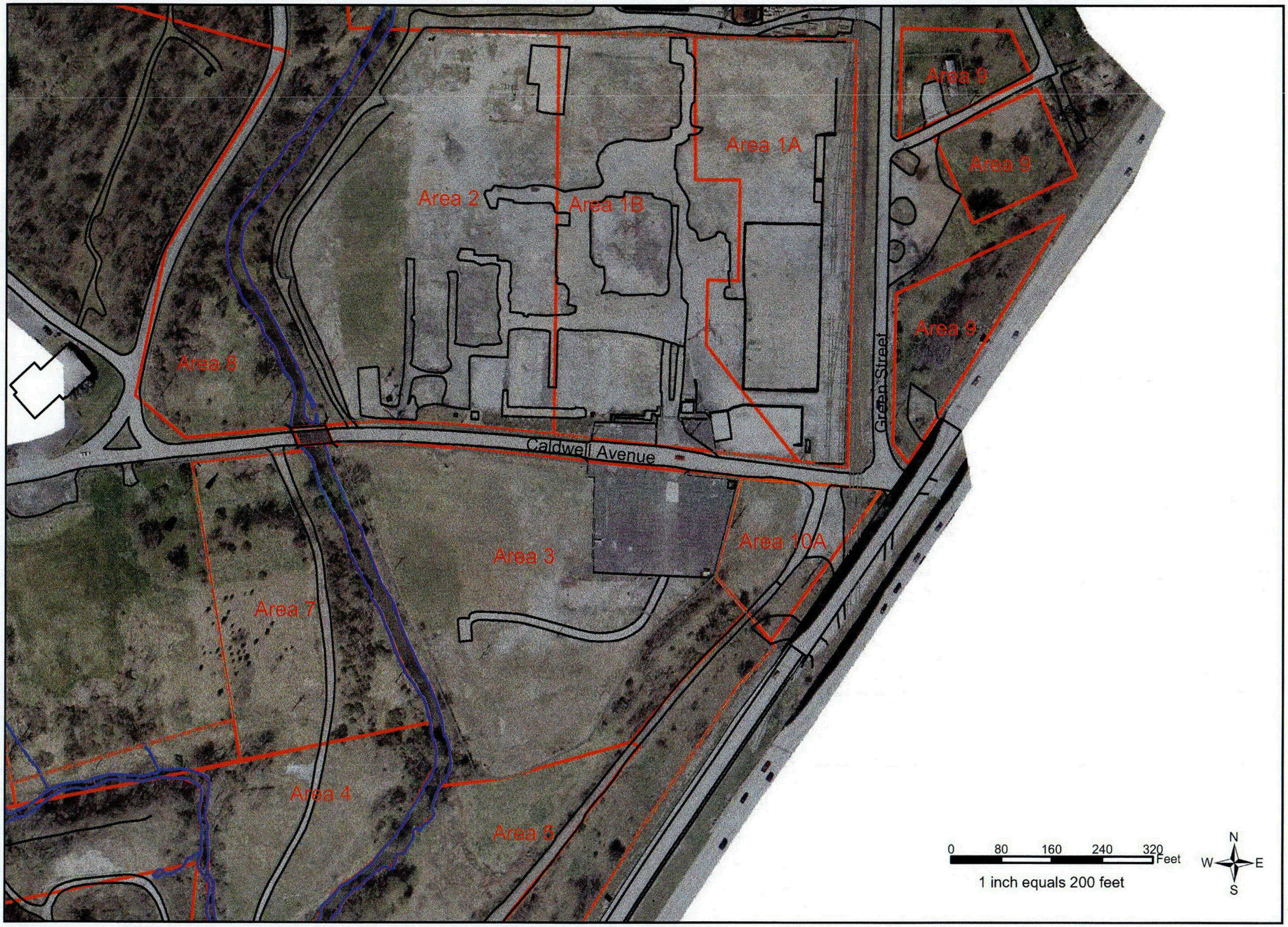
FIG



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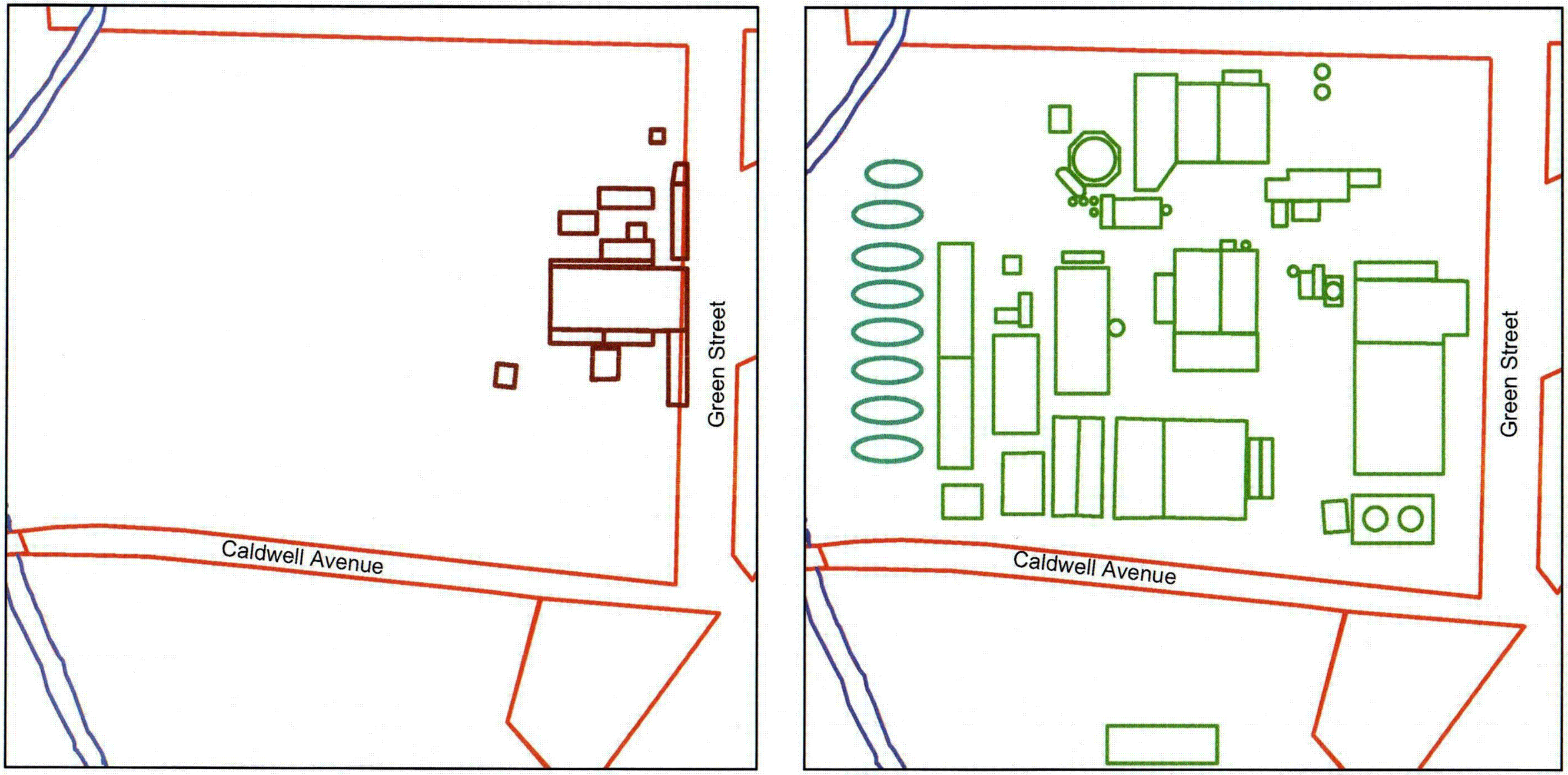
Molycorp, Washington Pennsylvania Site

January 2005

Figure 2-1
Aerial Photo
with Area Designations

C01



Original Building Configuration
At Purchase (1916)

Final Building Configuration
Prior to Demolition (2002)

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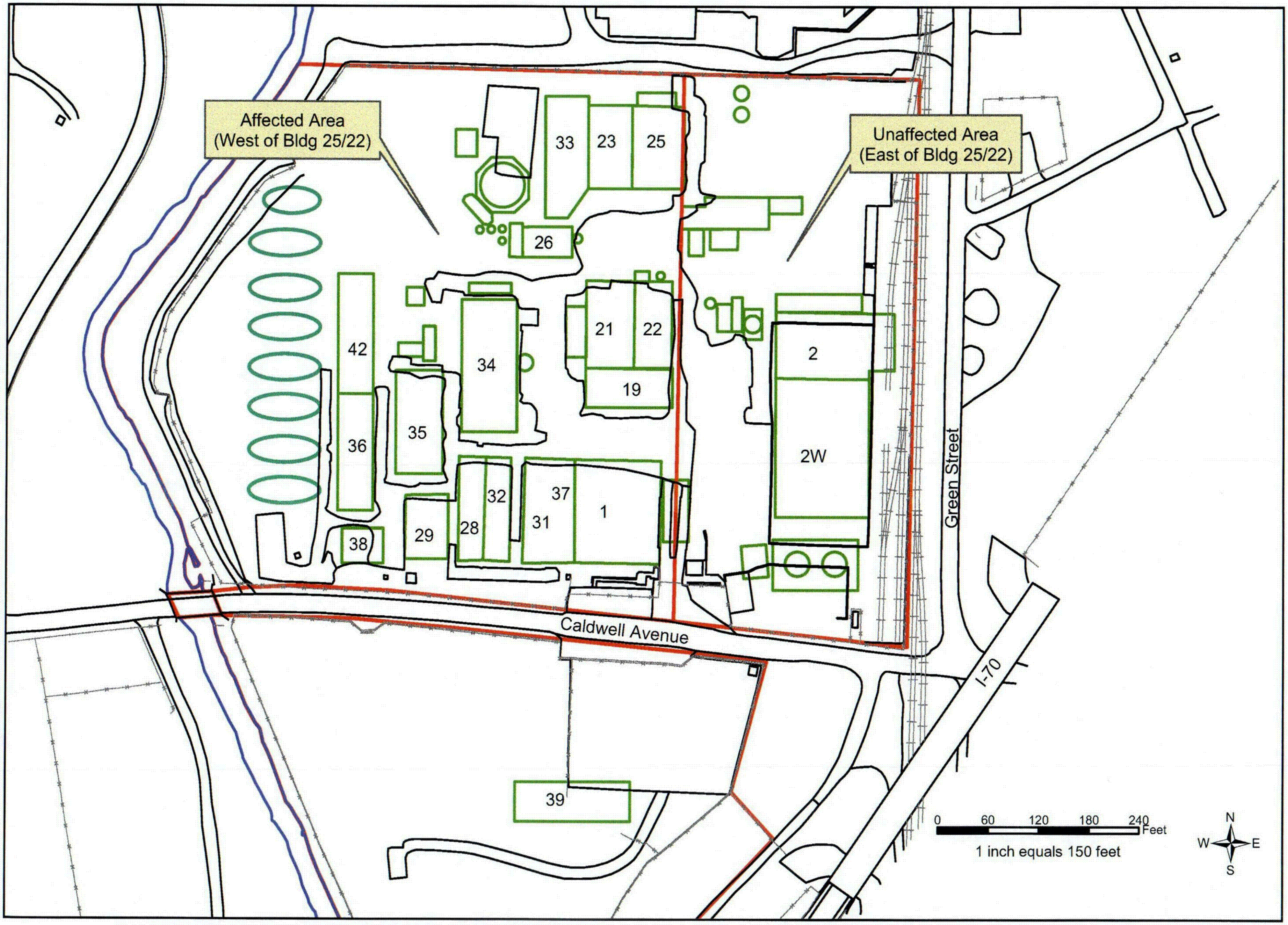
Molycorp, Washington Pennsylvania Site

January 2005

Figure 2-2
Building Configurations

C02



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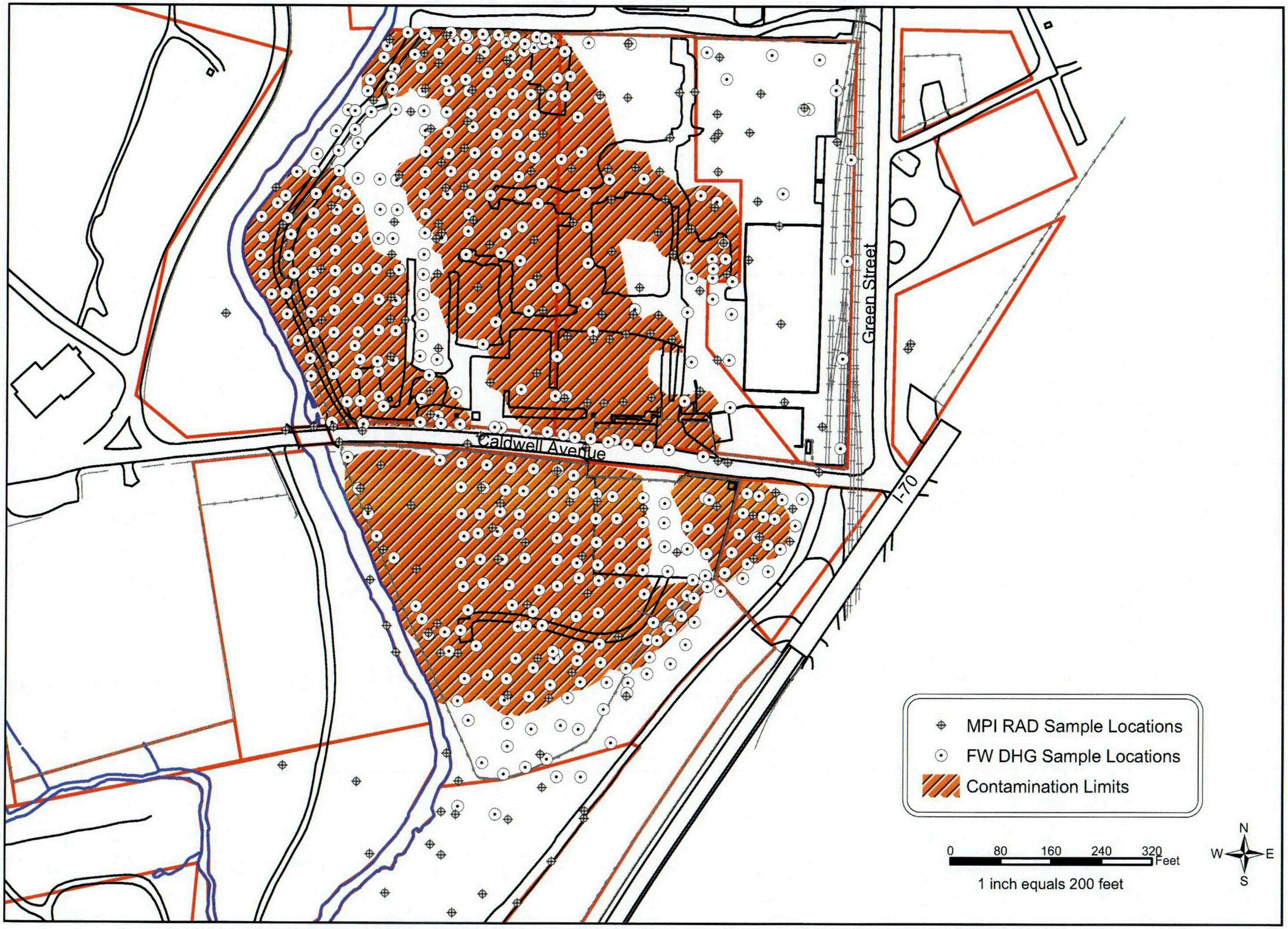
Molycorp, Washington Pennsylvania Site

January 2005

Figure 3-1
Interim Area Classification

C03



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Molycorp, Washington Pennsylvania Site

January 2005

Figure 3-2
Limits of Contamination

C04

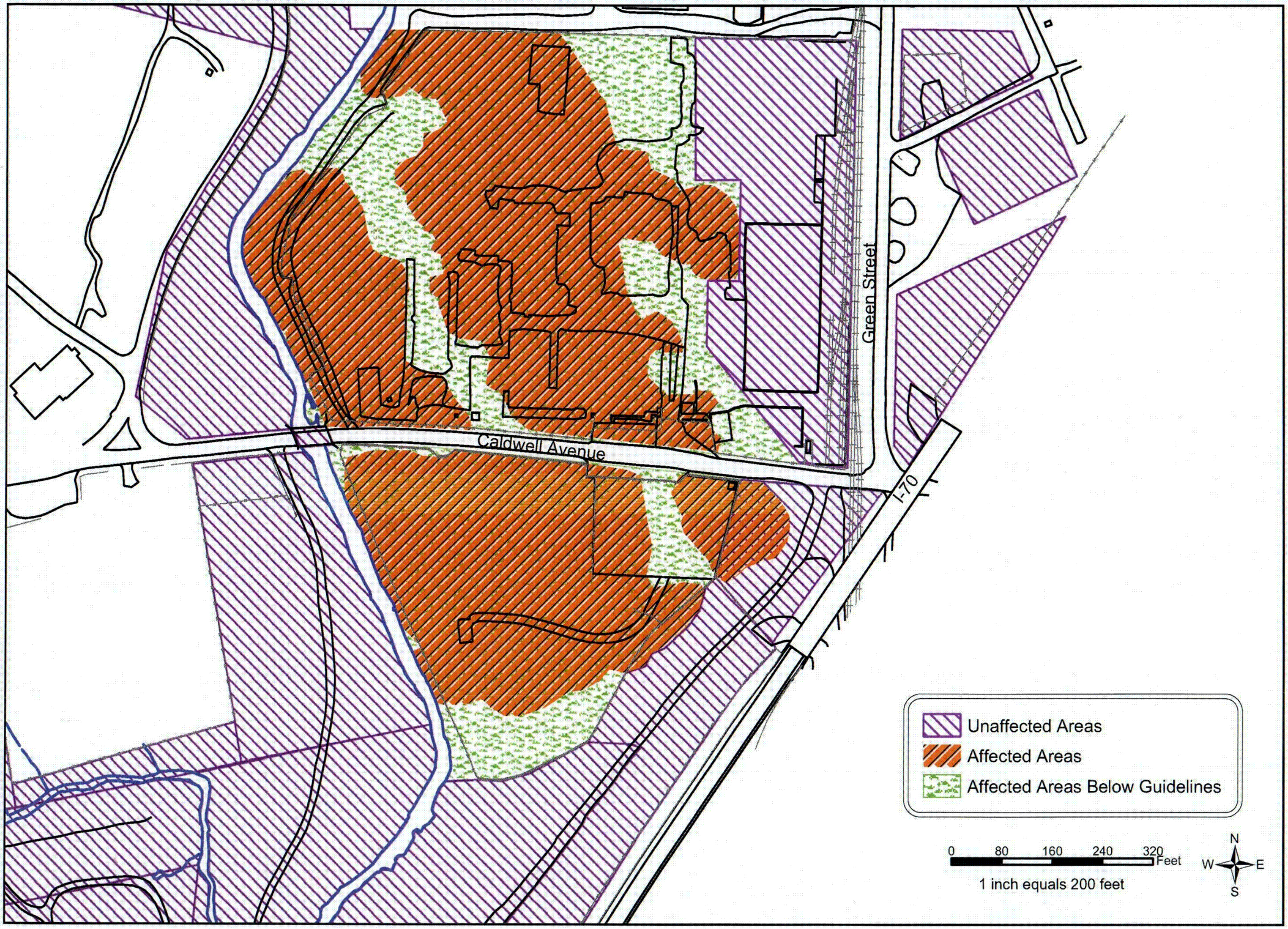

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Figure 3-3
Area Classification

C05

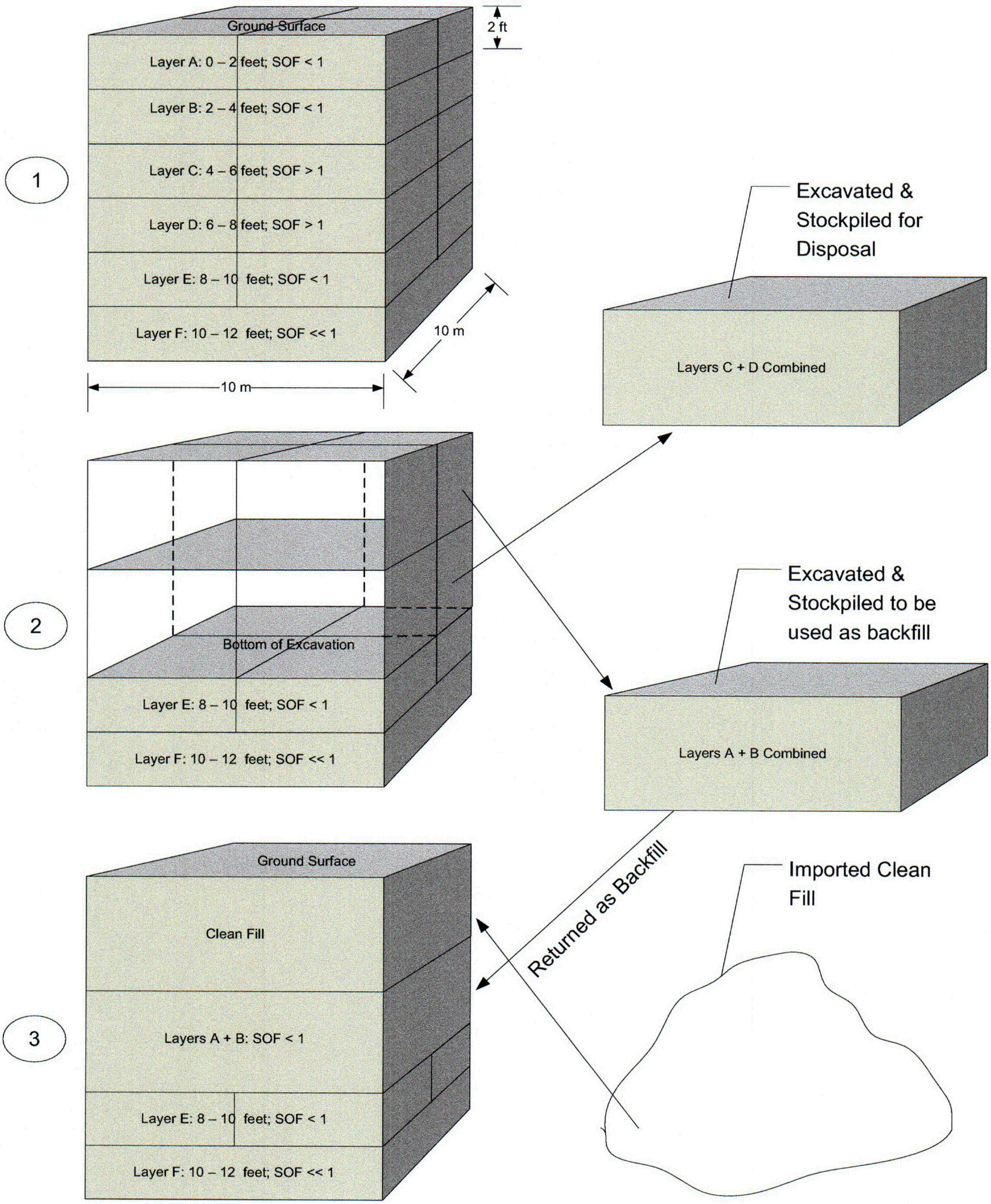

FIGURE 4-1 – Example Application of AAR Subsurface Soil Concentration Limits to Washington Site

C06

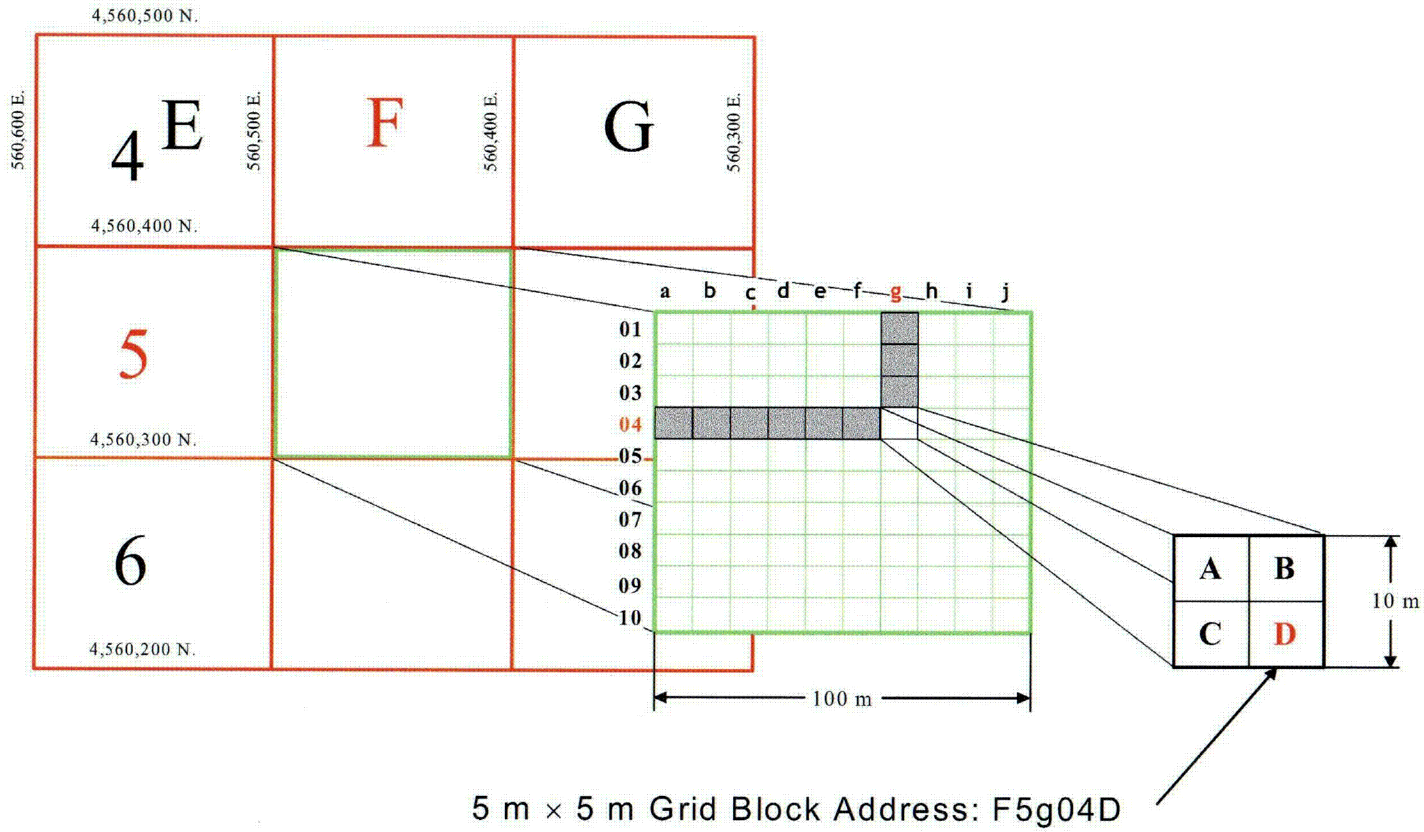

Figure 5-1 Coordinate System

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TABLES

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TAB

TABLE 4-1
Tabular Data Set from RESRAD Modeling Runs Conducted for the Molycorp Washington, PA Site

Dimensions for Table			1	2	3	4	5	6	7	8	12	16	20	24	28	197
Volume (ft3)	50	200	538	1076	1615	2153	2691	3229	3767	4306	6458	8611	10764	12917	15069	105944
Thickness (ft)	0.984	0.984	0.984	0.984	0.984	0.984	0.984	0.984	0.984	0.984	0.984	0.984	0.984	0.984	0.984	0.984
Area (ft2)	51	203.3	546.8	1093.6	1640.4	2187.2	2734.0	3280.8	3827.6	4374.4	6561.7	8748.9	10936.1	13123.3	15310.6	107639.0
Dimensions for RESRAD Input																
Thickness (m)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Area (m2)	4.7	18.9	50.8	101.6	152.4	203.2	254.0	304.8	355.6	406.4	609.6	812.8	1016.0	1219.2	1422.4	10000.0
Maximum Annual Dose Modeled																
Uranium (10 pCi/g)	6.32	12.65	16.74	19.48	21.16	22.71	23.93	25.12	26.30	27.46	31.85	36.03	39.87	39.96	40.06	42.49
Thorium (10 pCi/g)	9.23	17.99	23.33	26.37	27.88	29.20	30.02	30.80	31.56	32.30	34.86	37.11	39.14	39.27	39.38	41.52
Radium (5 pCi/g)	5.95	11.99	15.64	17.75	18.83	19.78	20.41	21.01	21.47	22.18	24.22	26.07	27.75	27.82	27.88	29.28
Percent of Baseline Annual Dose																
Uranium	14.9%	29.8%	39.4%	45.8%	49.8%	53.4%	56.3%	59.1%	61.9%	64.6%	75.0%	84.8%	93.8%	94.0%	94.3%	100.0%
Thorium	22.2%	43.3%	56.2%	63.5%	67.1%	70.3%	72.3%	74.2%	76.0%	77.8%	84.0%	89.4%	94.3%	94.6%	94.8%	100.0%
Radium	20.3%	40.9%	53.4%	60.6%	64.3%	67.6%	69.7%	71.8%	73.3%	75.8%	82.7%	89.0%	94.8%	95.0%	95.2%	100.0%
Area Factors																
Uranium (10 pCi/g)	6.7	3.4	2.5	2.2	2.0	1.9	1.8	1.7	1.6	1.5	1.3	1.2	1.1	1.1	1.1	1.0
Thorium (10 pCi/g)	4.5	2.3	1.8	1.6	1.5	1.4	1.4	1.3	1.3	1.3	1.2	1.1	1.1	1.1	1.1	1.0
Radium (5 pCi/g)	4.9	2.4	1.9	1.6	1.6	1.5	1.4	1.4	1.4	1.3	1.2	1.1	1.1	1.1	1.1	1.0
Allowable Concentrations																
Uranium (pCi/g)	67.2	33.6	25.4	21.8	20.1	18.7	17.8	16.9	16.2	15.5	13.3	11.8	10.7	10.6	10.6	10.0
Thorium (pCi/g)	45.0	23.1	17.8	15.7	14.9	14.2	13.8	13.5	13.2	12.9	11.9	11.2	10.6	10.6	10.5	10.0
Radium (pCi/g)	24.6	12.2	9.4	8.2	7.8	7.4	7.2	7.0	6.8	6.6	6.0	5.6	5.3	5.3	5.3	5.0

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	active
6 -- aquatic foods	active
7 -- drinking water	active
8 -- soil ingestion	active
9 -- radon	suppressed

TABLE 4-2
Site-Specific Subsurface Soil Averaging Limits - Molycorp's Washington, PA Site

					Average, pCi/g	
Layer #	Layer	# of Quadrants	Volume (ft3)	Uranium (238 + 234)	Thorium (232 + 228)	Ra (226)
1	**0 to 2 feet Layer**				Average	
	4 Samples from Layer Area	4	2153	18.7	14.2	7.4
	Maximum in Layer	1	538	25.4	17.8	9.4
2	**0 to 4 feet Layer**					
	2 Vertical Quadrants	2	1076	21.8	15.7	8.2
	4 Samples from Layer Area	4	2153	30.9	25.7	13.2
	8 Samples from Surface to this Layer	8	4306	15.5	12.9	6.6
	Maximum in Layer	1	538	43.6	31.5	16.5
3	**0 to 6 feet Layer**					
	3 Vertical Quadrants	3	1615	20.1	14.9	7.8
	4 Samples from Layer Area	4	2153	40.0	35.7	18.1
	12 Samples from Surface to this Layer	12	6458	13.3	11.9	6.0
	Maximum in Layer	1	538	60.2	44.7	23.3
4	**0 to 8 feet Layer**					
	4 Vertical Quadrants	4	2153	18.7	14.2	7.4
	4 Samples from Layer Area	4	2153	47.2	44.8	22.5
	16 Samples from Surface to this Layer	16	8611	11.8	11.2	5.6
	Maximum in Layer	1	538	74.8	56.9	29.6
5	**0 to 10 feet Layer**					
	5 Vertical Quadrants	5	2691	17.8	13.8	7.2
	4 Samples from Layer Area	4	2153	53.3	53.0	26.4
	20 Samples from Surface to this Layer	20	10764	10.7	10.6	5.3
	Maximum in Layer	1	538	88.8	69.2	35.9
6	**0 to 12 feet Layer**					
	6 Vertical Quadrants	6	3229	16.9	13.5	7.0
	4 Samples from Layer Area	4	2153	63.8	63.4	31.6
	24 Samples from Surface to this Layer	24	12917	10.6	10.6	5.3
	Maximum in Layer	1	538	101.5	80.9	41.8
7	**0 to 14 feet Layer**					
	7 Vertical Quadrants	7	3767	16.2	13.2	6.8
	4 Samples from Layer Area	4	2153	74.2	73.8	36.8
	28 Samples from Surface to this Layer	28	15069	10.6	10.5	5.3
	Maximum in Layer	1	538	113.1	92.1	47.7
8	**Each Layer deeper than 14 feet**					
	Maximum in Layer	1	538	129.2	105.2	54.6

Assumptions

Area:	100	m2	1076	ft2
Quadrants:	25	m2	269	ft2
Thickness:	NA		2	ft
Area Volume:	NA		2153	ft3
Quadrant Volume:	NA		538	ft3

TABLE 4-3
Initial Concentrations for Step 1 of AAR Example Application

LAYER	DEPTH (feet)	U-238 (pCi/g)	Th-232 (pCi/g)	Ra-226 (pCi/g)
A	0 to 2	1	1	1
B	2 to 4	2	3	2
C	4 to 6	20	25	5
D	6 to 8	20	30	20
E	8 to 10	2	16	2

TABLE 4-4

Isotope Concentrations, AAR Averaging Limits and SOF Estimates for Step 2 of AAR Example Application

LAYER	DESCRIPTION	Net U-238 (pCi/g)	Net Th-232 (pCi/g)	Net Ra-226 (pCi/g)	Excess Ra-226 (pCi/g)	AAR U238 (pCi/g)	AAR Th-232 (pCi/g)	AAR Ra-226 (pCi/g)	SOF
A	4 Samples from Layer Area	1	1	1		9.4	7.1	7.4	0.25
	Maximum in Area	1	1	1		12.7	8.9	9.4	0.19
B	2 Vertical Quadrants	1.5	2	1.5		10.9	7.9	8.2	0.39
	4 Samples from this Layer	2	3	2		15.5	12.9	13.2	0.36
	8 Samples from Surface to this Layer	1.5	2	1.5		7.8	6.5	6.6	0.50
	Maximum in Layer	2	3	2		21.8	15.8	26.5	0.28
C	3 Vertical Quadrants	7.7	9.7	7.7		10.1	7.5	7.8	2.06
	4 Samples from Layer Area	20	25	20		20.0	17.9	18.1	2.40
	12 Samples from Surface to this Layer	7.7	9.7	7.7		6.7	6.0	6.0	2.78
	Maximum in this Layer	20	25	20		30.1	22.4	23.3	1.78
Assume Layer C is disposed and replaced with clean fill for SOF calculations associated with increasing depth									
D	4 Vertical Quadrants	5.75	8.5	5.75		9.4	7.1	7.4	1.81
	4 Samples from Layer Area	20	30	20		23.6	22.4	22.5	2.19
	16 Samples from Surface to this Layer	5.75	8.5	5.75		5.9	5.6	5.6	2.49
	Maximum in this Layer	20	30	20		37.4	28.5	29.6	1.59
Assume Layer D is disposed and replaced with clean fill for SOF calculations associated with increasing depth									
E	5 Vertical Quadrants	1	4	1		8.9	6.9	7.2	0.69
	4 Samples from Layer Area	2	16	2		26.7	26.5	26.4	0.68
	20 Samples from Surface to this Layer	1	4	1		5.4	5.3	5.3	0.94
	Maximum in this Layer	2	16	2		44.4	34.6	35.9	0.51

TABLE 4- 5

Isotope Concentrations, AAR Averaging Limits and SOF Estimates for Step 3 of AAR Example Application

LAYER	DESCRIPTION	Net U-238 (pCi/g)	Net Th-232 (pCi/g)	Net Ra-226 (pCi/g)	Excess Ra-226 (pCi/g)	AAR U-238 (pCi/g)	AAR Th-232 (pCi/g)	AAR Ra-226 (pCi/g)	SOF
A	4 Samples from Layer Area	0.0	0.0	0.0	0.0	9.4	7.1	7.4	0.00
	Maximum in Area	0.0	0.0	0.0	0.0	12.7	8.9	9.4	0.00
B	2 Vertical Quadrants	0.0	0.0	0.0	0.0	10.9	7.9	8.2	0.00
	4 Samples from this Layer	0.0	0.0	0.0	0.0	15.5	12.9	13.2	0.00
	8 Samples from Surface to this Layer	0.0	0.0	0.0	0.0	7.8	6.5	6.6	0.00
	Maximum in Layer	0.0	0.0	0.0	0.0	21.8	15.8	26.5	0.00
C *	3 Vertical Quadrants	0.5	0.7	0.5	0.0	10.1	7.5	7.8	0.14
	4 Samples from Layer Area	1.5	2.0	1.5	0.0	20.0	17.9	18.1	0.19
	12 Samples from Surface to this Layer	0.5	0.7	0.5	0.0	6.7	6.0	6.0	0.19
	Maximum in this Layer	1.5	2.0	1.5	0.0	30.1	22.4	23.3	0.14
D*	4 Vertical Quadrants	0.4	0.5	0.4	0.0	9.4	7.1	7.4	0.11
	4 Samples from Layer Area	1.5	2.0	1.5	0.0	23.6	22.4	22.5	0.15
	16 Samples from Surface to this Layer	0.4	0.5	0.4	0.0	5.9	5.6	5.6	0.15
	Maximum in this Layer	1.5	2.0	1.5	0.0	37.4	28.5	29.6	0.11
E	5 Vertical Quadrants	1.0	4.0	1.0	0.0	8.9	6.9	7.2	0.69
	4 Samples from Layer Area	2.0	16.0	2.0	0.0	26.7	26.5	26.4	0.68
	20 Samples from Surface to this Layer	1.0	4.0	1.0	0.0	5.4	5.3	5.3	0.94
	Maximum in this Layer	2.0	16.0	2.0	0.0	44.4	34.6	35.9	0.51

*Stockpile material formerly layers A and B.

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A

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APPENDIX A

AAR METHOD

METHOD FOR SURVEYING AND AVERAGING CONCENTRATIONS OF THORIUM IN CONTAMINATED SUBSURFACE SOIL

Prepared by NRC Staff in Connection
With the Review of the AAR "Site
Remediation Plan for the Former Brooks
and Perkins, Inc. Site," Docket #040-00235
NRC Contact: David Fauver, 301-415-6625

I. INTRODUCTION

Current NRC guidance for conducting final surveys at decommissioning facilities is contained in Draft NUREG/CR-5849, "Manual for Conducting Surveys in Support of License Termination." NUREG/CR-5849 primarily addresses the final surveys of surface contamination on both buildings and open land areas, including guidance on acceptable averaging methods for surface contamination that exceeds the unrestricted use criteria (i.e., elevated areas). However, methods for surveying and averaging subsurface contamination are not discussed. This document provides a method for averaging elevated areas of subsurface soil contamination. Note that the potential for exposure from subsurface contamination via the groundwater pathway is not addressed in this document. The groundwater pathway should be evaluated on a case-by-case basis.

The averaging method in NUREG/CR-5849 assumes that soil samples are collected from the ground surface (first 15 cm). This sampling and averaging method is acceptable for the majority of decommissioning sites since the surface samples are considered sufficiently representative to assess the potential dose using conventional pathway analysis. However, conventional pathway analysis, and the NUREG/CR-5849 averaging method, may not be appropriate if significant subsurface contamination is present.

Conventional pathway analysis concludes that the dose from subsurface contamination is essentially zero, except from the groundwater pathway (see discussion below for other exceptions). This conclusion assumes that the contamination will remain at depth for very long periods of time (the typical pathway analysis is run for a 1000 year period). Since it is not reasonable to assume that the subsurface soil will remain undisturbed for a 1000 year period, simple scenarios were developed to predict how subsurface soil would be excavated in the future, the volume of the excavated soil, and the dose consequences of the contaminated soil in the post-excavation geometry. Based on the predicted excavation volumes and the dose consequences, surveying and averaging protocol were developed for in-situ subsurface soil.

Two excavation scenarios were evaluated. The first scenario assumes the construction of a slab-on-grade house; the second a house with a basement. For each of the construction scenarios, the volume of excavated soil and the extent of surface spreading, as well as the depth of surfaces on which the foundations could be built, were estimated. The potential dose from the subsurface soil, after excavation, was estimated by: 1) calculating the dose

Attachment

from the contaminated soil spread on the ground surface and 2) calculating the dose from the in-situ contaminated surface that is exposed after excavation, assuming that the foundation of the house is built on the exposed surface.

It is recognized that subsurface contamination contained closer to the surface, say 0-1 meter, may deliver dose without being excavated. This exposure may occur from: 1) direct gamma radiation from in-situ soil closer to the surface, 2) the root uptake pathway down to about the first meter, and 3) the uncovering of contaminated surfaces through grading during construction, and surface erosion over time, which could then cause dose through surface exposure pathways. However, the average concentration allowed for the in-situ soil from 0-1 meter would be greater than that allowed under the excavation scenario due to the soil being spread over a larger area after excavation. Therefore, the excavation scenario is used to determine acceptable averaging limits for the 0-1 meter layer. This conservatism is appropriate because of the uncertainty as to potential exposure pathways for near surface contamination.

Finally, after the concentrations and averaging volumes were determined, a survey method was developed that would be acceptable to NRC for demonstrating that the averaging criteria are met. Section II describes the survey method. The technical basis for the averaging concentrations and survey method is presented in Section III.

II. SURVEY METHOD FOR SUBSURFACE THORIUM CONTAMINATION

The final survey method for subsurface contamination should ensure that the number and location of samples are sufficient to; 1) demonstrate, with reasonable confidence, that a significant volume of subsurface contamination is identified by one of the samples, and 2) demonstrate that the average contamination level in the identified volume would not result in a significant dose after excavation.

The survey method described below can be used to satisfy the above two objectives. The technical basis for this survey method is presented in Section III. The concentration values are based on the current unrestricted use limit of 10 pCi/g total thorium for widespread surface contamination. If the guideline value changes, the averaging criteria will change accordingly. Other survey methods may be acceptable if they are justified on a dose basis and provide sufficient confidence that significant volumes of soil are identified.

Survey Assumptions:

1. Samples are collected on a 5 meter square grid.

2. Samples are composited over each 1 meter layer of soil.

3. Each sample is assumed to represent 25 m^3.

4. 100 m^3 averages are represented by the average of four samples collected from each 1 meter layer of soil.

5. Volumetric averages greater than 100 m^3 are calculated assuming each sample represents 25 m^3.

Averaging Criteria for Total Thorium (Th-232 + Th-228):

0-1 meter depth	Maximum Individual Sample < 50 pCi/g 10 m^3 average < 20 pCi/g 100 m^3 average < 13 pCi/g
1-2 meter depth	Maximum < 50 pCi/g 200 m^3 (0-2 m depth) < 10 pCi/g
2-3 meter depth	Maximum < 50 pCi/g 300 m^3 (0-3 m depth) < 10 pCi/g
3-4 meter depth	Maximum < 50 pCi/g 100 m^3 < 13 pCi/g 400 m^3 (0-4 m depth) < 10 pCi/g
> 4 meter depth	maximum < 50 pCi/g volume from surface to depth "x" < 10 pCi/g
survey unit	The volumetric average over the entire survey unit < the unrestricted use limit (10 pCi/g for total thorium)

The averaging criteria apply to any contiguous volume defined by the given number of 5 m grid samples, where each sample represents 25 m^3. For averaging over a 100 m^3 volume, each combination of four samples in a given 1 m layer should be evaluated. This would only be necessary if an individual sample exceeds 10 pCi/g. To calculate the average for volumes greater than 100 m^3, consider the samples in a given 10 m X 10 m area projected to the depth of interest. For example, the 300 m^3 volume average is calculated by averaging 12 samples represented by the four samples in the 0-1 m layer of a given 10 X 10 m area (assuming 5 m grid), and the 4 samples each in the 1-2 m and 2-3 m layers directly below the given 10 X 10 area. The samples at the respective depths would likely be from the same borehole.

In addition to the above, a vertical averaging criteria is also defined. This averaging criteria is intended to identify significant volumes of contiguous contamination in the vertical, as opposed to the horizontal, direction. The sampling and averaging described below also assumes a 5 m grid size.

- The average of the two samples from 0-2 meters in same borehole (50 m^3) < 14 pCi/g total thorium

- The average of the three samples from 0-3 meters in same borehole (75 m^3) < 13 pCi/g total thorium

III. TECHNICAL BASIS FOR SUBSURFACE SURVEYING AND AVERAGING METHOD

Discussion

After the contaminated soil is excavated and brought to the surface, the surface exposure pathways, and the surface averaging methods apply. The surface averaging method used for excavated subsurface soil is consistent with that used in NUREG/CR-5849. However, the NUREG/CR-5849 procedure was modified to reduce the conservatism. A discussion of how the NUREG/CR-5849 averaging method for surface contamination was modified is presented in the following section. How the modified averaging method was applied to excavated subsurface soil is presented in subsequent sections.

The averaging method in NUREG/CR-5849 was based on a combination of past practice and dose assessments. The averaging method has three steps:

1) elevated areas should be less than 3 times the release criteria,

2) the concentration in the elevated area should not be greater than $(100/A)^{1/2}$ times the release criteria, where "A" is the size of the elevated area in m^2, and

3) the average over any 100 m^2 area should be less than the release criteria.

The maximum criterion of 3 times the average limit in NUREG/CR-5849 (step #1 above) was based on a qualitative ALARA judgement and a comparison with the maximum criteria in "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material," which also uses 3 times the average value as the maximum. Since radionuclide specific evaluations will be performed (as described below), the 3 times maximum criterion was not used in the volumetric averaging method for subsurface contamination. The maximum criterion was determined by estimating the minimum volume of soil that could be excavated without mixing with surrounding soil and assessing the relative dose from this volume of soil compared to uniform, widespread contamination.

The area averaging criterion in NUREG/CR-5849 (step #2 above) was based on a dose assessment made in 1985 for the Department of Energy using the DOE "Manual for Implementing Residual Radioactivity Guidelines." This manual was eventually updated and codified in 1989 as DOE's RESRAD pathway analysis/dose assessment code. The dose from elevated areas of various sizes was estimated using default input parameters for the code. The conclusion from these dose estimations was that the dose is reduced as the area of contamination is reduced, assuming the same concentration. The extent of the reduction in dose as a function of area depends on whether the predominant dose pathway is from direct exposure, or from one or more of the other pathways such as inhalation and ingestion. In general, there is a greater dose reduction for elevated areas containing radionuclides that deliver a significant fraction of the dose through the inhalation and ingestion pathway than for radionuclides that deliver a higher fraction of dose via the direct exposure pathway. The formula in NUREG/CR-5849 (restated below) was derived from the 1985 DOE study of the dose consequences of elevated areas of various sizes.

$$\text{Allowable Concentration in Elevated Area} < C(100/A)^{1/2}$$

where: C = unrestricted use criteria
A = area of elevated area, m^2

The above formula represents the lower bound of acceptable concentrations in an elevated area of size "A" for all of the radionuclides evaluated. A similar dose assessment for a specific radionuclide will very likely result in an allowable concentration exceeding that calculated using the above formula. This is evidenced by Enclosure 1, which shows the nuclide specific dose consequences of elevated areas (represented by the multiple of the authorized limit on the Y axis) ranging in size from 1 m^2 to 100 m^2. Enclosure 1 also includes a line defined by the $(100/A)^{1/2}$ formula. Note that the $(100/A)^{1/2}$ line is below all of the nuclide specific curves, and represents the most conservative result.

Enclosure 1 was generated in 1985 and summarizes the results of the dose assessments used to select the $(100/A)^{1/2}$ formula for determining acceptable concentrations of contamination in elevated areas. To ensure that the current version of RESRAD is consistent with the 1985 dose assessments, a similar series of dose assessments were conducted using a recent version of RESRAD. As shown in Enclosure 2, the results are very similar. This demonstrates that RESRAD is appropriate, and will provide averaging criteria that is consistent with, albeit less conservative than, the $(100/A)^{1/2}$ criteria. Therefore, in order to provide more realistic criteria, the volumetric averaging method described below relies on radionuclide specific dose assessments, using the DOE RESRAD code, to determine the acceptable concentration in subsurface soil containing elevated contamination levels.

The third part of the averaging method in NUREG/CR-5849 (step #3 above) is that the average over any 100 m^2 should be less than the release criteria. The 100 m^2 average limitation was intended to address the potential for a 10 m x 10 m house being built on the 100 m^2 parcel of land. The 10 m x 10 m averaging criteria is essentially maintained in the subsurface volumetric averaging method.

The following sections describe the assumptions and calculations used to develop the volumetric averaging criteria for subsurface soil.

Excavation Assumptions

- Excavation scenarios for both a house w/basement and a house w/out basement

- House Size: 10 m x 10 m

- Dimensions of footers for house w/no basement: 1 m deep x 1 m wide x 10 m long
- Basement Depth: 3 m
- Excavation Equipment Bucket Size: 1 m^3
- Five excavation scenarios evaluated:

  1) each of four 1 m deep x 1 m wide x 10 m long footer excavation for a house w/out basement is placed in separate pile

  2) the 1 m deep x 10 m wide x 10 m long portion of soil from the surface to a depth of 1 m is excavated for a house with no basement and placed in separate pile

  3) each 3 m deep x 2.5 m wide x 10 m long portion of soil for basement excavation placed in separate pile

  4) entire 3 m deep x 10 m wide x 10 m long excavation for house w/basement placed in one pile

  5) one bucket (1 m x 1 m x 1 m) of excavated soil placed in separate pile

- Each excavated pile uniformly blended
- Each pile spread over a 1 foot depth

Method for Calculating Acceptable Averaging Volumes and Concentrations for Subsurface Contamination

To determine the averaging volume for subsurface contamination, and the acceptable concentration as a function of volume, the first step was to calculate the volume of soil excavated in each of the above five scenarios. The dose from the excavated soil was then estimated and compared to the dose from widespread, uniform contamination.

To estimate the dose, the soil volumes defined by the five excavation scenarios were assumed to be brought to the surface and spread over a 1 foot depth. Using the resulting calculated surface area as input to the RESRAD code, the dose from the excavated soil was estimated using the resident farmer scenario and the input parameters from Policy and Guidance Directive PG-8-08 "Scenarios for Assessing Potential Doses Associated with Residual Radioactivity," May 1994. A second RESRAD run was then made, using the same concentration, and assuming the default area of 10,000 m^2. The ratio of the dose from the 10,000 m^2 area to the dose from the calculated area was then multiplied by the unrestricted use criteria to determine the acceptable concentration in the elevated area, and hence the corresponding subsurface volume. This concentration is considered acceptable since the dose from the elevated area containing this concentration will deliver the same dose as a large area contaminated at the unrestricted use level. To determine compliance with the volumetric averaging criteria, the average concentration over the in-situ volume of soil defined in the scenario must be less than the above ratio times the guideline.

For example, the following calculation provides the averaging volume and concentration for excavation Scenario #1, assuming that the contamination is total thorium (Th-232 + Th-228):

1. Volume of 1 m deep x 1 m wide x 10 m long footer is 10 m^3.

2. Assuming the 10 m^3 volume is excavated and spread over a 1 foot depth, the area of contamination on the surface would be 30 m^2.

3. Run RESRAD to estimate dose assuming 10 pCi/g total thorium and assuming that the contaminated area is 30 m^2 (Enclosure 3).

4. Run RESRAD to estimate dose, also assuming 10 pCi/g total thorium, but using the RESRAD default area of 10,000 m^2 (Enclosure 4).

5. Calculate the ratio of the dose from Step 4 to the dose from Step 3. For total thorium, the ratio is 2.0.

6. Multiply the ratio, i.e., 2.0, by the unrestricted use limit for total thorium, i.e., 10 pCi/g. The resulting concentration is 20 pCi/g, which represents the acceptable average concentration in a 10 m^3 volume of soil.

Note that Scenario #1 applies only to volumes of soil starting on the surface and ending at the first meter since the excavation is assumed to be for a footer, and would not go below 1 m.

The same calculations were performed for the other four excavation scenarios. The resulting five volumetric averaging guidelines for subsurface thorium contamination are listed below. The criteria for other radionuclides should be developed on a case-by-case basis. The excavation scenarios described above for housing construction are assumed to result in conservative averaging criteria since excavations for larger structures should result in larger excavated volumes, and a greater degree of mixing with surrounding soil.

<u>Volumetric Averaging Guidelines For Subsurface Thorium Contamination</u>

The five excavation scenarios were evaluated to determine acceptable averaging volumes and concentrations for subsurface thorium contamination. Enclosure 5 contains the RESRAD output for each of the five evaluations.

1) The average concentration of total thorium in a 10 m^3 volume should be less than 20 pCi/g.

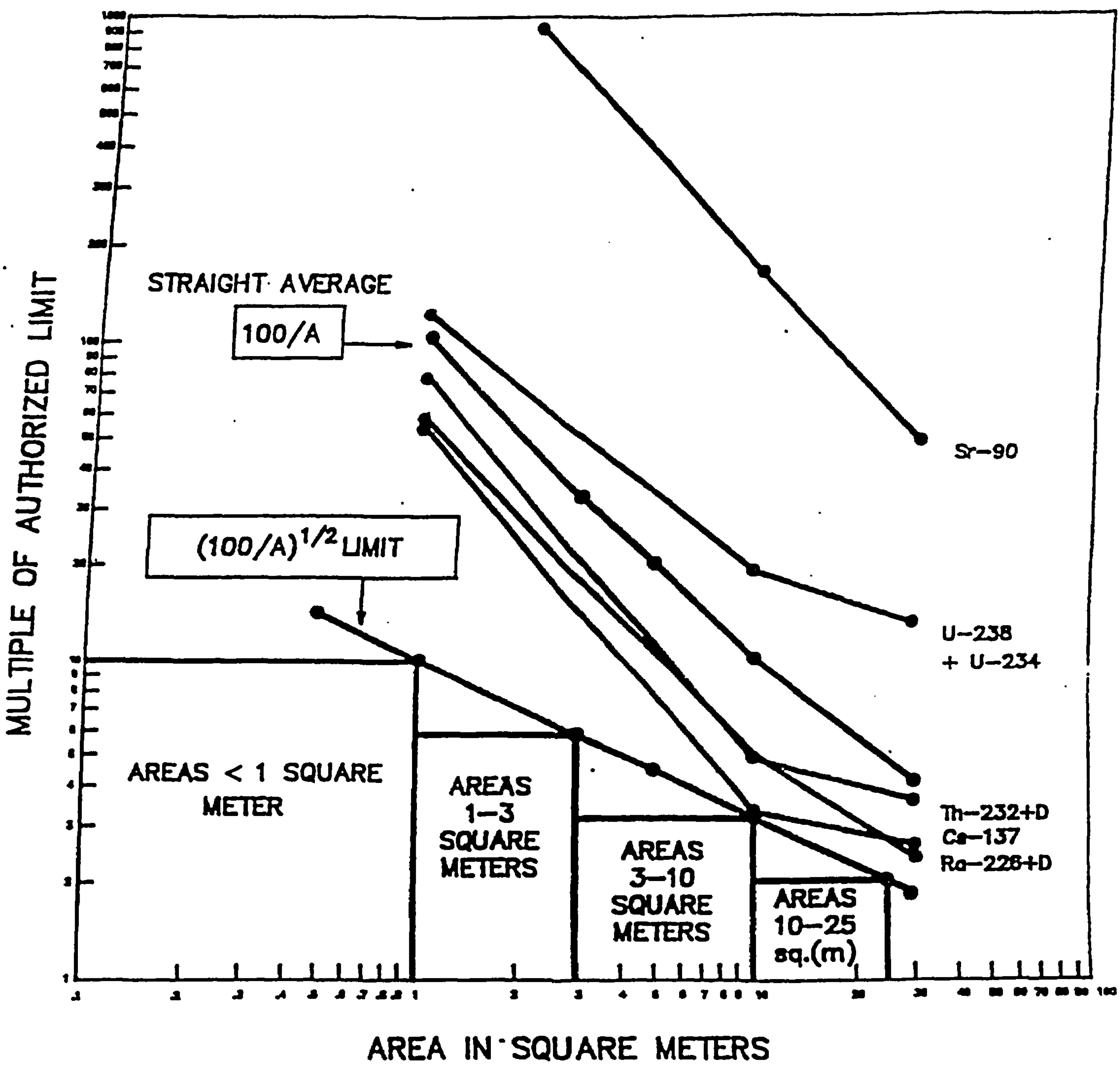
2) The average concentration of total thorium in a 100 m^3 volume of soil should be less than 13 pCi/g.

3) The average concentration of thorium in a 75 m^3 volume of soil should be less than 13 pCi/g.

4) The average concentration of thorium in a 300 m^3 volume of soil should be less than 10 pCi/g.

5) The average concentration of thorium in a 1 m^3 volume of soil should be less than 50 pCi/g. This concentration is considered the maximum value for an individual sample composited over a 1 meter depth.

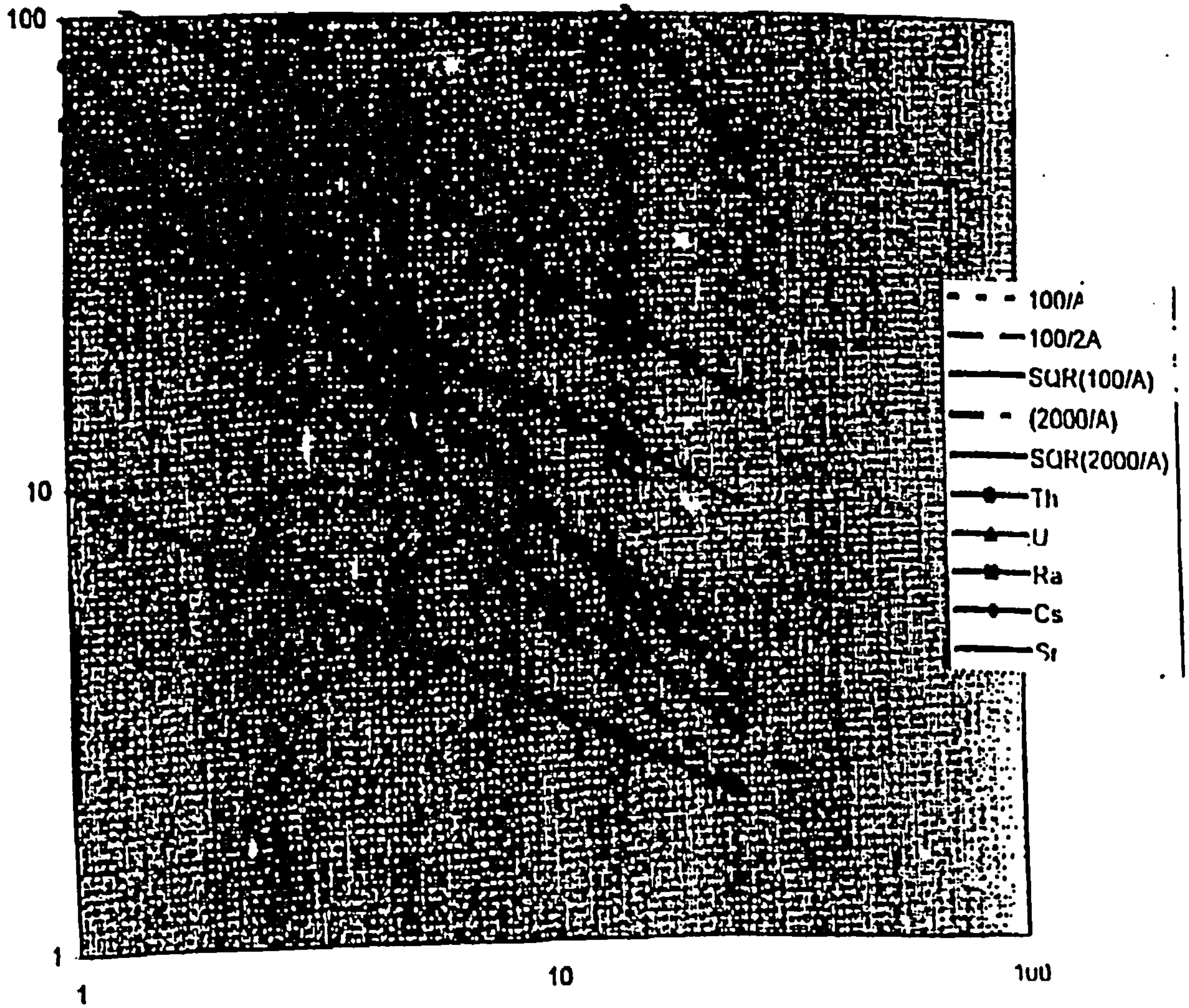
The above averaging guidelines were developed assuming that the soil is excavated and placed on the ground surface. The final step is to ensure that the volumetric averaging does not result in a layer of exposed soil with excessive concentrations. The soil layers of concern are the layer from 0-1 m and 3-4 m, which are the layers upon which the foundations for the slab-on-grade house and a house with a basement, respectively, are assumed to be built. To control these scenarios, the average over the 100 m^3 defined for these layers will be limited to the 100 m^3 averaging criteria.



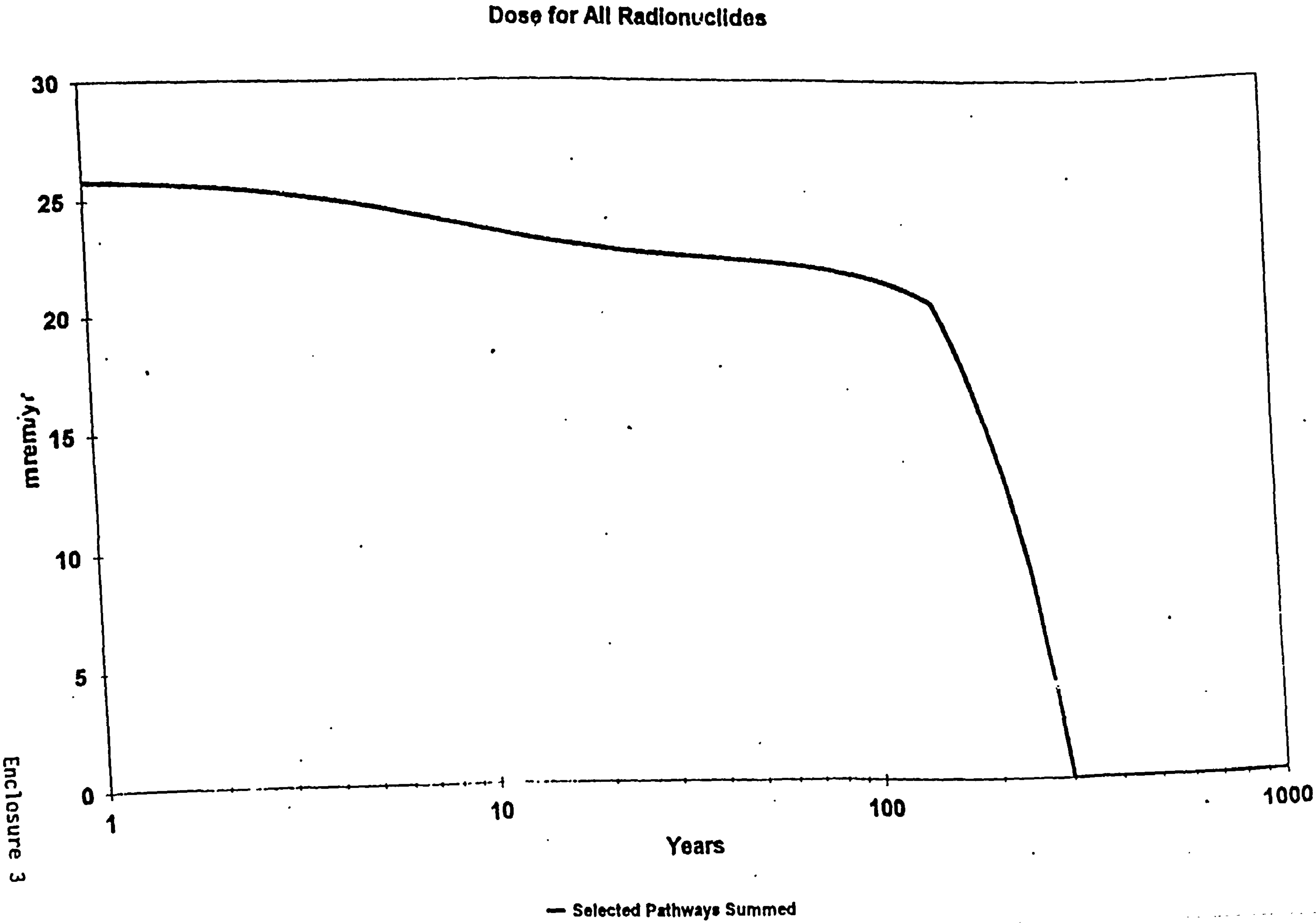
COMPARISION OF HOT SPOT LIMITS BASED ON $(100/A)^{1/2}$ AND mrem DOSE LIMIT

Enclosure 1

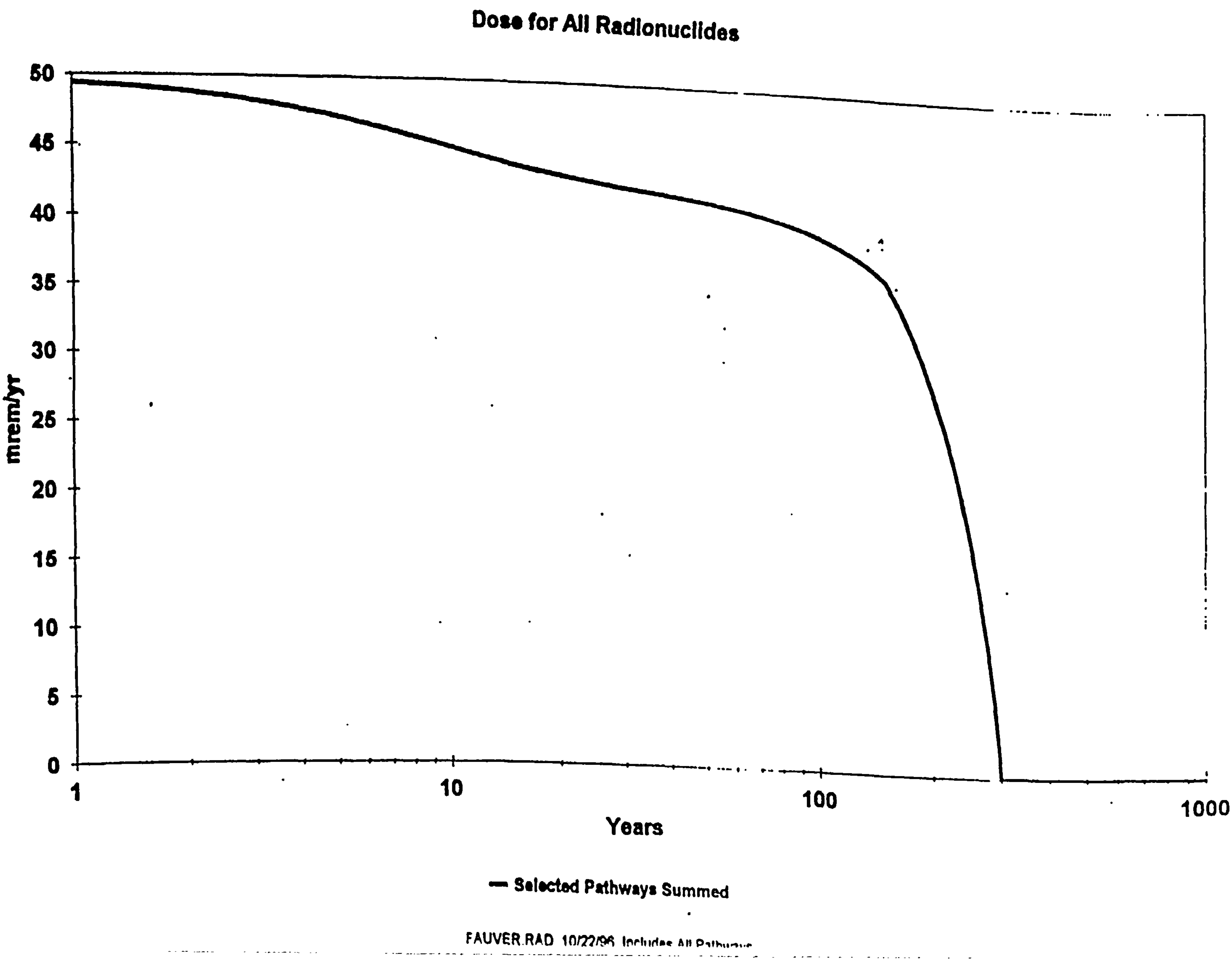
Area	100/A	100/2A	SQR(100/	(2000/A)	SQR(2000	Th	U	Ra	Cs	Sr
1	100	50	10	2000	44.72136	80	120	60	60	
3	33.33333	16.66667	5.773503	666.6667	25.81989	34	68	28	24	
10	10	5	3.162278	200	14.14214	8	27	8	5 5	180
25	4	2	2	80	8.944272	4	15	3 3	2.8	50



Enclosure 2


Dose for All Radionuclides
30
25
20
15
10
5
0
mrem/yr
1
10
100
1000
Years
Selected Pathways Summed

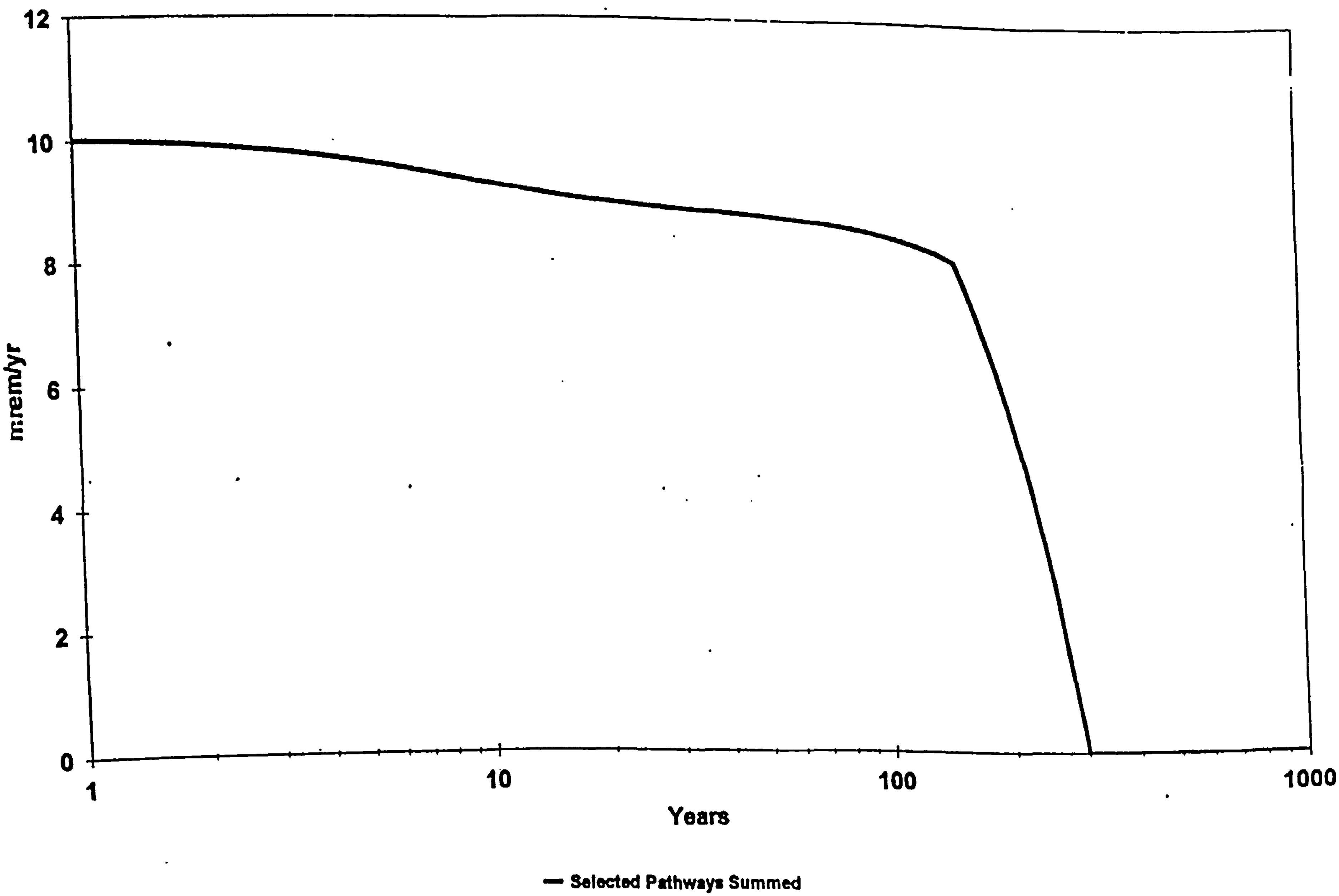
Enclosure 3



Dose for All Radionuclides
50
45
40
35
30
25
20
15
10
5
0
mrem/yr
1
10
100
1000
Years
Selected Pathways Summed
FAUVER.RAD 10/22/96 Includes All Pathways

Enclosure 4

Dose for All Radionuclides



Enclosure 5

Contaminated Zone Dimensions		Initial Soil Concentrations, pCi/g	
Area:	3.00 square meters	Ra-228	5.000E+00
Thickness:	0.30 meters	Th-228	5.000E+00
Cover Depth:	0.00 meters	Th-232	5.000E+00

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 30 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):	1.008E+01	1.001E+01	9.828E+00	9.295E+00	8.872E+00	8.479E+00	3.692E-09	2.756E-10
M(t):	3.360E-01	3.336E-01	3.276E-01	3.098E-01	2.957E-01	2.826E-01	1.231E-10	9.187E-12

Maximum TDOSE(t): 1.008E+01 mrem/yr at t = 0.000E+00 years

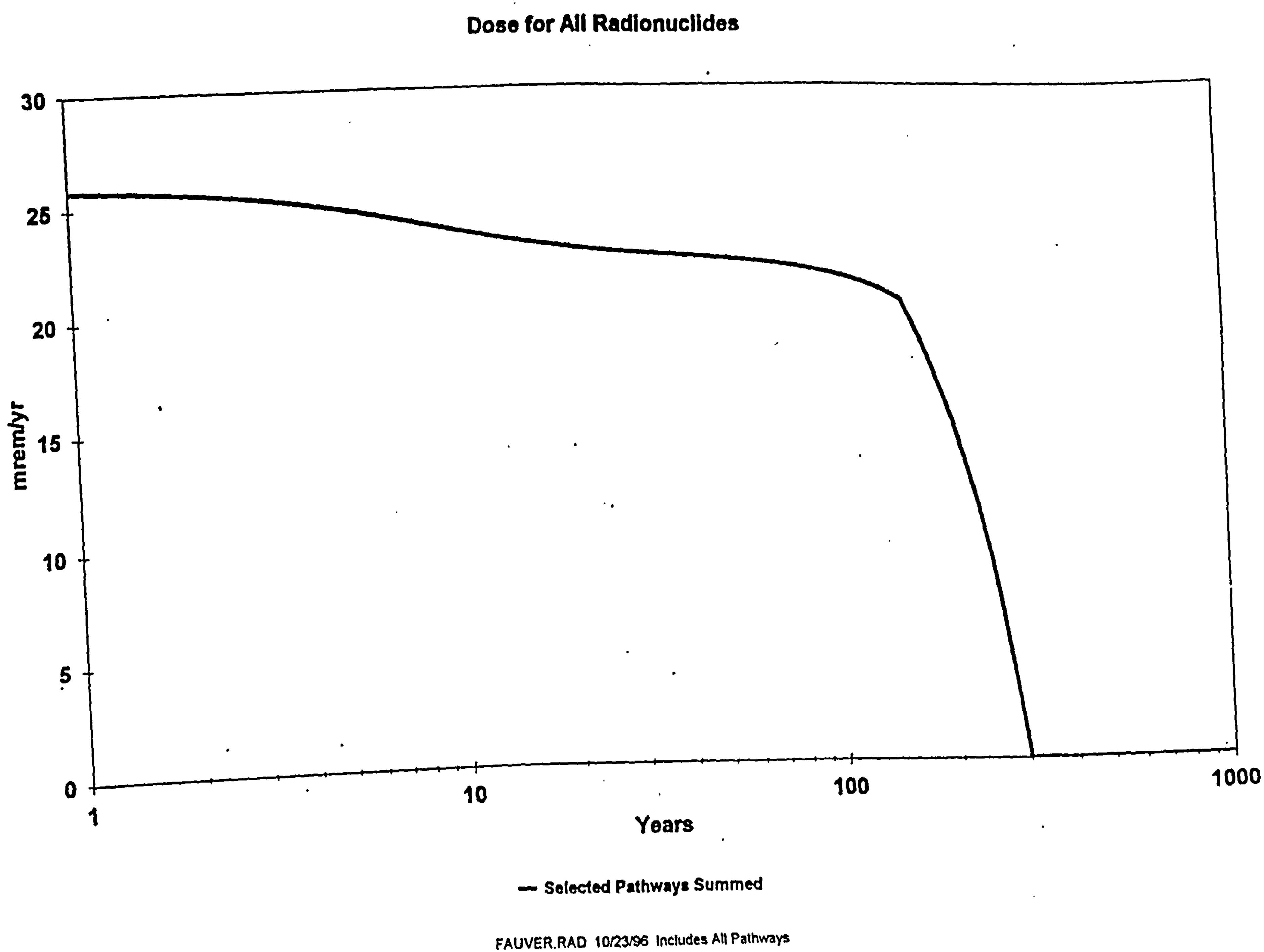
Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years
Water Independent Pathways (Inhalation excludes radon)

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.
Ra-228	2.405E+00	0.2386	9.480E-03	0.0009	0.000E+00	0.0000	2.538E-02	0.0025	9.422E-05	0.0000	1.321E-04	0.0000	2.996E-04	0.0000
Th-228	3.933E+00	0.3902	6.438E-01	0.0639	0.000E+00	0.0000	3.555E-04	0.0000	1.955E-06	0.0000	1.568E-07	0.0000	1.681E-04	0.0000
Th-232	2.657E-04	0.0000	3.060E+00	0.3036	0.000E+00	0.0000	1.217E-03	0.0001	6.751E-06	0.0000	5.312E-07	0.0000	5.680E-04	0.0001
Total	6.339E+00	0.6288	3.714E+00	0.3684	0.000E+00	0.0000	2.695E-02	0.0027	1.029E-04	0.0000	1.327E-04	0.0000	1.036E-03	0.0001

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
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.
Ra-228	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	2.441E+00	0.2421
Th-228	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	4.578E+00	0.4541
Th-232	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	3.062E+00	0.3038
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	1.008E+01	1.0000

*Sum of all water independent and dependent pathways.


Dose for All Radionuclides
30
25
20
15
10
5
0
mrem/yr
1
10
100
1000
Years
Selected Pathways Summed
FAUVER.RAD 10/23/96 Includes All Pathways

Contaminated Zone Dimensions		Initial Soil Concentrations, pCi/g	
Area:	30.00 square meters	Ra-228	5.000E+00
Thickness:	0.30 meters	Th-228	5.000E+00
Cover Depth:	0.00 meters	Th-232	5.000E+00

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 30 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):	2.599E+01	2.578E+01	2.525E+01	2.371E+01	2.253E+01	2.154E+01	3.713E-08	2.771E-09
M(t):	8.663E-01	8.593E-01	8.417E-01	7.903E-01	7.510E-01	7.179E-01	1.238E-09	9.237E-11

Maximum TDOSE(t): 2.599E+01 mrem/yr at t = 0.000E+00 years

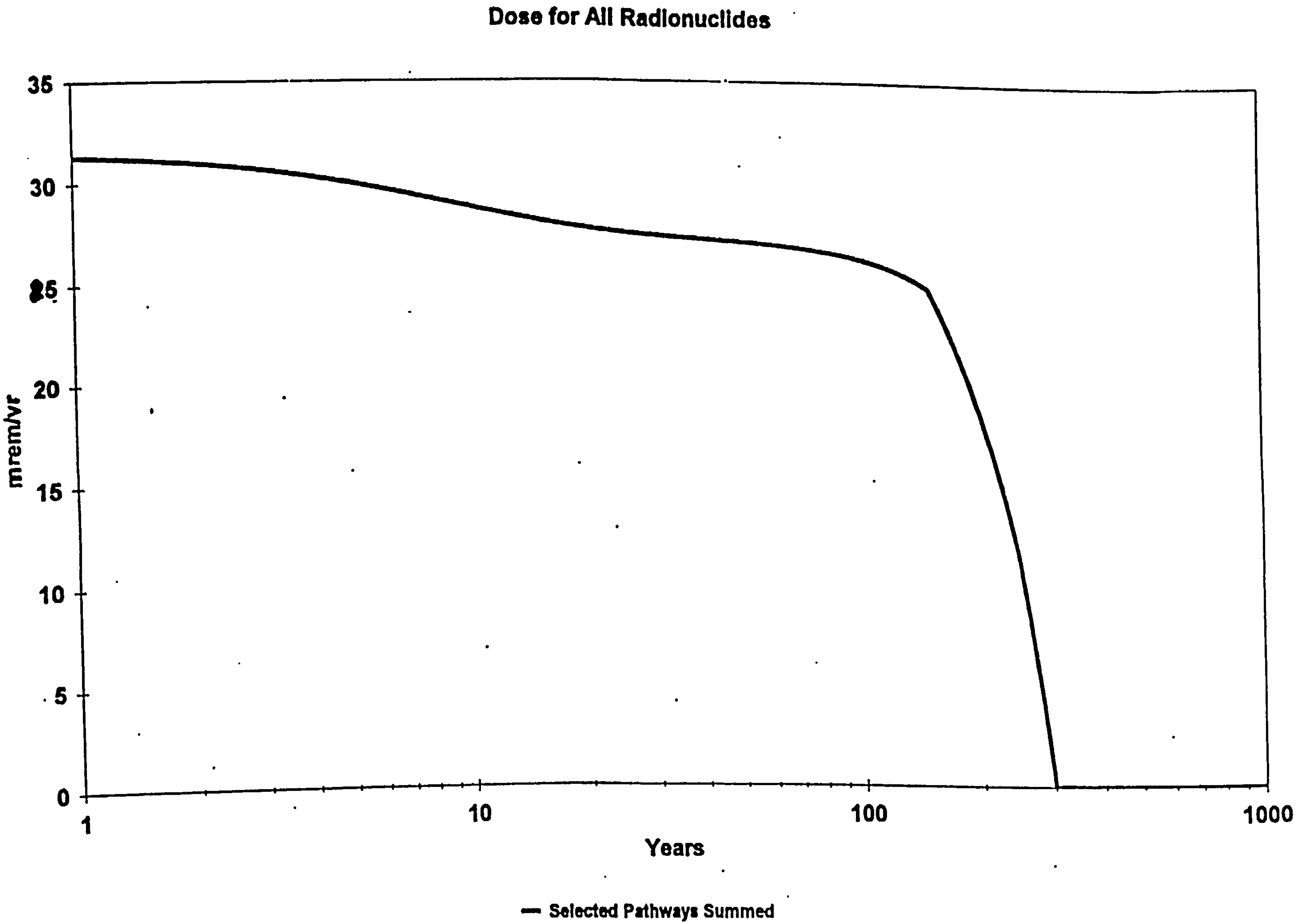
Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years
Water Independent Pathways (Inhalation excludes radon)

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.
Ra-228	7.218E+00	0.2777	1.673E-02	0.0006	0.000E+00	0.0000	2.539E-01	0.0098	9.426E-04	0.0000	1.321E-03	0.0001	2.996E-03	0.0001
Th-228	1.193E+01	0.4592	1.136E+00	0.0437	0.000E+00	0.0000	3.575E-03	0.0001	1.957E-05	0.0000	1.570E-06	0.0000	1.681E-03	0.0001
Th-232	7.110E-04	0.0000	5.402E+00	0.2079	0.000E+00	0.0000	1.224E-02	0.0005	6.758E-05	0.0000	5.317E-06	0.0000	5.680E-03	0.0002
Total	1.915E+01	0.7369	6.555E+00	0.2522	0.000E+00	0.0000	2.697E-01	0.0104	1.030E-03	0.0000	1.328E-03	0.0001	1.036E-02	0.0004

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
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.
Ra-228	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	7.494E+00	0.2883
Th-228	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	1.308E+01	0.5031
Th-232	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	5.421E+00	0.2086
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	2.599E+01	1.0000

*Sum of all water independent and dependent pathways.



FAUVER.RAD 01/14/97 Includes All Pathways

Contaminated Zone Dimensions		Initial Soil Concentrations, pCi/g	
Area:	75.00 square meters	Ra-228	5.000E+00
Thickness:	0.30 meters	Th-228	5.000E+00
Cover Depth:	0.00 meters	Th-232	5.000E+00

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 30 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):	3.154E+01	3.128E+01	3.063E+01	2.875E+01	2.733E+01	2.619E+01	1.076E-06	8.034E-08
M(t):	1.051E+00	1.043E+00	1.021E+00	9.583E-01	9.109E-01	8.731E-01	3.588E-08	2.678E-09

Maximum TDOSE(t): 3.154E+01 mrem/yr at t = 0.000E+00 years

Contaminated Zone Dimensions

Area:	10000.00 square meters
Thickness:	0.30 meters
Cover Depth:	0.00 meters

Initial Soil Concentrations, pCi/g

Ra-228	5.000E+00
Th-228	5.000E+00
Th-232	5.000E+00

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 30 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):	4.986E+01	4.938E+01	4.821E+01	4.507E+01	4.251E+01	3.955E+01	1.938E-06	1.445E-07
M(t):	1.662E+00	1.646E+00	1.607E+00	1.502E+00	1.417E+00	1.318E+00	6.459E-08	4.817E-09

Maximum TDOSE(t): 4.986E+01 mrem/yr   at t = 0.000E+00 years

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
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/y.	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	1.112E+01	0.2230	2.515E-02	0.0005	0.000E+00	0.0000	8.463E+00	0.1698	3.143E-01	0.0063	4.405E-01	0.0088	9.986E-02	0.0020
Th-228	1.876E+01	0.3763	1.708E+00	0.0343	0.000E+00	0.0000	1.199E-01	0.0024	6.531E-03	0.0001	5.237E-04	0.0000	5.603E-02	0.0011
Th-232	9.864E-04	0.0000	8.118E+00	0.1628	0.000E+00	0.0000	4.106E-01	0.0082	2.255E-02	0.0005	1.774E-03	0.0000	1.893E-01	0.0038
Total	2.988E+01	0.5993	9.851E+00	0.1976	0.000E+00	0.0000	8.994E+00	0.1804	3.434E-01	0.0069	4.428E-01	0.0089	3.452E-01	0.0069

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
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.
Ra-228	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	2.046E+01	0.4104
Th-228	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	2.065E+01	0.4142
Th-232	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	8.743E+00	0.1754
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	4.986E+01	1.0000

*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.
Ra-228	1.492E+01	0.3022	5.033E-01	0.0102	0.000E+00	0.0000	7.396E+00	0.1498	2.771E-01	0.0056	3.813E-01	0.0077	1.023E-01	0.0021
Th-228	1.306E+01	0.2644	1.189E+00	0.0241	0.000E+00	0.0000	8.321E-02	0.0017	4.545E-03	0.0001	3.645E-04	0.0000	3.900E-02	0.0008
Th-232	1.597E+00	0.0323	8.152E+00	0.1651	0.000E+00	0.0000	1.367E+00	0.0277	5.845E-02	0.0012	5.129E-02	0.0010	2.016E-01	0.0041
Total	2.957E+01	0.5989	9.844E+00	0.1994	0.000E+00	0.0000	8.846E+00	0.1791	3.401E-01	0.0069	4.330E-01	0.0088	3.429E-01	0.0069

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.
Ra-228	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	2.358E+01	0.4776
Th-228	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	1.437E+01	0.2910
Th-232	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	1.143E+01	0.2314
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	4.938E+01	1.0000

*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
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.
Ra-228	1.695E+01	0.3516	9.015E-01	0.0187	0.000E+00	0.0000	5.553E+00	0.1152	2.091E-01	0.0043	2.854E-01	0.0059	9.402E-02	0.0020
Th-228	6.323E+00	0.1312	5.759E-01	0.0119	0.000E+00	0.0000	4.005E-02	0.0008	2.201E-03	0.0000	1.765E-04	0.0000	1.890E-02	0.0004
Th-232	5.546E+00	0.1150	8.332E+00	0.1728	0.000E+00	0.0000	2.903E+00	0.0602	1.165E-01	0.0024	1.307E-01	0.0027	2.255E-01	0.0047
Total	2.882E+01	0.5978	9.809E+00	0.2035	0.000E+00	0.0000	8.495E+00	0.1762	3.278E-01	0.0068	4.163E-01	0.0086	3.384E-01	0.0070

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
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.
Ra-228	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	2.399E+01	0.4977
Th-228	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	6.960E+00	0.1444
Th-232	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	1.725E+01	0.3579
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	4.821E+01	1.0000

*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
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.
Ra-228	9.213E+00	0.2044	6.046E-01	0.0134	0.000E+00	0.0000	2.007E+00	0.0445	7.662E-02	0.0017	1.033E-01	0.0023	4.347E-02	0.0010
Th-228	4.997E-01	0.0111	4.558E-02	0.0010	0.000E+00	0.0000	3.097E-03	0.0001	1.741E-04	0.0000	1.396E-05	0.0000	1.496E-03	0.0000
Th-232	1.692E+01	0.3754	9.026E+00	0.2003	0.000E+00	0.0000	5.737E+00	0.1273	2.256E-01	0.0050	2.789E-01	0.0062	2.826E-01	0.0063
Total	2.663E+01	0.5909	9.676E+00	0.2147	0.000E+00	0.0000	7.747E+00	0.1719	3.024E-01	0.0067	3.822E-01	0.0085	3.276E-01	0.0073

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
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.
Ra-228	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	1.205E+01	0.2673
Th-228	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	5.500E-01	0.0122
Th-232	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	3.247E+01	0.7205
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	4.507E+01	1.0000

*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
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.
Ra-228	5.683E-01	0.0134	3.867E-02	0.0009	0.000E+00	0.0000	1.067E-01	0.0025	4.194E-03	0.0001	5.648E-03	0.0001	2.615E-03	0.0001
Th-228	3.540E-04	0.0000	3.247E-05	0.0000	0.000E+00	0.0000	2.057E-06	0.0000	1.237E-07	0.0000	9.924E-09	0.0000	1.065E-06	0.0000
Th-232	2.449E+01	0.5760	9.536E+00	0.2243	0.000E+00	0.0000	6.823E+00	0.1605	2.750E-01	0.0065	3.463E-01	0.0081	3.181E-01	0.0075
Total	2.506E+01	0.5894	9.574E+00	0.2252	0.000E+00	0.0000	6.930E+00	0.1630	2.792E-01	0.0066	3.519E-01	0.0083	3.207E-01	0.0075

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
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.
Ra-228	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	7.261E-01	0.0171
Th-228	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	3.897E-04	0.0000
Th-232	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	4.179E+01	0.9829
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	4.251E+01	1.0000

*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
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.
Ra-228	2.413E-05	0.0000	1.706E-06	0.0000	0.000E+00	0.0000	3.485E-06	0.0000	1.565E-07	0.0000	2.125E-07	0.0000	1.153E-07	0.0000
Th-228	3.276E-15	0.0000	3.134E-16	0.0000	0.000E+00	0.0000	1.482E-17	0.0000	1.182E-18	0.0000	9.501E-20	0.0000	1.028E-17	0.0000
Th-232	2.403E+01	0.6075	9.550E+00	0.2415	0.000E+00	0.1000	5.115E+00	0.1293	2.378E-01	0.0060	2.994E-01	0.0076	3.197E-01	0.0081
Total	2.403E+01	0.6075	9.550E+00	0.2415	0.000E+00	0.0000	5.115E+00	0.1293	2.378E-01	0.0060	2.994E-01	0.0076	3.197E-01	0.0081

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
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.
Ra-228	9.812E-07	0.0000	3.332E-09	0.0000	0.000E+00	0.0000	1.942E-07	0.0000	2.154E-08	0.0000	3.585E-08	0.0000	3.104E-05	0.0000
Th-228	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	3.615E-15	0.0000
Th-232	1.484E-07	0.0000	5.020E-10	0.0000	0.000E+00	0.0000	2.937E-08	0.0000	3.260E-09	0.0000	5.424E-09	0.0000	3.955E+01	1.0000
Total	1.130E-06	0.0000	3.834E-09	0.0000	0.000E+00	0.0000	2.235E-07	0.0000	2.480E-08	0.0000	4.127E-08	0.0000	3.955E+01	1.0000

*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
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.
Ra-228	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	0.000E+00	0.0000
Th-228	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	0.000E+00	0.0000
Th-232	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	0.000E+00	0.0000
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	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 = 3.000E+02 years
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.
Ra-228	5.656E-16	0.0000	1.922E-18	0.0000	0.000E+00	0.0000	1.119E-16	0.0000	1.240E-17	0.0000	2.064E-17	0.0000	7.124E-16	0.0000
Th-228	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	0.000E+00	0.0000
Th-232	1.537E-06	0.7931	5.220E-09	0.0027	0.000E+00	0.0000	3.059E-07	0.1579	3.372E-08	0.0174	5.612E-08	0.0290	1.938E-06	1.0000
Total	1.537E-06	0.7931	5.220E-09	0.0027	0.000E+00	0.0000	3.059E-07	0.1579	3.372E-08	0.0174	5.612E-08	0.0290	1.938E-06	1.0000

*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
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.
Ra-228	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	0.000E+00	0.0000
Th-228	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	0.000E+00	0.0000
Th-232	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	0.000E+00	0.0000
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	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+03 years
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.
Ra-228	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	0.000E+00	0.0000
Th-228	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	0.000E+00	0.0000
Th-232	1.147E-07	0.7938	3.882E-10	0.0027	0.000E+00	0.0000	2.270E-08	0.1571	2.519E-09	0.0174	4.194E-09	0.0290	1.445E-07	1.0000
Total	1.147E-07	0.7938	3.882E-10	0.0027	0.000E+00	0.0000	2.270E-08	0.1571	2.519E-09	0.0174	4.194E-09	0.0290	1.445E-07	1.0000

*Sum of all water independent and dependent pathways.

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

Parent (i)	Product (j)	Branch Fraction	DSR(j,t) (mrem/yr)/(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
Ra-228	Ra-228	1.000E+00	4.092E+00	3.541E+00	2.650E+00	9.618E-01	5.307E-02	2.300E-06	1.423E-16	0.000E+00
Ra-228	Th-228	1.000E+00	0.000E+00	1.176E+00	2.148E+00	1.448E+00	9.216E-02	3.908E-06	2.105E-19	0.000E+00
Ra-228	ΣDSR(j)		4.092E+00	4.716E+00	4.798E+00	2.410E+00	1.452E-01	6.208E-06	1.425E-16	0.000E+00
Th-228	Th-228	1.000E+00	4.130E+00	2.874E+00	1.392E+00	1.100E-01	7.794E-05	7.231E-16	0.000E+00	0.000E+00
Th-232	Th-232	1.000E+00	1.749E+00	1.748E+00	1.748E+00	1.745E+00	1.739E+00	1.717E+00	0.000E+00	0.000E+00
Th-232	Ra-228	1.000E+00	0.000E+00	4.591E-01	1.198E+00	2.582E+00	3.239E+00	2.878E+00	3.867E-07	2.890E-08
Th-232	Th-228	1.000E+00	0.000E+00	7.787E-02	5.053E-01	2.167E+00	3.379E+00	3.314E+00	8.028E-10	0.000E+00
Th-232	ΣDSR(j)		1.749E+00	2.285E+00	3.451E+00	6.494E+00	8.357E+00	7.910E+00	3.875E-07	2.890E-08

Branch Fraction is the cumulative factor for the j'th principal radionuclide daughter: CUMBRF(j) = BRF(1)*BRF(2)* ... BRF(j).
The DSR includes contributions from associated (half-life ≤ 0.5 yr) daughters.

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 30 mrem/yr

Nuclide (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
Ra-228	7.331E+00	6.361E+00	6.252E+00	1.245E+01	2.066E+02	4.832E+06	*2.726E+14	*2.726E+14
Th-228	7.264E+00	1.044E+01	2.155E+01	2.727E+02	3.849E+05	*8.192E+14	*8.192E+14	*8.192E+14
Th-232	1.716E+01	1.313E+01	8.694E+00	4.620E+00	3.590E+00	3.793E+00	*1.096E+05	*1.096E+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 = 0.000E+00 years

Nuclide (i)	Initial pCi/g	tmin (years)	DSR(i,tmin)	G(i,tmin) (pCi/g)	DSR(i,tmax)	G(i,tmax) (pCi/g)
Ra-228	5.000E+00	2.070 ± 0.002	4.893E+00	6.132E+00	4.092E+00	7.331E+00
Th-228	5.000E+00	0.000E+00	4.130E+00	7.264E+00	4.130E+00	7.264E+00
Th-232	5.000E+00	36.29 ± 0.04	8.386E+00	3.577E+00	1.749E+00	1.716E+01

Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated
DOSE(j,t), mrem/yr

Nuclide (j)	Parent (i)	BRF(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
Ra-228	Ra-228	1.000E+00	2.046E+01	1.770E+01	1.325E+01	4.809E+00	2.654E-01	1.150E-05	7.114E-16*	0.000E+00
Ra-228	Th-232	1.000E+00	0.000E+00	2.296E+00	5.988E+00	1.291E+01	1.620E+01	1.439E+01	1.934E-06	1.445E-07
Ra-228	ΣDOSE(j):		2.046E+01	2.000E+01	1.924E+01	1.772E+01	1.646E+01	1.439E+01	1.934E-06	1.445E-07
Th-228	Ra-228	1.000E+00	0.000E+00	5.878E+00	1.074E+01	7.239E+00	4.608E-01	1.954E-05	1.052E-18	0.000E+00
Th-228	Th-228	1.000E+00	2.065E+01	1.437E+01	6.960E+00	5.500E-01	3.897E-04	3.615E-15	0.000E+00	0.000E+00
Th-228	Th-232	1.000E+00	0.000E+00	3.894E-01	2.526E+00	1.084E+01	1.689E+01	1.657E+01	4.014E-09	0.000E+00
Th-228	ΣDOSE(j):		2.065E+01	2.064E+01	2.023E+01	1.862E+01	1.736E+01	1.657E+01	4.014E-09	0.000E+00
Th-232	Th-232	1.000E+00	8.743E+00	8.741E+00	8.738E+00	8.727E+00	8.696E+00	8.586E+00	0.000E+00	0.000E+00

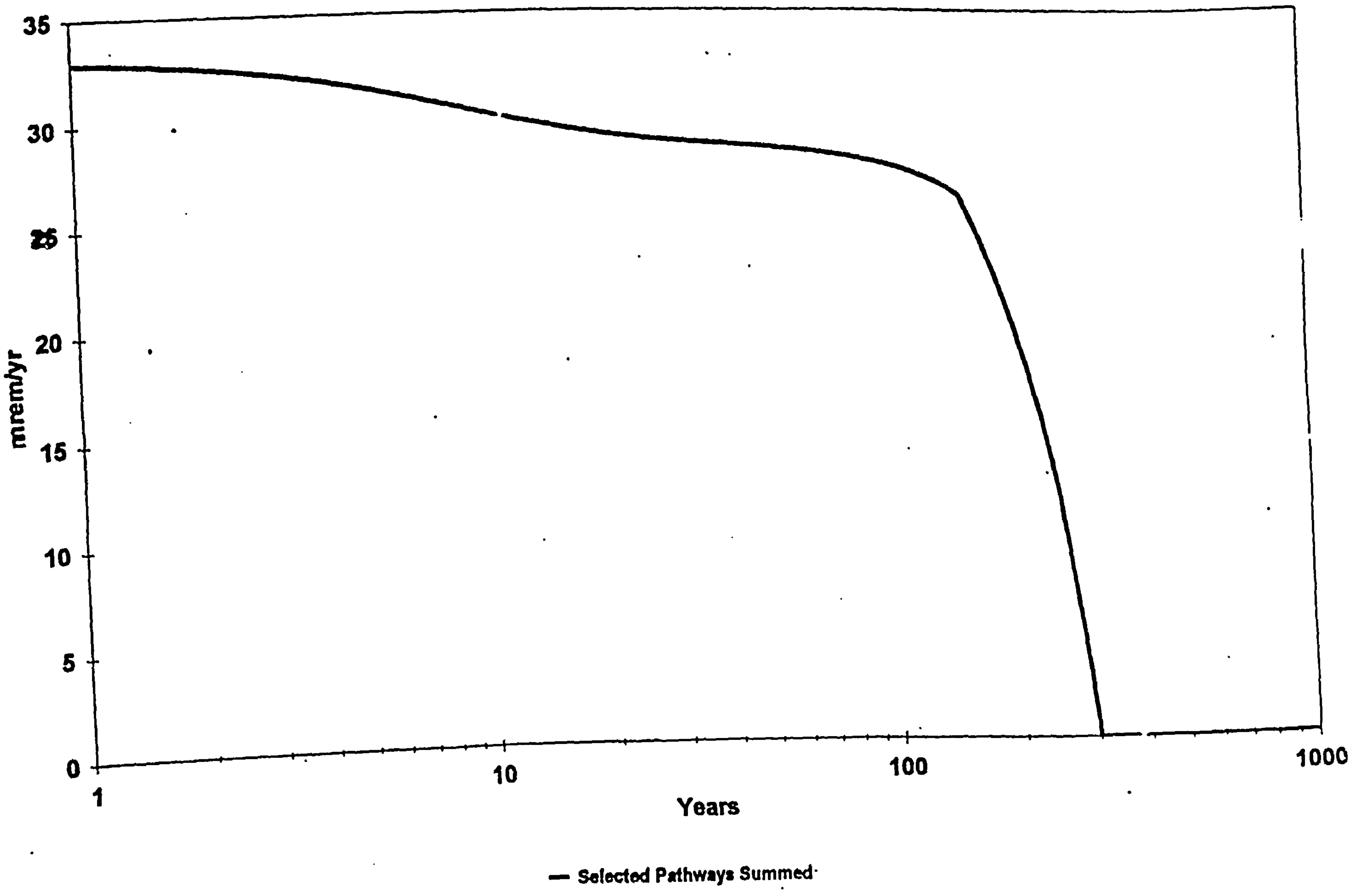
BRF(i) is the branch fraction of the parent nuclide.

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated
S(j,t), pCi/g

Nuclide (j)	Parent (i),	BRF(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
Ra-228	Ra-228	1.000E+00	5.000E+00	4.333E+00	3.253E+00	1.193E+00	6.794E-02	2.994E-06	1.073E-18	0.000E+00
Ra-228	Th-232	1.000E+00	0.000E+00	5.615E-01	1.470E+00	3.202E+00	4.147E+00	4.196E+00	4.174E+00	4.097E+00
Ra-228	ΣS(j):		5.000E+00	4.894E+00	4.723E+00	4.395E+00	4.215E+00	4.196E+00	4.174E+00	4.097E+00
Th-228	Ra-228	1.000E+00	0.000E+00	1.410E+00	2.592E+00	1.753E+00	1.122E-01	4.951E-06	1.775E-18	0.000E+00
Th-228	Th-228	1.000E+00	5.000E+00	3.480E+00	1.686E+00	1.335E-01	9.507E-05	9.175E-16	0.000E+00	0.000E+00
Th-228	Th-232	1.000E+00	0.000E+00	9.251E-02	6.074E-01	2.619E+00	4.109E+00	4.196E+00	4.174E+00	4.097E+00
Th-228	ΣS(j):		5.000E+00	4.982E+00	4.885E+00	4.505E+00	4.222E+00	4.196E+00	4.174E+00	4.097E+00
Th-232	Th-232	1.000E+00	5.000E+00	5.000E+00	5.000E+00	4.999E+00	4.996E+00	4.987E+00	4.960E+00	4.869E+00

BRF(i) is the branch fraction of the parent nuclide.

Dose for All Radionuclides



FALVER RAD 01/14/97 Includes All Pathways

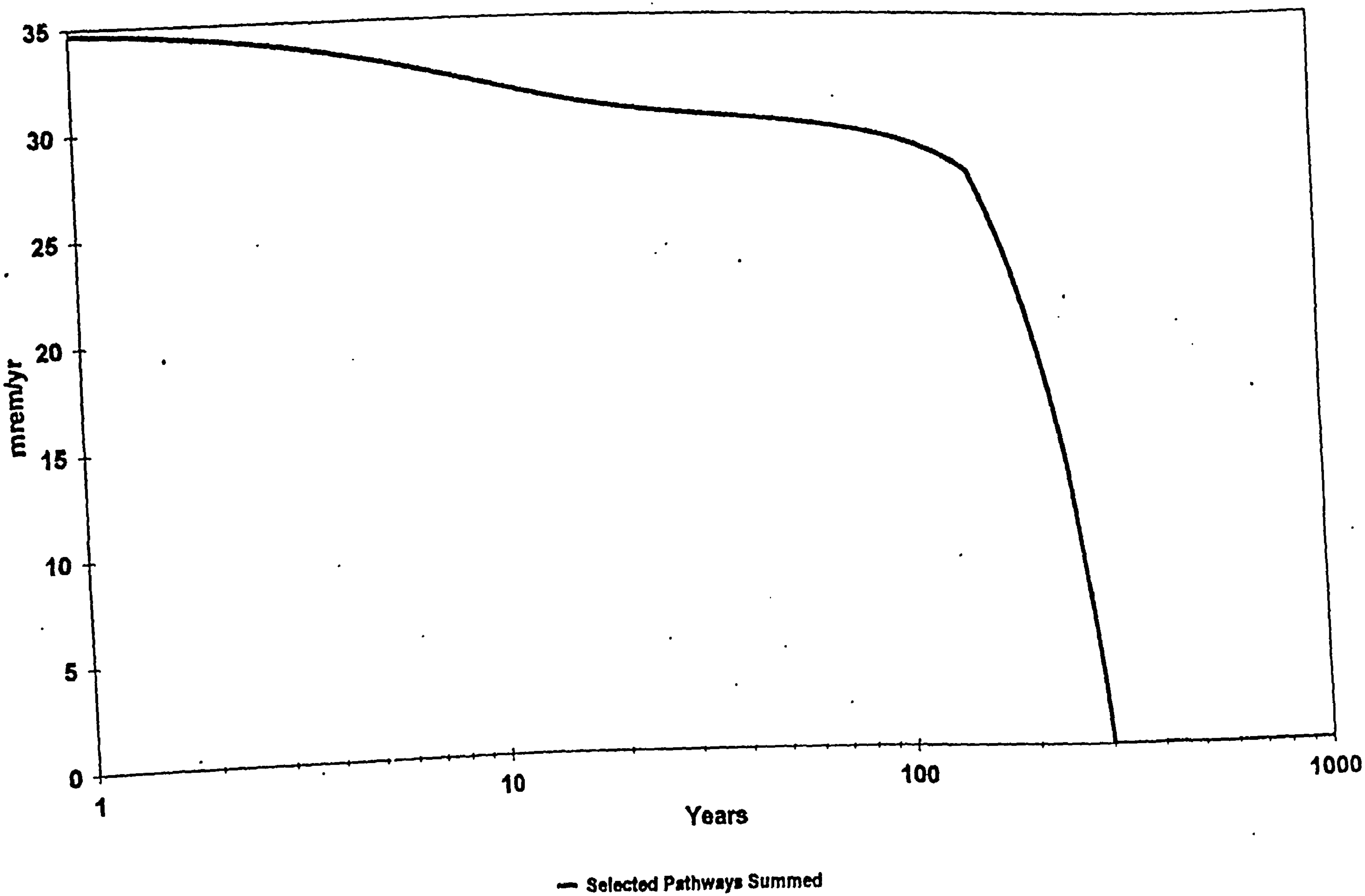
Contaminated Zone Dimensions		Initial Soil Concentrations, pCi/g	
Area:	100.00 square meters	Ra-228	5.000E+00
Thickness:	0.30 meters	Th-228	5.000E+00
Cover Depth:	0.00 meters	Th-232	5.000E+00

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 30 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):	3.319E+01	3.292E+01	3.223E+01	3.025E+01	2.875E+01	2.756E+01	1.255E-06	9.366E-08
M(t):	1.106E+00	1.097E+00	1.074E+00	1.008E+00	9.583E-01	9.188E-01	4.183E-08	3.122E-09

Maximum TDOSE(t): 3.319E+01 mrem/yr at t = 0.000E+00 years

Dose for All Radionuclides



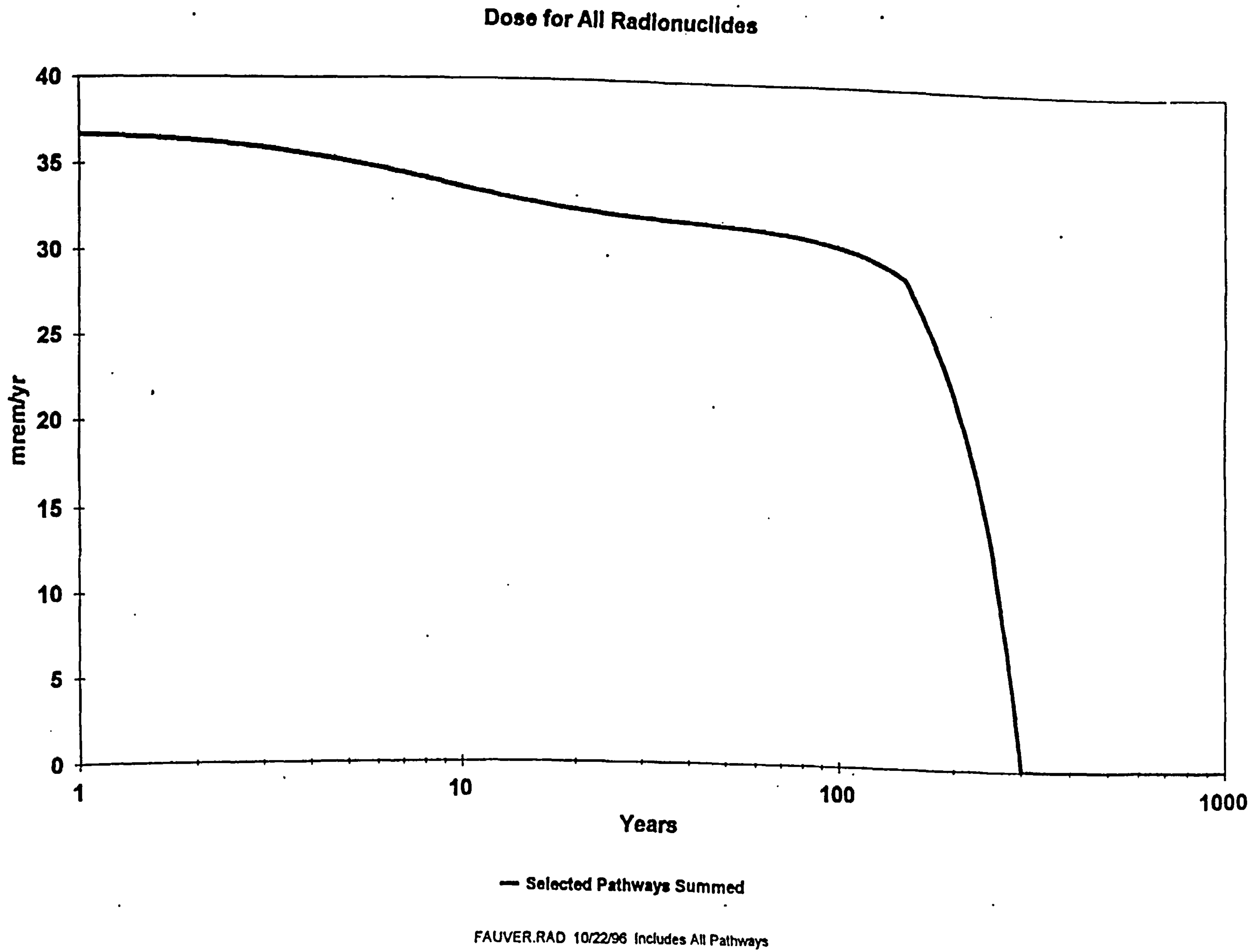
FAU /ER.RAD 01/14/97 Includes All Pathways

Contaminated Zone Dimensions		Initial Soil Concentrations, pCi/g	
Area:	150.00 square meters	Ra-228	5.000E+00
Thickness:	0.30 meters	Th-228	5.000E+00
Cover Depth:	0.00 meters	Th-232	5.000E+00

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 30 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):	3.499E+01	3.470E+01	3.397E+01	3.187E+01	3.029E+01	2.902E+01	1.558E-06	1.163E-07
M(t):	1.166E+00	1.157E+00	1.132E+00	1.062E+00	1.010E+00	9.672E-01	5.194E-08	3.877E-09

Maximum TDOSE(t): 3.499E+01 mrem/yr at t = 0.000E+00 years


Dose for All Radionuclides
40
35
30
25
20
15
10
5
0
mrem/yr
1
10
100
1000
Years
Selected Pathways Summed
FAUVER.RAD 10/22/96 Includes All Pathways

Contaminated Zone Dimensions	
Area:	225.00 square meters
Thickness:	0.30 meters
Cover Depth:	0.00 meters

Initial Soil Concentrations, pCi/g	
Ra-228	5.000E+00
Th-228	5.000E+00
Th-232	5.000E+00

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 30 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):	3.699E+01	3.668E+01	3.590E+01	3.368E+01	3.199E+01	3.058E+01	2.895E-07	2.160E-08
M(t):	1.233E+00	1.223E+00	1.197E+00	1.123E+00	1.066E+00	1.019E+00	9.650E-09	7.201E-10

Maximum TDOSE(t): 3.699E+01 mrem/yr   at t = 0.000E+00 years

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
Water Independent Pathways (Inhalation excludes radon)

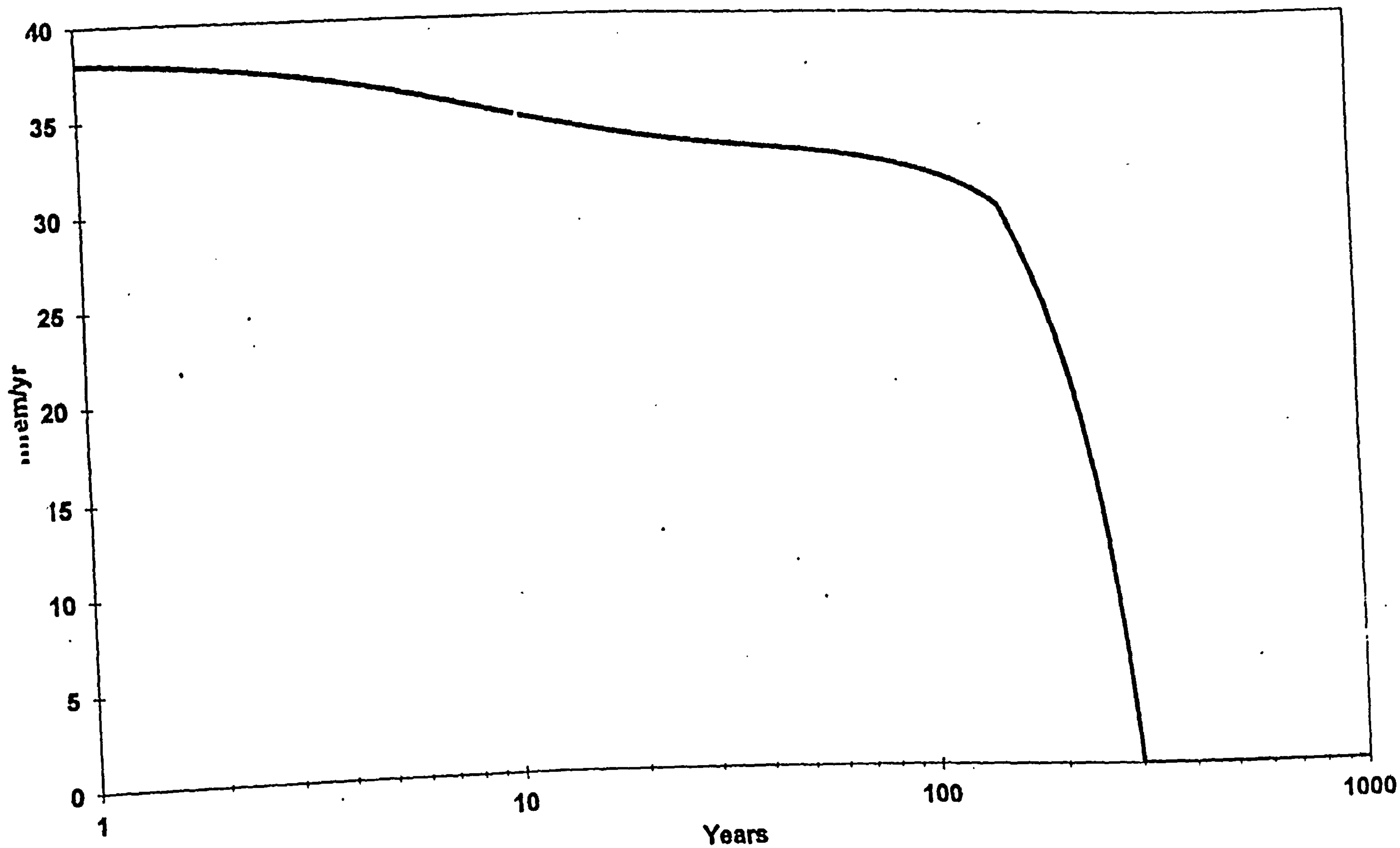
Radio-Nuclide	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	9.869E+00	0.2668	2.158E-02	0.0006	0.000E+00	0.0000	1.904E+00	0.0515	7.071E-03	0.0002	9.910E-03	0.0003	2.247E-02	0.0006
Th-228	1.655E+01	0.4474	1.466E+00	0.0396	0.000E+00	0.0000	2.691E-02	0.0007	1.469E-04	0.0000	1.178E-05	0.0000	1.261E-02	0.0003
Th-232	9.030E-04	0.0000	6.968E+00	0.1883	0.000E+00	0.0000	9.213E-02	0.0025	5.072E-04	0.0000	3.990E-05	0.0000	4.260E-02	0.0012
Total	2.642E+01	0.7142	8.455E+00	0.2285	0.000E+00	0.0000	2.023E+00	0.0547	7.725E-03	0.0002	9.961E-03	0.0003	7.768E-02	0.0021

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
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.
Ra-228	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	1.183E+01	0.3199
Th-228	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	1.806E+01	0.4881
Th-232	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	7.104E+00	0.1920
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	3.699E+01	1.0000

*Sum of all water independent and dependent pathways.

Dose for All Radionuclides



FAUVER.RAD 10/22/96 Includes All Pathways

Contaminated Zone Dimensions	
Area:	300.00 square meters
Thickness:	0.30 meters
Cover Depth:	0.00 meters

Initial Soil Concentrations, pCi/g	
Ra-228	5.000E+00
Th-228	5.000E+00
Th-232	5.000E+00

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 30 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):	3.833E+01	3.801E+01	3.719E+01	3.487E+01	3.310E+01	3.155E+01	3.917E-07	2.923E-08
M(t):	1.278E+00	1.267E+00	1.240E+00	1.162E+00	1.103E+00	1.052E+00	1.306E-08	9.742E-10

Maximum TDOSE(t): 3.833E+01 mrem/yr at t = 0.000E+00 years

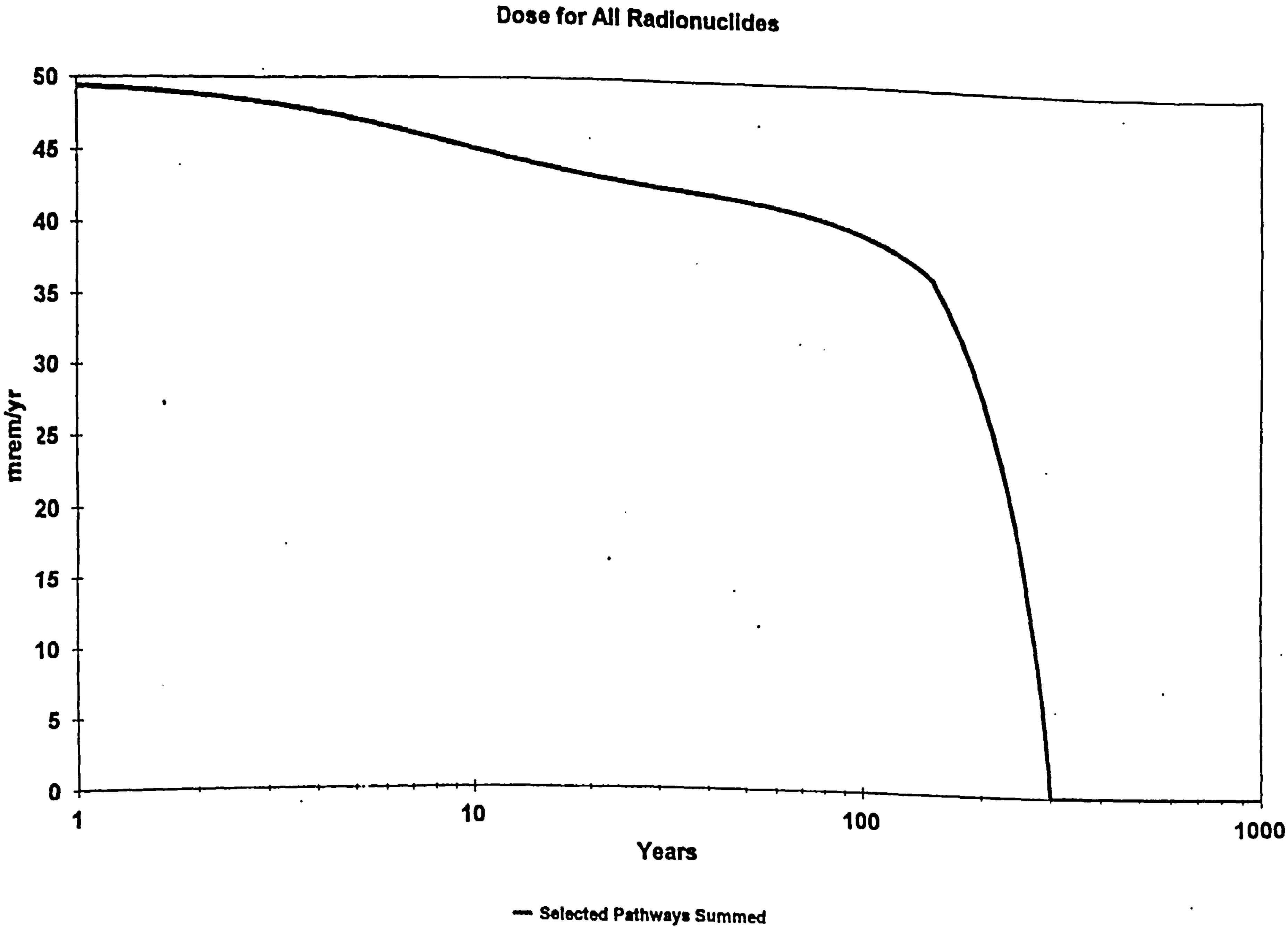
Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years
Water Independent Pathways (Inhalation excludes radon)

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.
Ra-228	1.002E+01	0.2615	2.208E-02	0.0006	0.000E+00	0.0000	2.539E+00	0.0662	9.429E-03	0.0002	1.321E-02	0.0003	2.996E-02	0.0008
Th-228	1.684E+01	0.4392	1.499E+00	0.0391	0.000E+00	0.0000	3.590E-02	0.0009	1.958E-04	0.0000	1.570E-05	0.0000	1.681E-02	0.0004
Th-232	9.119E-04	0.0000	7.127E+00	0.1859	0.000E+00	0.0000	1.229E-01	0.0032	6.763E-04	0.0000	5.320E-05	0.0000	5.680E-02	0.0015
Total	2.686E+01	0.7007	8.648E+00	0.2256	0.000E+00	0.0000	2.698E+00	0.0704	1.030E-02	0.0003	1.328E-02	0.0003	1.036E-01	0.0027

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
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.
Ra-228	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	1.264E+01	0.3297
Th-228	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	1.839E+01	0.4797
Th-232	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	7.308E+00	0.1906
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	3.833E+01	1.0000

*Sum of all water independent and dependent pathways.



FAUV :R.RAD 10/22/96 Includes All Pathways

Table of Contents

Part I: Mixture Sums and Single Radionuclide Guidelines

Dose Conversion Factor (and Related) Parameter Summary
File: DOSFAC.BIN

Menu	Parameter	Current Value	Default	Parameter Name
B-1	Dose conversion factors for inhalation, mrem/pCi:			
B-1	Ra-228+D	5.080E-03	5.080E-03	DCF2(1)
B-1	Th-228+D	3.450E-01	3.450E-01	DCF2(2)
B-1	Th-232	1.640E+00	1.640E+00	DCF2(3)
D-1	Dose conversion factors for ingestion, mrem/pCi:			
D-1	Ra-228+D	1.440E-03	1.440E-03	DCF3(1)
D-1	Th-228+D	8.080E-04	8.080E-04	DCF3(2)
D-1	Th-232	2.730E-03	2.730E-03	DCF3(3)
D-34	Food transfer factors:			
D-34	Ra-228+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(1,1)
D-34	Ra-228+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(1,2)
D-34	Ra-228+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(1,3)
D-34				
D-34	Th-228+D , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(2,1)
D-34	Th-228+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(2,2)
D-34	Th-228+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(2,3)
D-34				
D-34	Th-232 , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(3,1)
D-34	Th-232 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(3,2)
D-34	Th-232 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(3,3)
D-5	Bioaccumulation factors, fresh water, L/kg:			
D-5	Ra-228+D , fish	5.000E+01	5.000E+01	BIOFAC(1,1)
D-5	Ra-228+D , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(1,2)
D-5				
D-5	Th-228+D , fish	1.000E+02	1.000E+02	BIOFAC(2,1)
D-5	Th-228+D , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(2,2)
D-5				
D-5	Th-232 , fish	1.000E+02	1.000E+02	BIOFAC(3,1)
D-5	Th-232 , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(3,2)

Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R011	Area of contaminated zone (m**2)	1.000E+04	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	3.000E-01	2.000E+00	---	THICK0
R011	Length parallel to aquifer flow (m)	1.000E+02	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	3.000E+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): Ra-228	5.000E+00	0.000E+00	---	S1(1)
R012	Initial principal radionuclide (pCi/g): Th-228	5.000E+00	0.000E+00	---	S1(2)
R012	Initial principal radionuclide (pCi/g): Th-232	5.000E+00	0.000E+00	---	S1(3)
R012	Concentration in groundwater (pCi/L): Ra-228	not used	0.000E+00	---	W1(1)
R012	Concentration in groundwater (pCi/L): Th-228	not used	0.000E+00	---	W1(2)
R012	Concentration in groundwater (pCi/L): Th-232	not used	0.000E+00	---	W1(3)
R013	Cover depth (m)	0.000E+00	0.000E+00	---	COVER0
R013	Density of cover material (g/cm**3)	not used	1.500E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	not used	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.630E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	1.000E-03	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	3.000E-01	4.000E-01	---	TPCZ
R013	Contaminated zone effective porosity	2.000E-01	2.000E-01	---	EPCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	1.000E+01	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter	5.300E+00	5.300E+00	---	BCZ
R013	Humidity in air (g/cm**3)	not used	8.000E+00	---	HUMID
R013	Evapotranspiration coefficient	5.000E-01	5.000E-01	---	EVAPTR
R013	Precipitation (m/yr)	1.000E+00	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	7.600E-01	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	2.000E-01	2.000E-01	---	RUNOFF
R013	Watershed area for nearby stream or pond (m**2)	1.000E+06	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)	1.630E+00	1.500E+00	---	DENSAQ
R014	Saturated zone total porosity	3.000E-01	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	2.000E-01	2.000E-01	---	EPSZ
R014	Saturated zone hydraulic conductivity (m/yr)	1.000E+02	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	2.000E-02	2.000E-02	---	HGWT
R014	Saturated zone b parameter	5.300E+00	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	0.000E+00	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	1.000E+01	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	ND	ND	---	MODEL
R014	Well pumping rate (m**3/yr)	2.500E+02	2.500E+02	---	UW

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R015	Number of unsaturated zone strata	1	1	---	NS
R015	Unsat. zone 1, thickness (m)	1.000E+00	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	1.630E+00	1.500E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	3.000E-01	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	2.000E-01	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	5.300E+00	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	1.000E+01	1.000E+01	---	HCUZ(1)
R016	Distribution coefficients for Ra-228				
R016	Contaminated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCC(1)
R016	Unsaturated zone 1 (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCU(1,1)
R016	Saturated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCS(1)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.274E-02	ALEACH(1)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(1)
R016	Distribution coefficients for Th-228				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(2)
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCU(2,1)
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCS(2)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.658E-05	ALEACH(2)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(2)
R016	Distribution coefficients for Th-232				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(3)
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCU(3,1)
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCS(3)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.658E-05	ALEACH(3)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(3)
R017	Inhalation rate (m**3/yr)	1.051E+04	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	2.000E-04	2.000E-04	---	MLINH
R017	Dilution length for airborne dust, inhalation (m)	3.000E+00	3.000E+00	---	LM
R017	Exposure duration	3.000E+01	3.000E+01	---	ED
R017	Shielding factor, inhalation	5.000E-01	4.000E-01	---	SHF3
R017	Shielding factor, external gamma	3.300E-01	7.000E-01	---	SHF1
R017	Fraction of time spent indoors	5.500E-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	1 shows circular AREA.	FS

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
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)
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)	1.660E+02	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	1.100E+01	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	1.000E+02	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)	5.400E+00	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	9.000E-01	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	1.825E+01	3.650E+01	---	SOIL
R018	Drinking water intake (L/yr)	7.300E+02	5.100E+02	---	DWI
R018	Contamination fraction of drinking water	1.000E+00	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	1.000E+00	1.000E+00	---	FIRW
R018	Contamination fraction of aquatic food	5.000E-01	5.000E-01	---	FR9
R018	Contamination fraction of plant food	-1	-1	0.500E+00	FPLANT
R018	Contamination fraction of meat	-1	-1	0.500E+00	FMEAT
R018	Contamination fraction of milk	-1	-1	0.500E+00	FMILK
R019	Livestock fodder intake for meat (kg/day)	6.800E+01	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	5.500E+01	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)	1.600E+02	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

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	9.000E-01	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	1.000E+00	1.000E+00	---	FGWDW
R019	Household water fraction from ground water	1.000E+00	1.000E+00	---	FGWHH
R019	Livestock water fraction from ground water	not used	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	1.000E+00	1.000E+00	---	FGWIR
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	---	FLOOR
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 annual wind speed (m/sec)	not used	2.000E+00	---	WIND
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)

B

APPENDIX B

MACTEC DOCUMENT

Method for Surveying and Averaging Concentrations of Radioactivity in Potentially Contaminated Subsurface Soil, Molycorp's York, PA Site

TECHNICAL BASIS DOCUMENT

METHOD FOR SURVEYING AND AVERAGING CONCENTRATIONS OF RADIOACTIVITY IN POTENTIALLY CONTAMINATED SUBSURFACE SOIL

MOLYCORP'S YORK PA SITE
SOILS REMEDIATION PROJECT

Prepared for:
MOLYCORP, INC.
350 NORTH SHERMAN STREET
YORK, PA 17402

Prepared by:
MACTEC Development Corp., Inc.
751 Horizon Court, Suite 104
Grand Junction, Colorado 81506

February, 2003

METHOD FOR SURVEYING AND AVERAGING CONCENTRATIONS OF RADIOACTIVITY IN POTENTIALLY CONTAMINATED SUBSURFACE SOIL

Molycorp, Inc. Soils Remediation Project
York, PA

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EXECUTIVE SUMMARY

Current U.S. Nuclear Regulatory Commission (NRC) guidance for conducting final surveys at decommissioning facilities is contained in:

- NUREG 1575, "*Multi-Agency Radiation Survey and Site Investigation Manual*" (NRC 2000), for sites currently entering the decommissioning phase of site operations, and

- Draft NUREG/CR-5849, "*Manual for Conducting Surveys in Support of License Termination*" (NRC 1992), for Sites being decommissioned under the NRC's Site Decommissioning Management Plan (SDMP) and with decommissioning plans approved prior to August 20, 1999 (NRC 1997a)

While both of these guidance documents provide guidance for performing surveys and sampling of areas having residual radioactivity in surface soils, neither discusses methods for surveying and averaging residual radioactivity in subsurface soils.

In 1997, the NRC, in connection with their review of the "*Site Remediation Plan for the Former Brooks and Perkins, Inc. Site,*" produced a technical basis document that supplements the guidance in Draft NUREG/CR-5849 and established an NRC approved method for surveying and averaging concentrations of residual radioactivity in subsurface soils. The technical basis document is titled "*Method for Surveying and Averaging Concentrations of Thorium in Contaminated Subsurface Soil*" and is often referred to as the AAR method (NRC 1997).

The approved *Decommissioning Plan for the York, PA Facility* (Molycorp 1999) specifically cites the supplemental NRC guidance (NRC 1997) in the section itemizing the unrestricted use limits for soil and slag. Because the isotopes present at the York, PA facility are not completely consistent with those evaluated by the NRC in establishing the supplemental guidance (specifically for the AAR site), a site-specific evaluation of the subsurface soil averaging criteria is warranted. This report documents the technical basis for applying the AAR method to the evaluation of subsurface residual radioactivity at the York, PA site being decommissioned by Molycorp, Inc.

1.0 INTRODUCTION

The approved *Decommissioning Plan for the York, PA Facility* (Molycorp 1999) specifically cites supplemental NRC guidance (NRC 1997) in the section itemizing the unrestricted use limits for soil and slag. Because the isotopes present at the York, PA facility are not completely consistent with those evaluated by the NRC in its supplemental guidance, a site-specific evaluation of the subsurface soil averaging criteria is warranted. This report documents the technical basis for applying the NRC's supplemental guidance on surveying and averaging of residual radioactivity in subsurface soils to the final radiological status survey of subsurface residual radioactivity at the York, PA site being decommissioned by Molycorp, Inc.

1.1 BACKGROUND

Current NRC general guidance for conducting final radiological status surveys at decommissioning sites and facilities (NRC 1992, NRC 2000) specifically addresses measurement and averaging criteria for "surface" radioactivity of both land areas and buildings but does not speak to the acceptable criteria or averaging methods for demonstrating that residual radioactivity in subsurface soils is within the approved guideline limits. In the absence of general guidance on how to deal with residual radioactivity in subsurface soils, the NRC prepared a technical basis document specifically describing an acceptable method for surveying and averaging concentrations of residual radioactivity in subsurface soils. The technical basis document (NRC 1997) was prepared in conjunction with the NRC's review of the AAR Site's *"Site Remediation Plan for the Former Brooks and Perkins, Inc. Site."* It provides the technical rationale for demonstrating compliance with the approved decommissioning standards when residual radioactivity is present (or potentially present) in subsurface soils and thus supplements the general guidance published by the NRC. However, rather than provide generally applicable guidance, the NRC's technical basis document focuses specifically on the application of the methodology for the AAR site and its suite of radionuclides. Thus, it is necessary to derive a set a site-specific criteria for addressing subsurface residual radioactivity applicable to Molycorp's York, PA site using the same logic and methods applied by the NRC to the AAR site.

1.2 GENERAL SITE DESCRIPTION

The Molycorp, Inc. York, PA Facility is situated on the outskirts of the City of York, PA at 350 North Sherman St., in Spring Garden Township, PA. The active site consists of approximately six fenced acres bounded by Olive St. to the north, Hudson St. to the west, N. Sherman St. to the east, and by the Norfolk and Southern Railroad track to the south.

The site was used by Molycorp, Inc. to produce a broad line of inorganic rare earth chemicals used to make catalysts for the chemical industry and for various other industrial purposes. The rare earth processing plant was part of the facility that had raw material containing naturally occurring uranium and thorium. In 1981, Molycorp acquired a radioactive source materials license, SMB-1408, in compliance with applicable federal regulation and based upon the quantity and concentrations of thorium in rare earth materials being processed at the site (NRC 1981).

1.3 CURRENT SITE CONDITIONS

All of the buildings and structures that were at one time in place at the site have since been radiologically surveyed and removed. Approximately two-thirds of the site (~ 4 acres) have already been released from radiological controls by the NRC based upon extensive excavation of subsurface materials and the application of the surface soil concentration limits to subsurface soils. While the approved decommissioning plan (DP) for the site (Molycorp 1999) specifically says that "subsurface soils and slag will be surveyed and averaged to demonstrate compliance with the unrestricted use limits *using the [AAR Method]*...," it was not employed by Molycorp's remediation contractor to achieve the release decision (italics ours). The conservatism introduced by applying surface soil concentration guidelines, surface soil measurement methods, and surface soil averaging criteria to subsurface soils led to significant over excavation and waste disposal costs.

The remaining portion of the site for which compliance with the release criteria have not been demonstrated (~ 2 acres) will be surveyed in accordance with the requirements of the approved DP in order to demonstrate compliance with the specified unrestricted release criteria, including the requirement for subsurface soils to be surveyed and averaged using the approved AAR method developed in NRC supplemental guidance (NRC 1997).

1.4 CONCEPTUAL BASIS FOR THE AAR SUBSURFACE SOIL ASSESSMENT METHOD

The NRC acknowledged that the averaging method in NUREG/CR-5849 assumes that soil samples and measurements collected from the ground surface are sufficiently representative to assess the potential dose to a receptor but that the NUREG/CR-5849 surface soil sampling and averaging method may not be appropriate if significant subsurface contamination is present (NRC 1997).

Conventional pathway analysis concludes that the dose from subsurface contamination at depths deeper than approximately 0.3 meters is essentially zero (except dose that might arise from radioactivity in subsurface soil migrating downward and impacting the groundwater pathway). This conclusion assumes that residual radioactivity in subsurface soil will remain at depth over the period considered in the analysis. Depending upon the site specific conditions, it may not be reasonable to assume that subsurface soil will remain undisturbed for a 1000 year period, the evaluation period considered in determining whether a site has met the criteria for decommissioning. Therefore, in considering the potential impact that residual radioactivity in subsurface soils might have on future exposures at the site, a range of simple scenarios were developed to predict: 1) how subsurface soil might be excavated in the future, 2) the volume of the soil that might reasonably be expected to be excavated, and 3) the dose consequences of the contaminated soil in the post-excavation geometry. Based on these predicted excavation volumes and dose consequences, the NRC developed a surveying and averaging protocol for in-situ subsurface soil at the AAR site.

The basic concept and precepts of the NRC approved method rely upon a comparative dose evaluation of the potential future dose to a receptor. First, the dose to a hypothetical receptor is calculated assuming that the surface soil at the site is uniformly contaminated with residual radioactivity at the approved surface soil activity limit and over what is in effect an infinite area.[1] This calculated potential dose serves as the baseline against which the exposure potential to the receptor from a variety of scenarios in which subsurface radioactivity is brought to the surface is compared. As the amount of subsurface radioactivity brought to the surface decreases, the areal size impacted by such actions also decreases and thus the potential dose consequence is correspondingly reduced. By calculating the potential future dose resulting from a range of scenarios in which varying amounts of subsurface soils having residual radioactivity are brought to the surface and then comparing these with the baseline dose from an infinite "slab" of surface soils, the NRC was able to arrive at factors (or increments) by which the residual radioactivity concentration in subsurface soil might exceed the specified surface soil guideline values without compromising the protectiveness of the release decision.

The basic process can be summarized in the five major steps outlined below. The subsequent sections of this technical basis document correspond to these major steps in the process.

- Development of a range of potential future excavation scenarios in order bound the relative potential exposure from subsurface radioactivity that might be brought to the surface.
- Description of the Site-Specific Source Term
- Performance of dose modeling to provide the basis for comparison of the potential future dose from subsurface residual radioactivity to that produced by residual radioactivity in surface soil.
- Derivation of averaging criteria for subsurface soils
- Development of the survey method for subsurface residual radioactivity

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1 This represents the worst case hypothetical condition that might exist and still satisfy the approved surface soil concentration guidelines using the methods and techniques described in NUREG/CR-5849 (NRC 1992).

2.0 TECHNICAL BASIS FOR SUBSURFACE AVERAGING CRITERIA

The technical basis developed in this paper follows that developed and described by the NRC in conjunction with their review of the AAR Site's *"Site Remediation Plan for the Former Brooks and Perkins, Inc. Site."* It provides the technical rationale for demonstrating compliance with the approved decommissioning standards when residual radioactivity is present (or potentially present) in subsurface soils and thus supplements the surface soil guidance published by the NRC (NRC 1992).

2.1 EXCAVATION SCENARIOS

It was conceived that excavation of soils at the site might likely be associated with the placement of the foundation for a house. The averaging method described in NUREG/CR-5849 specifies that the average residual radioactivity concentration over any 100 m^2 area should be less than the approved release criteria. The 100 m^2 area averaging limit was intended to address the potential for a 10 m by 10 m house being built on the 100 m^2 parcel of land (NRC 1997). Considering the variety of foundation types that could be employed, a range of potential excavation scenarios from a slab-on-grade house to a house with a full basement was evaluated. For each of the excavation scenarios, the volume of excavated soil and the extent of surface spreading, as well as the depth of surfaces on which the foundation could be built, were estimated. The potential dose from the subsurface soil, after excavation, was estimated by calculating the dose from the contaminated soil spread on the ground surface.

2.1.1 Evacuation Assumptions

- House size is assumed to be 10 m by 10 m (100 m^2, 1075 ft^2)
- A house with a spanned floor and crawl space built on a stem wall foundation would result in the excavation of a perimeter trench 1 meter deep and 1 meter wide with each side being 10 meters in length.
- The depth of the excavation needed to build a house with a full basement is 3 meters
- The smallest volume of soil that could be excavated from a subsurface layer without mixing with surrounding soil is limited by the bucket size of the excavation equipment, and assumed to be 1 m^3.
- Each excavated pile is uniformly blended
- Each pile is subsequently spread over the ground surface in a 1 foot thick lift.

2.1.2 Excavation Volumes Evaluated

Based upon the excavation assumptions described above and the fundamental assumption that the size of a residential house is 100 m^2, the volumes of subsurface soils that must be considered in deriving subsurface soil concentration limits and averaging criteria ranges from 1 m^3 up to 300m^3. In the technical basis document derived for the AAR Site (NRC 1997), the NRC evaluated a discrete set of five excavation volumes corresponding to excavation assumptions identical to those presented in section 2.1.1 above and itemized in Table 2-1. As described in the NRC's technical basis document for the AAR site, "the excavation scenarios described (in Table 2-1) for housing construction are assumed to result in conservative averaging criteria since excavations for larger structures should result in larger excavated volumes, and a greater degree of mixing with surrounding soil." In reality, these are discrete points on a response curve that describes the relationship between the areal size of a soil deposit having residual radioactivity at a fixed concentration and the potential radiation dose it might produce.

Table 2-1 Excavation Volumes Considered in the AAR Technical Basis Document

	Foundation Type	Description	Volume	Area[1]
1	Stem wall w/crawl space	Each of four 1 m deep by 1 m wide by 10 m long trenches excavated for footers and stem wall is placed in a separate pile	10 m^3	33 m^2
2	Stem wall w/crawl space	The 1 m deep by 10 m wide by 10 m long footprint for a house with no basement is excavated and placed in a single pile	100 m^3	333 m^2
3	Full Basement	Each of four 3 m deep by 2.5 m wide by 10 m long portions of soil for a full basement are excavated and placed in a separate pile.	75 m^3	250 m^2
4	Full Basement	The entire soil volume from an excavation 3 m deep by 10 m wide by 10 m long for a full basement foundation is placed in a single pile	300 m^3	1000 m^2
5	One bucket	One bucket (1 m x 1 m x 1 m) of excavated soil is placed in a single pile.	1 m^3	3.3 m^2

1 Assumes that the volume of soil is spread out over the ground surface in a one foot (0.3 meter) thick lift. These are the source term dimensions used in the RESRAD calculations. The baseline RESRAD calculation is based on a source term that is 0.3 meters thick and distributed over an area of 10,000 m^2 (effectively infinite).

This technical basis document likewise considers the discrete excavation volumes previously considered by the NRC, but in addition considers 18 other soil volumes in order to generate enough data in the region where the slope of the curve is rapidly changing to graphically construct the dose response (Appendix A). In this way, the subsurface soil averaging criteria for any hypothesized excavation volume can be readily determined.

2.2 SITE SPECIFIC SOURCE TERM

The source term in soil at Molycorp's York, PA facility consists of relatively insoluble forms of natural uranium and thorium series radionuclides in soils. Prior characterization and remediation efforts at the site have shown that residual radioactivity is present in soils on the site at depths greater than is considered in the sampling and survey method specified in NUREG/CR-5849 (NRC 1992). While residual radioactivity in soils deeper than approximately 0.3 meters produces little radiological dose to a potential receptor provided it remains in the subsurface position (due to the self-attenuating effect of the overlying soil layer), the possibility exists that subsurface soils might be brought to the surface as a result of human activities such as excavation. To ascertain the potential dose consequence associated with bringing subsurface deposited residual radioactivity to the surface where exposure might occur, it is conservatively assumed that a subsurface soil brought to the surface is uniformly spread on the ground surface in a 0.3 meter thick lift. Thus, the physical configuration of each source term modeled and evaluated, regardless of its origin of depth, is defined by the volume distributed over the area corresponding to a 0.3 meter thick source. RESRAD assumes that the source is cylindrical in shape with the thickness describing the height of the right cylinder. The receptor is assumed to be exposed at the center of the circular ellipse. The receptor to source term geometry as portrayed in Figure 2-1 is evaluated for a series of source sizes, the largest representing an essentially infinite geometry corresponding to 10,000 m^2.

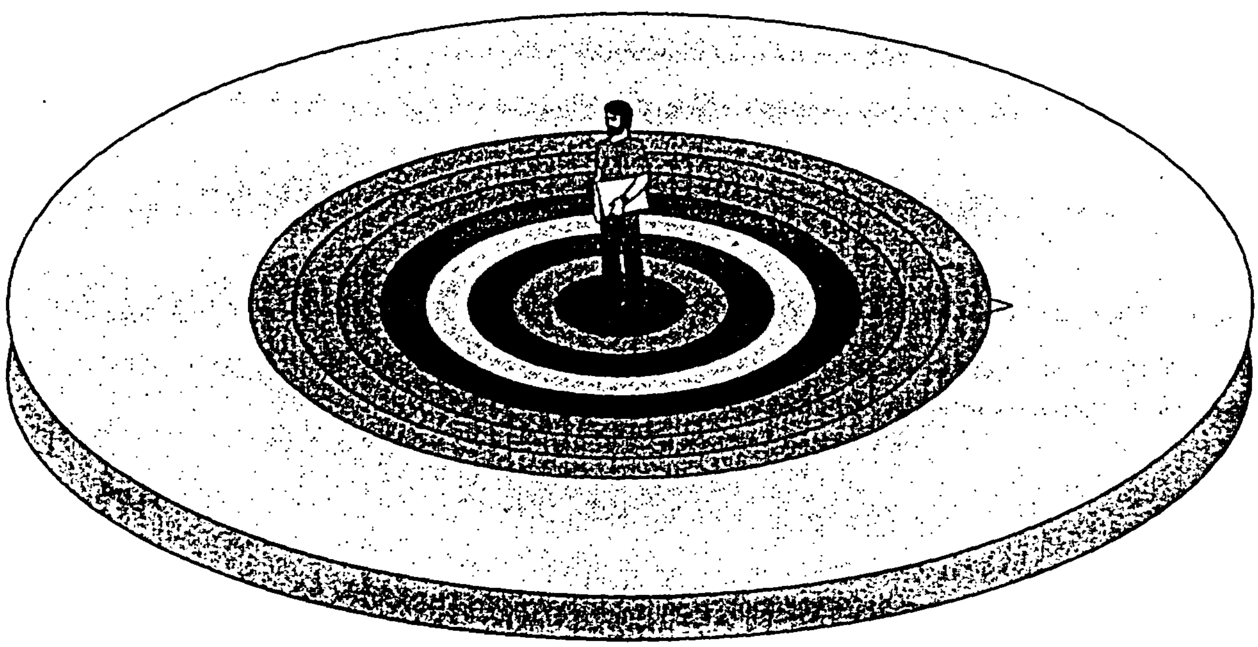

Figure 2-1 Physical Configuration of Source Term

The York, PA site decommissioning plan (Molycorp 1999) specifies the approved unrestricted use limits for concentrations of residual radioactivity in soil and slag as follows:

- 10 pCi/g average[2] Total Thorium (Th-232 + Th-228)
- 10 pCi/g average Natural Uranium (U-238 + U-234, assuming all daughters in equilibrium and includes 5 pCi/g Ra-226)
- 5 pCi/g average [excess] Ra-226

Since there are essentially three soil concentration limits applicable to the York, PA site, three separate sets of evaluations are needed in order to apply the AAR methodology (NRC 1997) to the York site. To accommodate this, three distinct isotopic profiles were used; one for each of the three isotopic concentration limits described above.

Thorium 232 and 228 are assumed to be in secular equilibrium. The isotopic profile for the thorium source term contains 5 pCi/g each of Th-232, Th-228, and Ra-228 (Figure 2-2). That Ra-228 is included in the source term is an artifact of the way RESRAD accounts for radionuclides having radioactive parents and progeny. Even though Ra-228 is not part of the stated thorium concentration limit, it is present in thorium bearing soils. Further, its inclusion in the source term is appropriate since the AAR method (NRC 1997) establishes ratios based on the ability of the source term to produce dose, and the most conservative derivation assumes that radioactive decay series are in secular equilibrium.

2. All soil concentration averages are expressed as the average over a 100 m2 grid area.

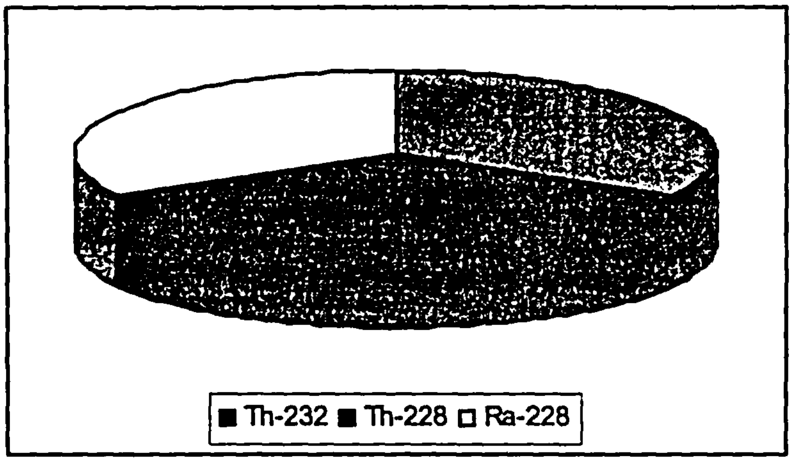

Figure 2-2 Isotopic Composition of Thorium Source Term

Uranium 234 and 238 isotopes are likewise presumed to be in secular equilibrium. Uranium 235 is not identified as a contaminant of concern. The isotopic profile for the uranium source term contains 5 pCi/g each of U-238, U-234, Th-230, Ra-226 and Pb-210 (Figure 2-3). Again, the source term used reflects the limiting assumption of secular equilibrium.

The third source term includes Ra-226 alone with a concentration in soil equal to 5 pCi/g.

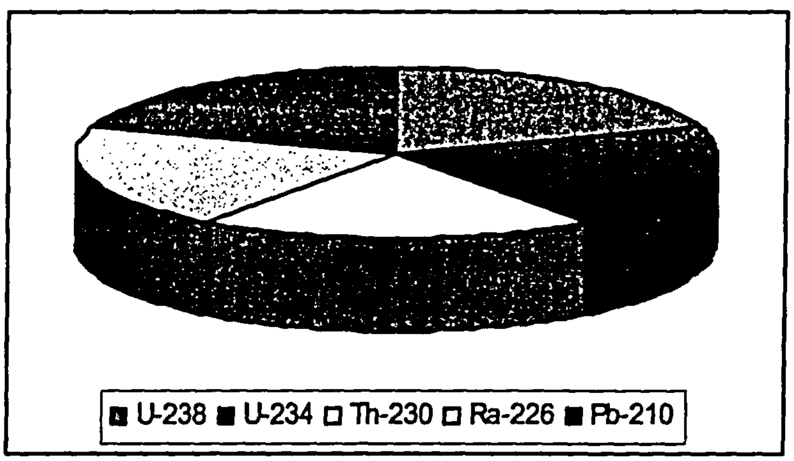

Figure 2-3 Isotopic Composition of Uranium Source Term

2.3 DOSE MODELING

Dose modeling, using the site specific suite of radionuclides at the York site is used to arrive at site specific averaging criteria for the site. This is in lieu of the default averaging criteria specified in NUREG/CR-5849 (NRC 1992) and in order to establish subsurface soil residual radioactivity concentration limits that are as protective as those already approved for surface soils in the site decommissioning plan (Molycorp 1999). The area averaging criteria in NUREG/CR-5849 specifies that the concentration of residual radioactivity in an area with elevated radioactivity should not be greater than $(100/A)^{1/2}$ times allowable average release criteria, where "A" is the size of the elevated area in m^2 and is further limited (based primarily on traditional practice) to a maximum concentration of less than 3 times the allowable average concentration limit.

These averaging criteria were taken from a dose assessment made in 1985 for the Department of Energy (DOE) using the DOE's *Manual for Implementing Residual Radioactivity Guidelines* (Yu 1993). In that assessment, the dose from elevated areas of various sizes was estimated using default input parameters to the RESRAD code. This early study concluded that dose is reduced as the area of contamination is reduced, assuming the same concentration of radioactivity.

The extent of the reduction in dose as a function of area depends on whether the predominant dose pathway is from direct exposure, or from one or more of the other possible pathways such as inhalation or ingestion. In general, there is a greater dose reduction for elevated areas containing radionuclides that deliver a significant fraction of the dose through the inhalation and ingestion pathway than for radionuclides that deliver a higher fraction of dose via the direct exposure (from penetrating gamma radiation) pathway.

The area averaging formula recommended in NUREG/CR-5849 (NRC 1992) was arrived at by evaluating a broad spectrum of radionuclides considering the relationship between dose and size of elevated area. It was determined that the $(100/A)^{1/2}$ relationship would conservatively bound the concentration of residual radioactivity in an area of size "A" for all radionuclides evaluated such that localized concentrations of elevated radioactivity would not likely result in a dose greater than the allowable average concentration over an area of 100 m^2 (NRC 1997). A comparable dose assessment (the essence of the AAR method, and this technical basis document) for site specific radionuclides will typically show that a less conservative, yet appropriate relationship exists between dose and size of area having elevated concentrations of residual radioactivity.

The dose modeling code RESRAD, Version 6.21 (Yu 2002) was used to calculate the dose that would result from various sizes of 0.3 meter thick, right cylinder, source term geometries (See Figure 2-1). In developing the AAR methodology originally, the NRC used RESRAD version 5.62 (Yu 1996), which was the current version available at the time (NRC 1997). As a first step in developing the technical basis for applying the AAR method at the York, PA site, RESRAD 6.21 was benchmarked with version 5.62 using the same input parameter set, most of which are assigned the default value[3]. While some minor differences exist between the two versions, the resulting doses projected by the two versions of RESRAD are nearly identical with differences less than 1 mrem per year. More importantly, when the baseline case (10,000 m^2) using version 6.21 is compared with the volume specific cases presented in the NRC's technical basis document (NRC 1997) and again using version 6.21, the area factors were identical for the thorium series radionuclides[4]. This indicates that in spite of minor dose projection differences between generations of the RESRAD code, the same area factor result is achieved using either version, and thus RESRAD Version 6.21 is shown to be functionally equivalent to version 5.62 previously used by the NRC.

Three separate RESRAD input files were created in order to perform the dose modeling; one for each of the three distinct radionuclide compositions described above (See Figure 2-2 and Figure 2-3). In each case, the radionuclide concentration was set at 5 pCi/g—corresponding to the activity limit from the approved decommissioning plan (Molycorp 1999). All other input parameters were set equal to those used by the NRC in developing the AAR method (NRC 1997) or the RESRAD default value was used. Dose modeling was performed as follows:

- A baseline case (contaminated area = 10,000 m^2, volume = 3000 m^3) was run for each of the three source terms. The maximum annual dose in the ensuing 1000 year period was recorded.

- A series of potential excavation volumes was identified ranging from 1 m^3 to 3000 m^3. Excavation volumes corresponding to the excavation cases specifically evaluated in the AAR site technical basis document (NRC 1997) were included along with a number of other volumes such that a well defined dose response curve as a function of area could be developed.

- Source size (area of the contaminated zone) was calculated for each excavation volume assuming that the subsurface soil, once excavated, was spread over the ground surface in a lift having a thickness of 0.3 meters (e.g., 3000 m^3/0.3m = 10,000 m^2).

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3 The input parameter data set used by the NRC in establishing the technical basis for the AAR method was that identified in NRC Policy and Guidance Directive PG-8-08 (NRC 1994) as appropriate for a resident (subsistence) farmer scenario.

4 The NRC in its technical basis considered only thorium series radionuclides since only thorium series radionuclides were present at the AAR Site. Since there are both thorium and uranium series radionuclides as well as the potential for radium to be present in concentrations disproportionate to those associated with uranium series secular equilibrium, each of three radionuclide series have been considered in establishing the technical basis for application of the AAR methodology to the York, PA site.

- The size of the contaminated area (area of the contaminated zone) in the RESRAD input file was incrementally reduced while holding all other parameters constant. The case was rerun and again the maximum annual dose in the ensuing 1000 year period was recorded.
  - This process was repeated using 15 different volume/areas for each of the three radionuclide profiles corresponding to the concentration limits applicable at the York, PA site.

2.4 DERIVATION OF AVERAGING CRITERIA FOR SUBSURFACE SOILS

Having performed the isotope specific dose modeling as described above, a set of dose response curves relating the maximum annual dose to the size of the contaminated area (using essentially default input parameters corresponding to a subsistence farming scenario) were derived (Figure 2-4). Using the derived relative dose producing capability of each source term for varying source sizes, an area factor can be calculated. The area factor is simply the ratio of the dose produced by the baseline case source term (10,000 m^2) to the dose produced by a smaller area source (Equation 1).

$$AF = \frac{DR_{Baseline}}{DR_{Area}}$$

Equation 1

For instance, the maximum annual dose produced by the thorium source term uniformly deposited over 10,000 m^2 is a factor of two larger than the maximum annual dose produced by the same concentration of thorium in soil uniformly deposited over only 33 m^2, thus the area factor for the thorium source term in a 33m^2 area is 2.0. A new set of curves was generated to express the dose response relationship in terms of the area factor (Figure 2-5). Area factor curves are the inverse of the relative dose response curves presented in Figure 2-4.

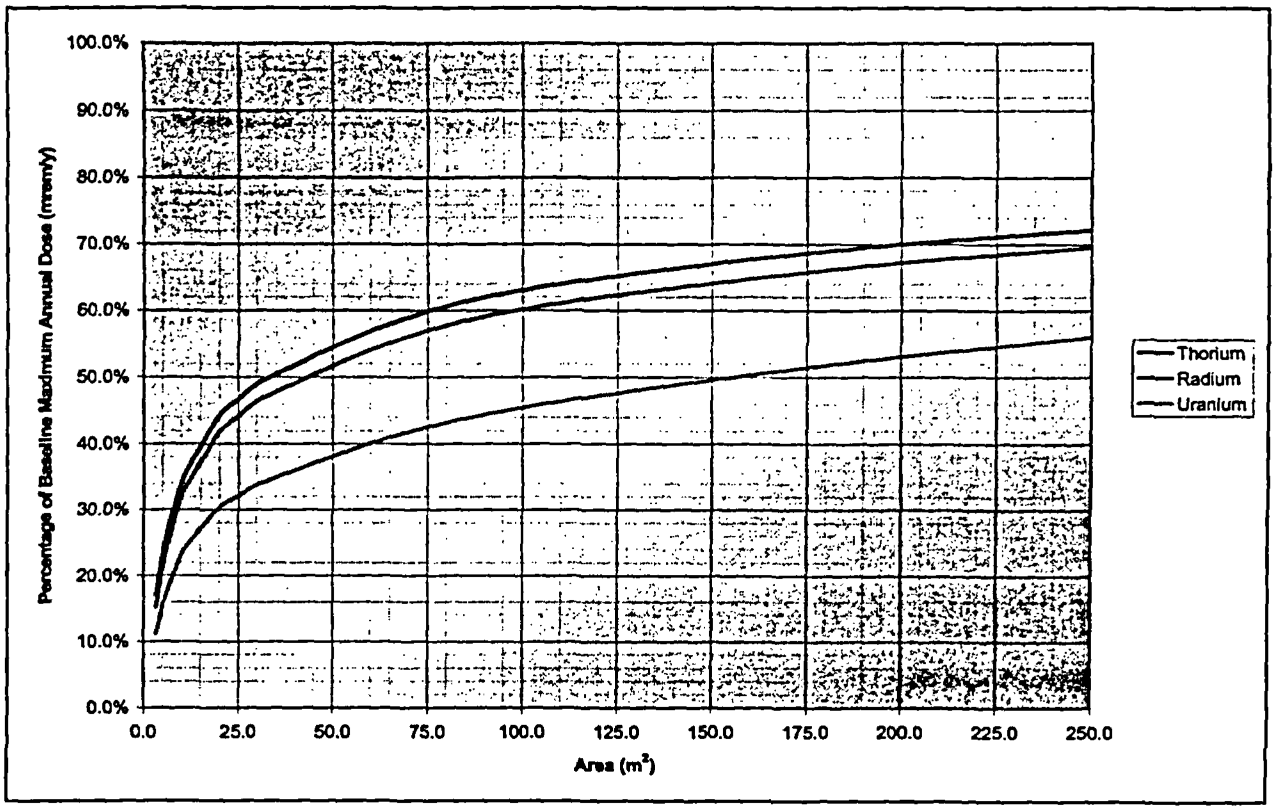

Figure 2-4 Relative Dose Response Curves as a Function of Source Size (Area)

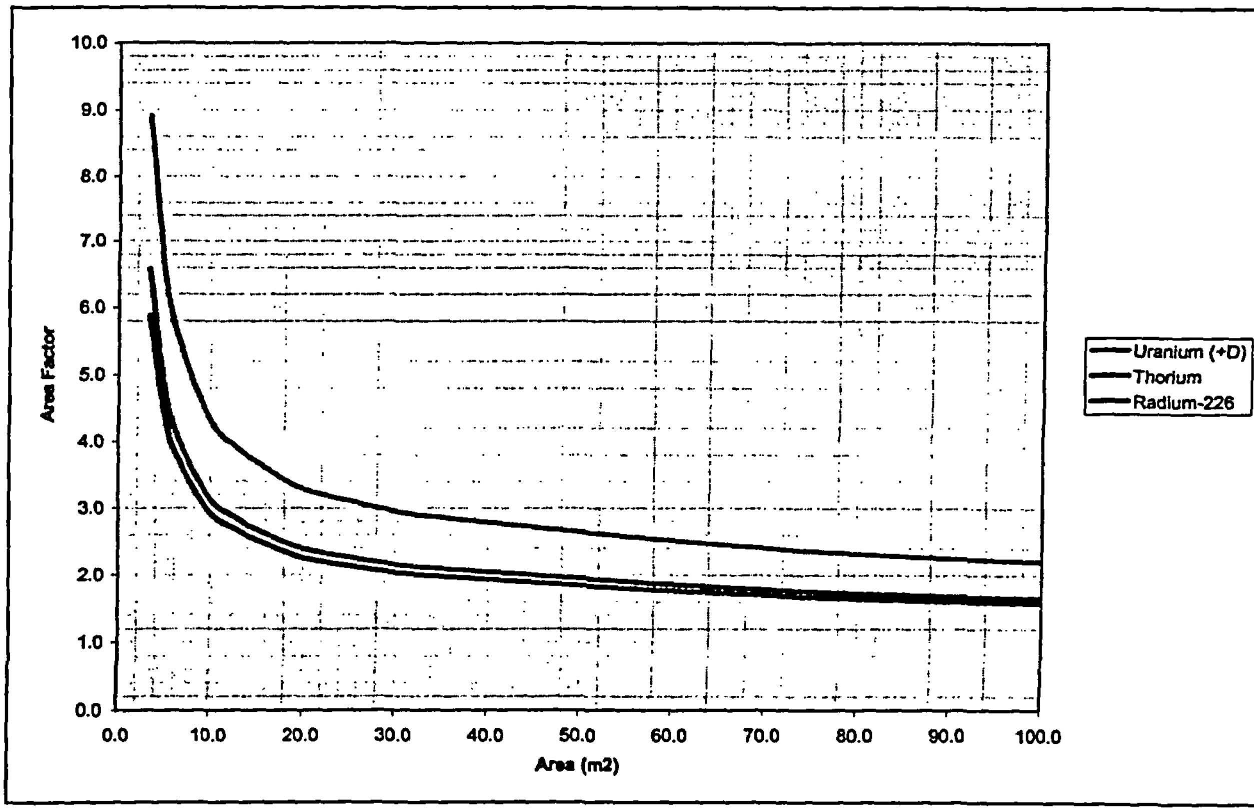

Figure 2-5 Area Factor Curves for the York, PA Site

Since the relationship between dose production and source term concentration is exactly linear, all other things being equal, the area factor can be used as a factor by which the concentration in a localized area containing residual radioactivity might be allowed to exceed the approved site wide average limit approved (Equation 2).

$$C_{Area,n} = C_{Avg.}(AF_n)$$

Equation 2

The area factor curves presented in Figure 2-5 can be further refined for application at the York, PA site by producing a third set of curves which represent the allowable concentration that might exist in any given area with elevated residual radioactivity in soil. With these curves, any combination of acceptable area and residual radioactivity concentration in soil can be determined (See Figure 2-6). In this way, the technical basis document does not unnecessarily constrain the elevated concentration criterion to volumes or areas for which discrete calculations were performed or based upon some presumed sampling and survey density. A printout of the tabulated results used to produce the curves in Figure 2-4, Figure 2-5, and Figure 2-6 are provided in Appendix B.

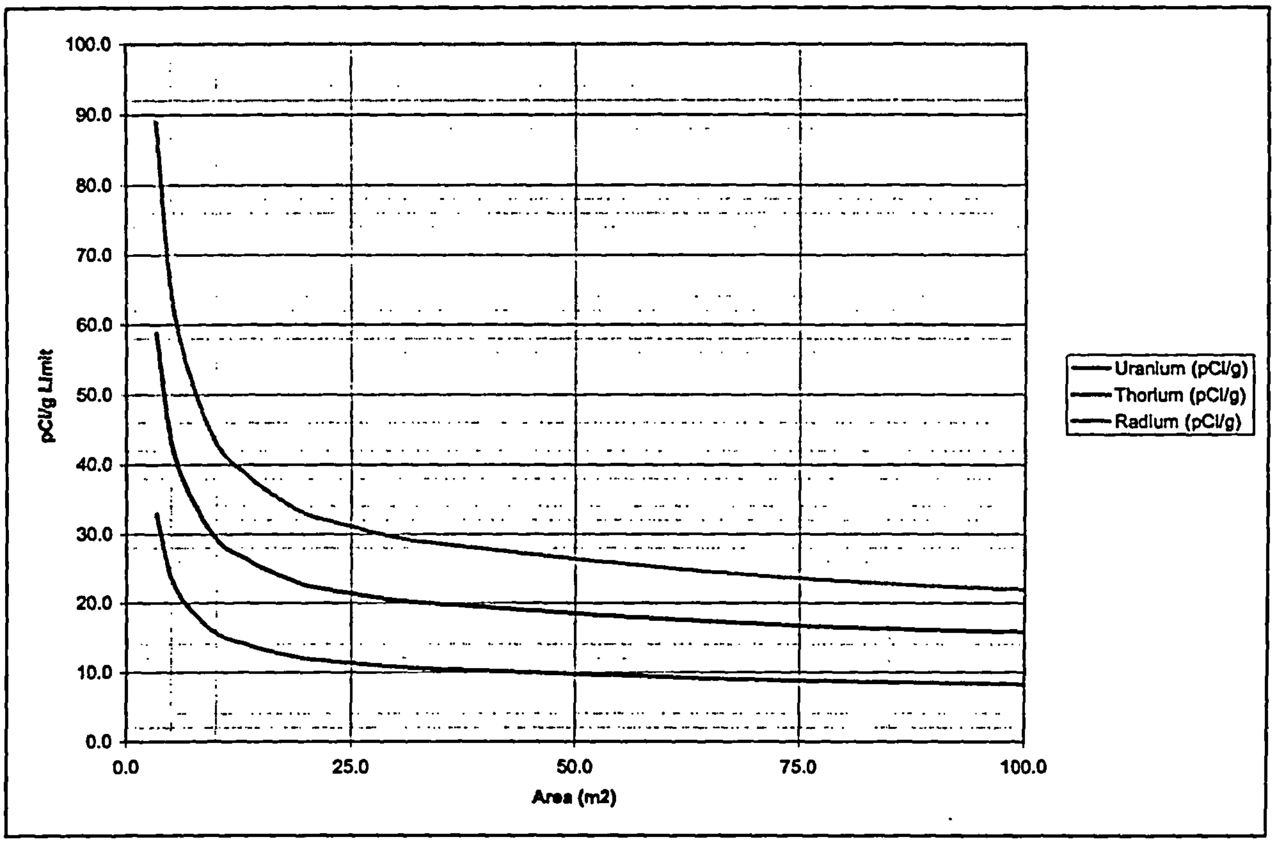

Figure 2-6 Permissible Residual Radioactivity in Soil vs. Area

It is recognized that subsurface contamination contained closer to the surface, say 0-1 meter, may deliver dose without being excavated. This exposure may occur from: 1) direct gamma radiation from in-situ soil close to the surface, 2) the root uptake pathway down to about the first meter, and 3) the uncovering of contaminated surfaces through grading during construction and surface erosion over time, which could than cause dose through surface exposure pathways. However, the excavation scenarios considered yield more conservative estimates of the dose response (and thus averaging criteria) than would in-situ near surface soils in the 0-1 meter bgs position because the in the excavation scenarios, soil is presumed to be spread over a large area after excavation. Therefore, the excavation scenario is used to determine conservative averaging limits for the 0-1 meter layer as well as for deeper subsurface layer. This conservatism is appropriate due to the uncertainty associated with potential exposure pathways for near-surface residual radioactivity in soil.

3.0 SURVEY METHOD FOR SUBSURFACE RESIDUAL RADIOACTIVITY

After the concentrations and averaging volumes were determined, a survey method for assessing the concentrations of residual radioactivity in soil was developed. This survey method is identical to that derived by the NRC staff in review of the AAR site remediation plan (NRC 1997). While other sampling plans[5] might also be supported by the dose response curves derived for the York, PA site, Molycorp and MACTEC have chosen to replicate the survey method identified in the AAR report given that it has already been shown to be acceptable to the NRC for demonstrating that the averaging criteria are met and specifically called out and approved as part of the site decommissioning plan (Molycorp 1999). Section 3 describes the survey method.

3.1 SURVEY METHOD OBJECTIVES

The survey method for assessing residual radioactivity in subsurface soils is designed to ensure that the number and location of samples are sufficient to: 1) demonstrate, with reasonable confidence, that a significant volume of subsurface contamination is identified by one of the samples, and 2) demonstrate that the average contamination level in the identified volume would not result in a significant dose if it were excavated and brought to the surface where human exposure is possible. It is also designed with the objective of maintaining a measure of consistency with the sampling and survey protocol described in NUREG/CR-5849 (NRC 1992) for surface soils.

The survey method described below can be used to satisfy the above two objectives. The concentration values are derived using the dose response curves presented in section 2.0 above which are derived from the currently approved unrestricted use limits for widespread (average) residual radioactivity in surface soils.

- 10 pCi/g total thorium (average)
- 10 pCi/g total uranium (average)
- 5 pCi/g excess Ra-226 (average)

5 The NRC's technical basis document for the AAR site (NRC 1997d) states that: "Other survey methods may be acceptable if they are justified on a dose basis and provide sufficient confidence that significant volumes of soil are identified."

If the approved guideline value changes, the averaging criteria will change accordingly.

3.2 SURVEY ASSUMPTIONS

The survey method for assessing the residual radioactivity in subsurface soils involves the physical collection of soil samples from corings advanced to depth at the site. The core holes from which volumetric samples are obtained are placed using a systematic square sample grid.

Survey Assumptions:

1. Samples are collected on a 5 meter square grid. This grid system places four core holes in each 100 m^2 area (the fundamental averaging area described in NUREG/CR-5849).
2. Samples are composited over each 1 meter-thick layer of soil. The smallest thickness of soil of significance is one meter thick. Core holes advanced to depths greater than 1 meter will yield a discrete soil sample from each 1 meter-thick increment below the ground surface.
3. Each sample is assumed to represent 25 m^3 (5m x 5m x 1m).
4. 100 m^3 averages are represented by the average of four "nearest neighbor" samples collected from each 1 meter layer of soil (Figure 3-1).
5. Volumetric averages greater than 100 m^3 are calculated assuming each sample represents 25 m^3 and that averaging in the lateral direction is limited to no more than 100 m^2.

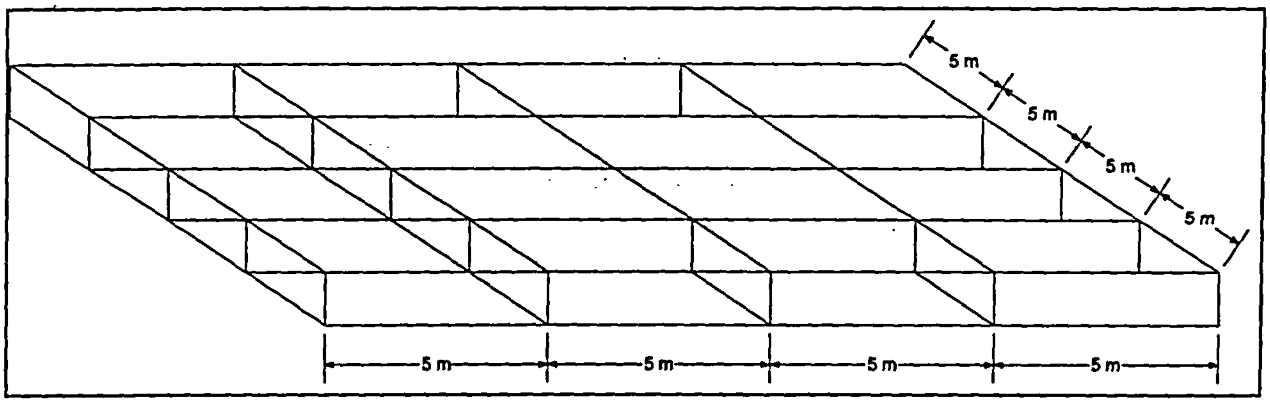

Figure 3-1 Nearest Neighbor Grid Geometry for Determining 100 m^2 Averages

The averaging criteria apply to any contiguous volume defined by the given number of 5 m grid samples, where each sample represents 25 m^3. For averaging over a 100 m^2 area, each combination of the four "nearest neighbor" samples in a given 1 meter layer should be evaluated. This means that each 5m x 5m grid (except those on the boundary of a survey unit) would be evaluated as a part of four different 100 m^2 areas (Figure 3-2).

Volumes greater than 100 m^3 can and must be evaluated but must be limited laterally to an area of 10 x 10 meters. This means, for example, that a volume of 200 m^3 is evaluated by considering the eight samples in a 10 x 10 meter area projected to a depth of 2 meters (Figure 3-3).

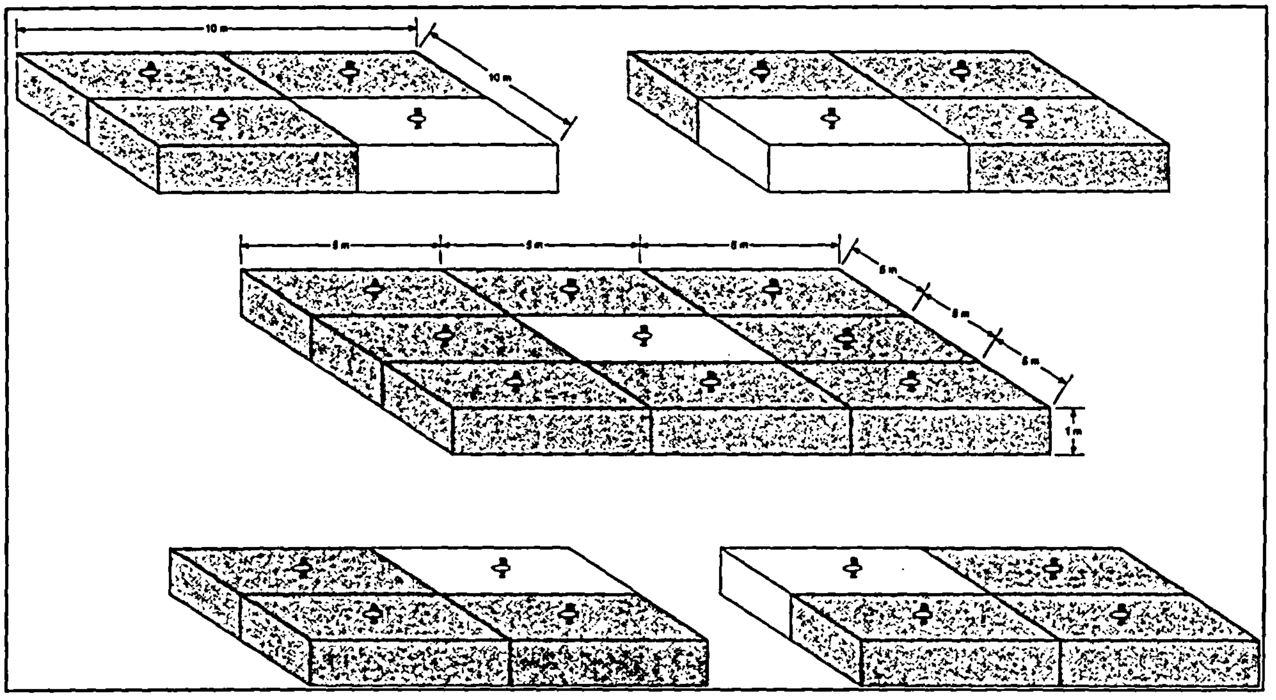

Figure 3-2 Four Possible Combinations of "Nearest Neighbors" Occurring for Each Sample

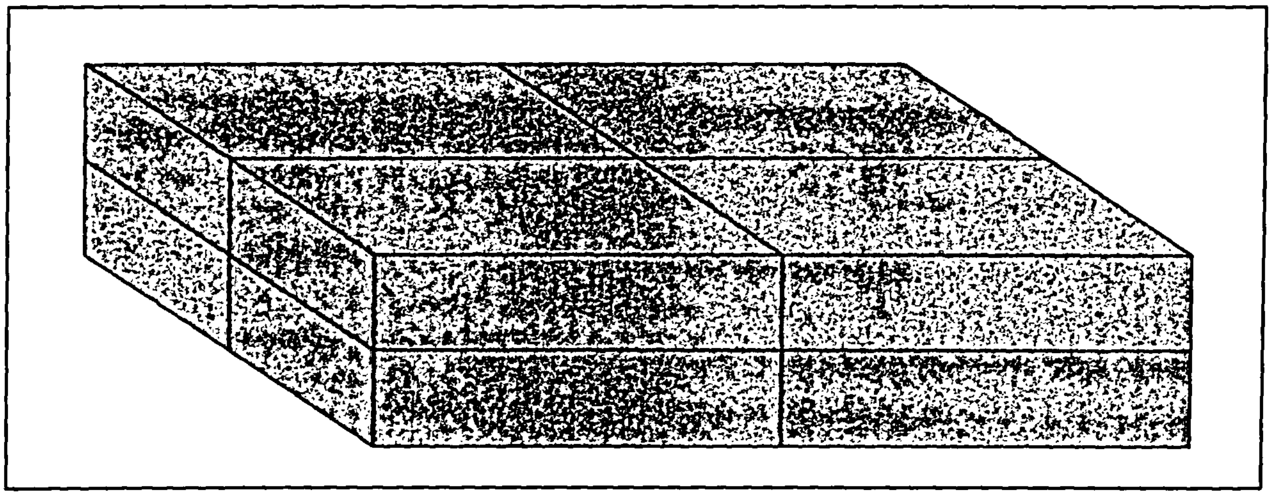

Figure 3-3 Volumetric Averaging over Greater Than 100 m^3.

In addition to the areal averaging described above, a vertical averaging criterion is also defined. These averaging criteria are intended to identify significant volumes of residual radioactivity in contiguous volumes in the vertical, as opposed to the horizontal (lateral) direction. Again, the sampling upon which the vertical averaging criteria is derived assumes a 5 meter grid size with one sample collected from each $25m^2$ area and 1 meter depth increment. For example, the two samples from the o to 1 meter and 1 to 2 meter depths and from the same borehole would be averaged together. As each of these samples represents 25 m^3 of soil volume, the two samples represent 50 m^3, and the averaging criteria is derived from the dose response curves corresponding to a volume of 50 m^3. Likewise, a vertical (columnar) average will be calculated for each contiguous combination of samples in a single vertical column starting with the ground surface.

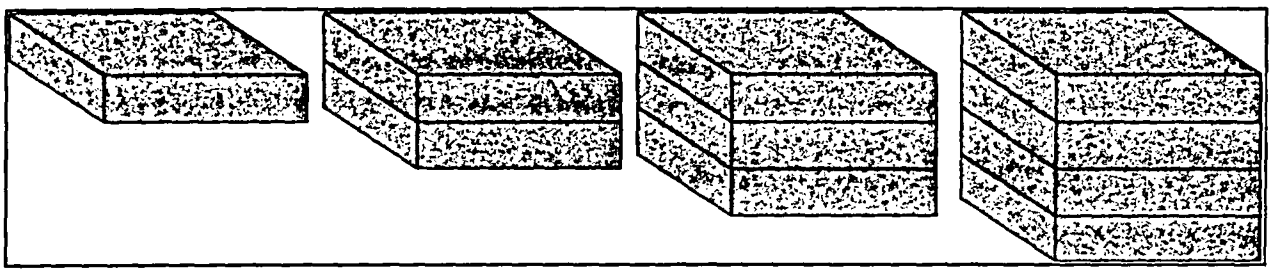

Figure 3-4 Progressively Deeper Vertical Averaging in a Single $25m^2$ Column

For the Subsurface soil in the depth increment from 0 to 1 meter below ground surface, there are two criteria that apply as illustrated in Figure 3-5:

- Average of four "nearest neighbor" samples (100 m^3), and
- Individual sample (25 m^3)

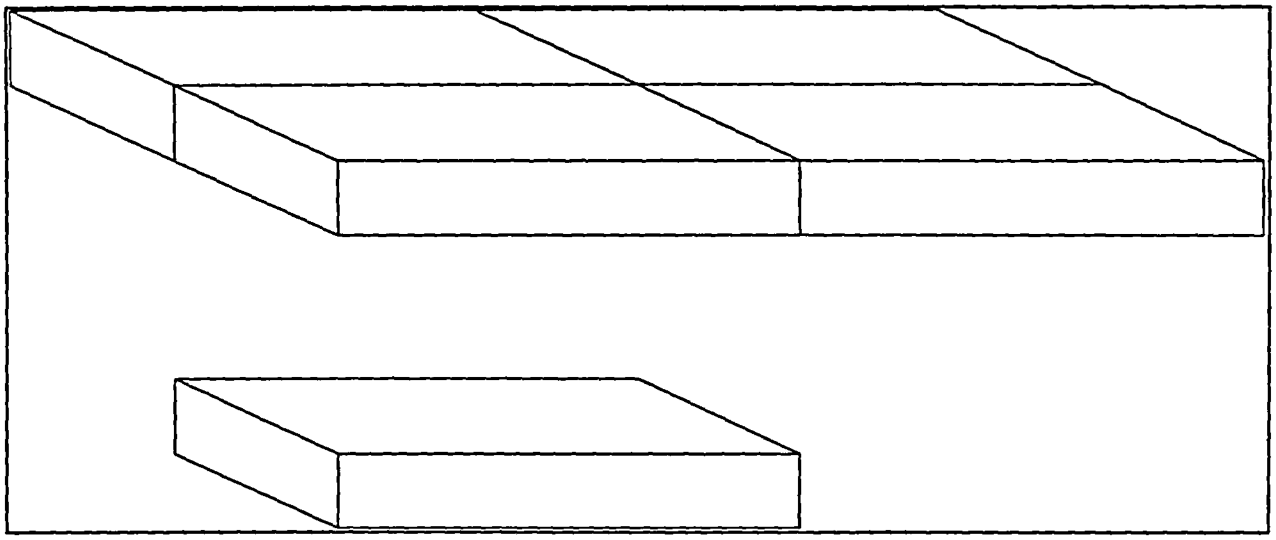

Figure 3-5 Subsurface Soil Averaging Criteria—0 to 1 Meter Depth

For the Subsurface soil in the depth increment from 0 to 2 meter below ground surface, the criteria applicable to the 0 to 1 meter increment apply in addition to four other criteria as illustrated in:

- Average of four "nearest neighbor" samples (100 m^3) in the 1 to 2 meter depth increment,
- Average of the eight samples in a 10 x 10 m in the 0 to 2 meter depth increment (200 m^3),
- Individual sample (25 m^3) from the 1 to 2 meter increment, and
- Average of the two samples from the 0 to 2 meter increment (50 m^3) in each vertical column,

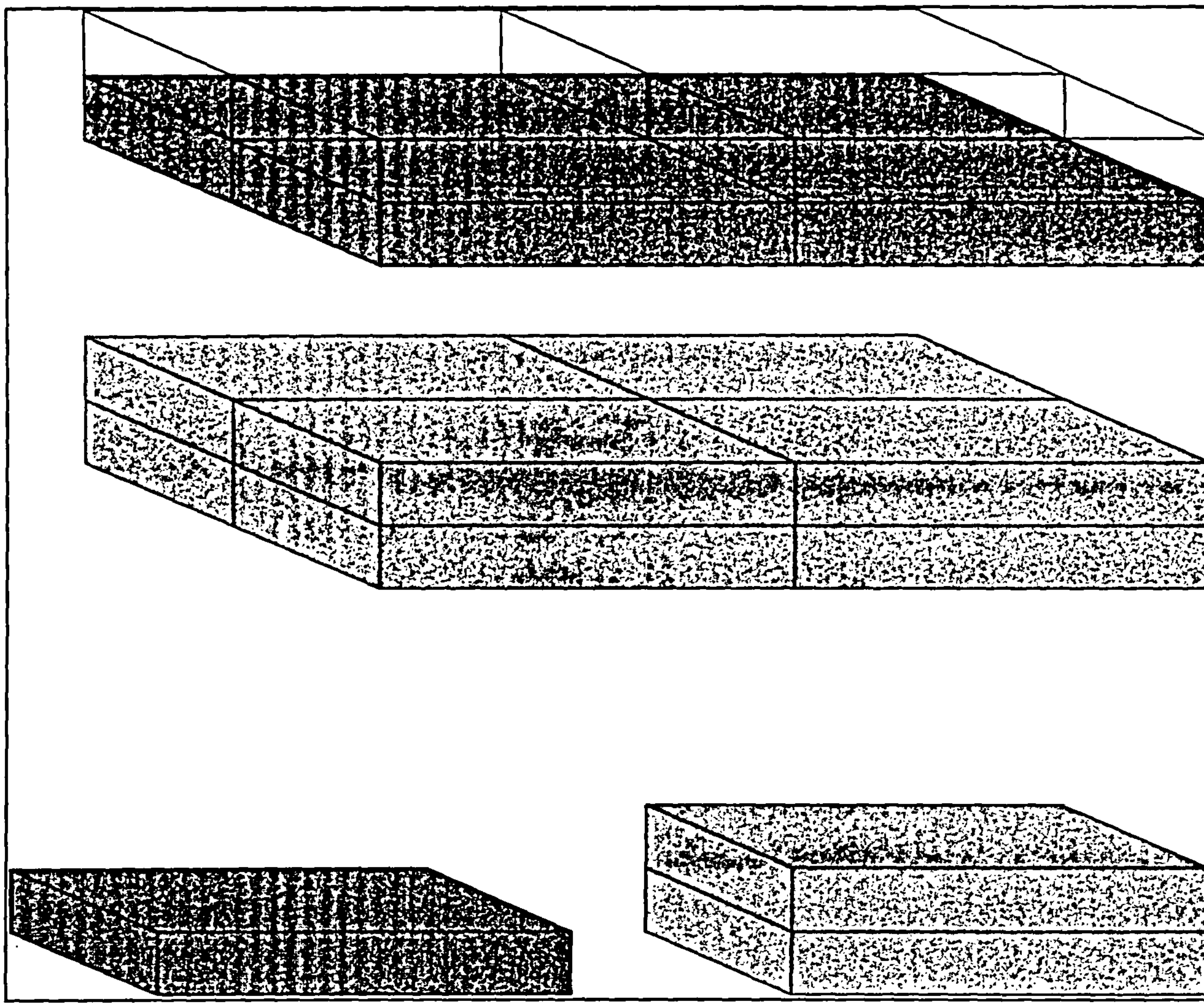

Figure 3-6 Subsurface Soil Averaging Criteria—1 to 2 Meter Depth

For the Subsurface soil in the depth increment from 0 to 3 meter below ground surface, the criteria applicable to the 0 to 1 and 1 to 2 meter increment apply in addition to four other criteria as illustrated in :

- Average of four "nearest neighbor" samples (100 m^3) in the 2 to 3 meter depth increment,
- Average of the twelve samples in a 10 x 10 m in the 0 to 3 meter depth increment (300 m^3),
- Individual sample (25 m^3) from the 2 to 3 meter increment, and
- Average of the three samples from the 0 to 3 meter increment (75 m^3) in each vertical column,

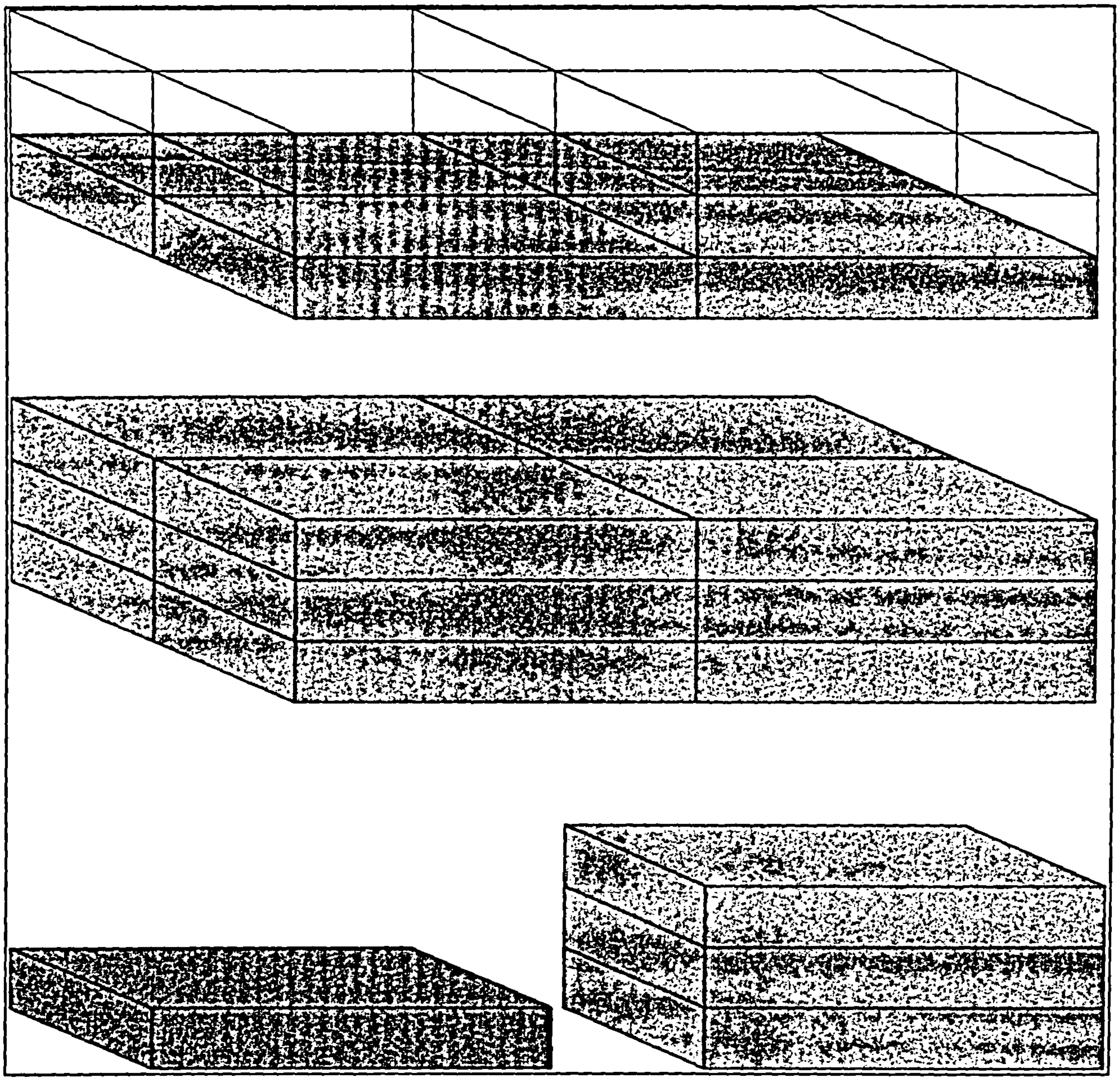

Figure 3-7 Subsurface Soil Averaging Criteria—2 to3 Meter Depth

For the Subsurface soil in the depth increment from 0 to 4 meter below ground surface, the criteria applicable to the 0 to 1, 1 to 2, and 2 to 3 meter increments apply in addition to four other criteria as illustrated in :

- Average of four "nearest neighbor" samples (100 m^3) in the 3 to 4 meter depth increment,

- Average of the sixteen samples in a 10 x 10 m in the 0 to 4 meter depth increment (400 m^3),
- Individual sample (25 m^3) from the 3 to 4 meter increment, and
- Average of the four samples from the 0 to 4 meter increment (100 m^3) in each vertical column

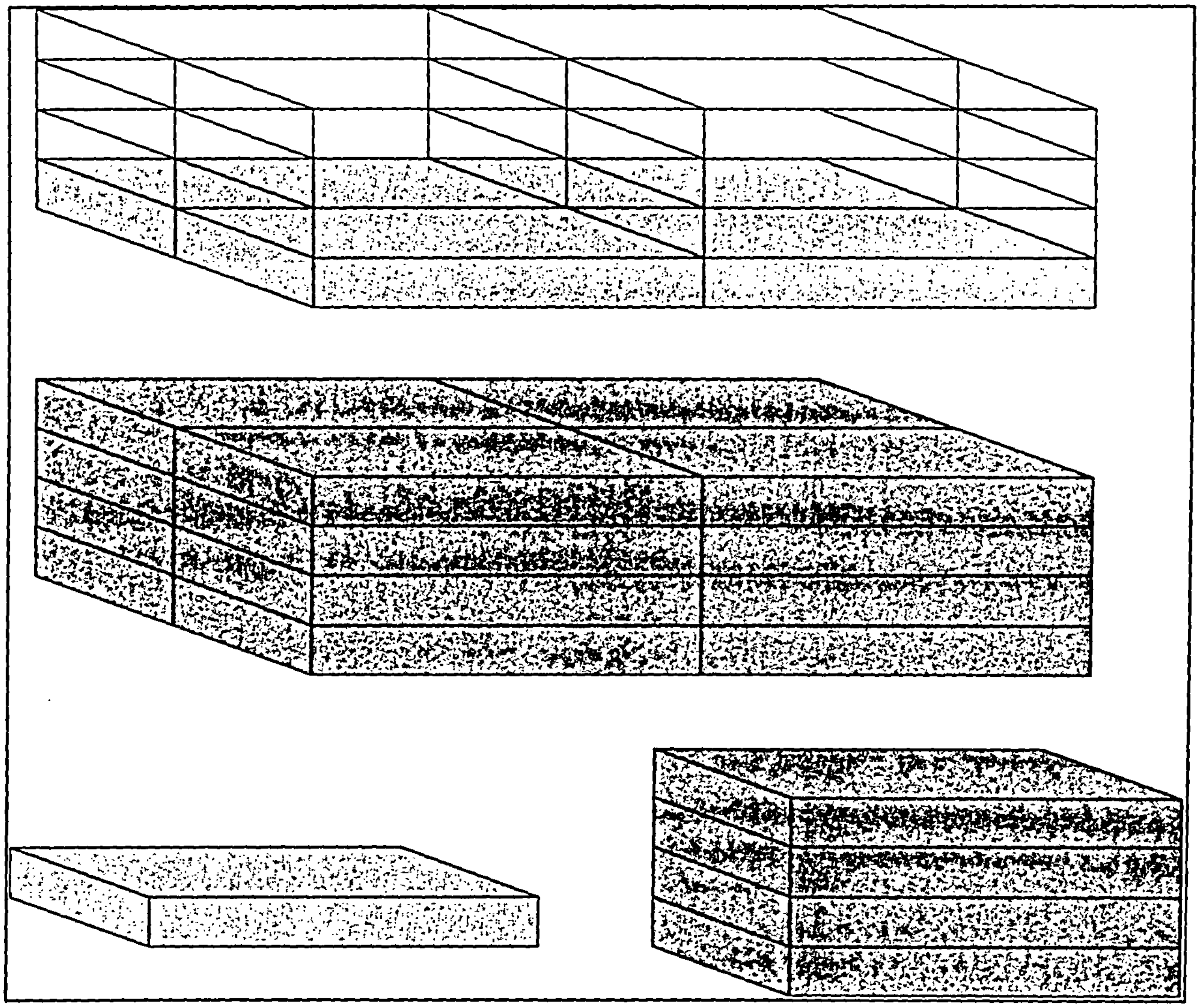

Figure 3-8 Subsurface Soil Averaging Criteria—3 to4 Meter Depth

For the Subsurface soil in the depth increment from 0 to 5 meter below ground surface, the criteria applicable to the 0 to 1, 1 to 2, 2 to 3, and 3 to 4 meter increments apply in addition to four other criteria as illustrated in :

- Average of four "nearest neighbor" samples (100 m^3) in the 4 to 5 meter depth increment,
- Average of the twenty samples in a 10 x 10 m in the 0 to 5 meter depth increment (500 m^3),
- Individual sample (25 m^3) from the 4 to 5 meter increment, and
- Average of the five samples from the 0 to 5 meter increment (125 m^3) in each vertical column

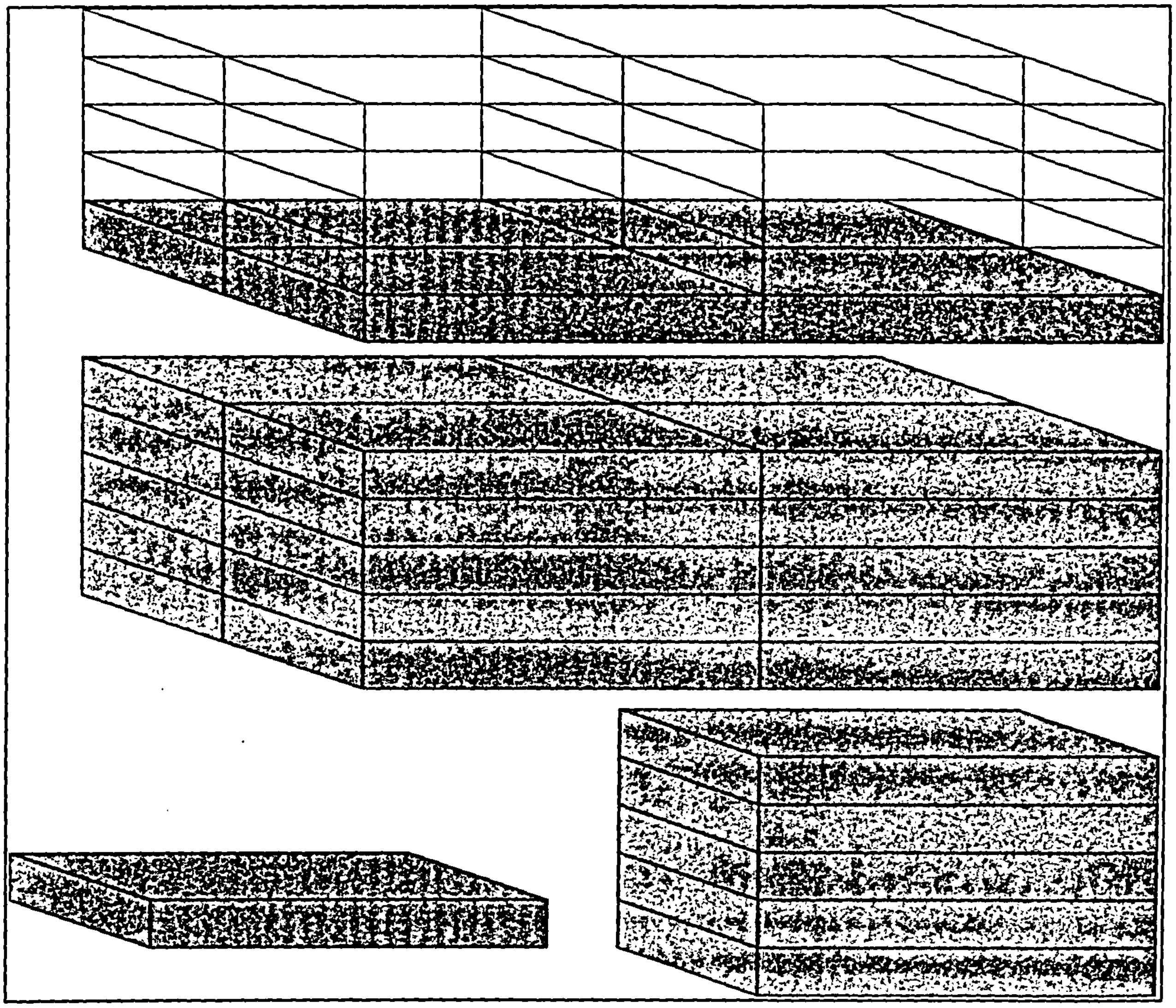

Figure 3-9 Subsurface Soil Averaging Criteria—4 to5 Meter Depth

Based upon the comparative dose modeling performed in this assessment a tabular set of subsurface soil concentration limits was calculated. Each of the calculated concentration limits for subsurface units of soil is derived from the approved surface soil concentration limits for residual radioactivity specified in the York, PA Site decommissioning plan (Molycorp 1999) using the dose response relationship as a function of volume excavated and brought to the surface where human exposure might occur. Soil concentration limits for each of the three isotopes series identified in the DP are presented in Table 3-1 below.

Table 3-1 Site-Specific Subsurface Soil Averaging Limits—Molycorp's York, PA Facility

Layer	Volume	Average, pCi/g		
		Uranium (238 + 234)	Thorium (232 + 228)	Ra-226
0 to 1 meter Layer			Layer Average	
Four samples from 0-1 meter depth	100 m^3	16	13	7
Maximum 25 m^3	25 m^3	23	16	9
0 to 2 meter Layer				
50 m^3 in a vertical column	50 m^3	20	15	8
Four Samples from 1-2 meter Depth	100 m^3	26	23	12
Eight Samples from the 0-2 meter Depth	200 m^3	13	12	6
Maximum 25 m^3 (1-2 meter depth)	25 m^3	39	29	15
0 to 3 meter Layer				
75 m^3 in a vertical column	75 m^3	18	14	7
Four Samples from 2-3 meter Depth	100 m^3	32	32	16
Twelve Samples from the 0-3 meter Depth	300 m^3	11	11	5
Maximum 25 m^3 (2-3 meter depth)	25 m^3	54	42	22
0 to 4 meter Layer				
100 m^3 in a vertical column	100 m^3	16	13	7
Four Samples from 3-4 meter Depth	100 m^3	42	42	21
Sixteen Samples from the 0-4 meter Depth	400 m^3	11	11	5
Maximum 25 m^3 (3-4 meter depth)	25 m^3	66	53	27
0 to 5 meter Layer				
125 m^3 in a vertical column	125 m^3	15	13	7
Four Samples from 4-5 meter Depth	100 m^3	50	50	25
Twenty Samples from the 0-4 meter Depth	500 m^3	10	10	5
Maximum 25 m^3 (4-5 meter depth)	25 m^3	77	59	33
Each layer deeper than 5 meters				
Maximum 25 m^3 (5-6 meter depth)	25 m^3	89	59	33

The concentration limits described in Table 3-1 were derived independent of one another. That is, there is no presumption about whether the concentration of uranium, thorium, and radium apply independently or as a component of a sum of fractions. If the approved concentration limits in the DP are viewed as components of a sum of fractions that must be demonstrated to be less than or equal to unity, then the same application applies to the subsurface averaging limits presented herein. In keeping with the previously established protocol at the York site, a sum of fractions treatment is assumed to be appropriate.

4.0 SUMMARY AND CONCLUSIONS

Having considered the NRC's technical basis and rationale for the development of subsurface soil measurement protocol and averaging criteria for the AAR site (NRC 1997), Molycorp concludes that the application of the AAR method at the York, PA site is appropriate. The isotopic composition present (or potentially present) at the York site yields averaging limits comparable to those derived for the AAR site by the NRC.

5.0 ACRONYMS

AAR	AAR Corporation
AF	area factor
C	concentration
D&D	decontamination and decommissioning
DCGL	derived concentration guideline level
$DCGL_W$	mean (or median) concentration guideline level
DOE	U.S. Department of Energy
DP	decommissioning plan
DR	dose rate
ft.	foot
HPGe	high purity germanium
HSA	Historical Site Assessment
m	meter
MACTEC	MACTEC Development Corporation, Inc.
MARSSIM	Multi-Agency Radiation Site Survey and Investigation Manual
n	number of measurements
NRC	United States Nuclear Regulatory Commission

PA	Pennsylvania
PADEP	Pennsylvannia Department of Environmental Protection
pCi/g	picoCuries per gram
QA	Quality Assurance
QC	Quality Control
Ra	radium
Site	Molycorp York, PA Site
SDMP	Site Decommissioning Management Plan
St.	street
TEDE	total effective dose equivalent
Th	thorium
U	uranium

6.0 REFERENCES

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Yu 1996 Yu, C., et. al., 1996. *RESRAD, Version 5.62,* Computer Modeling Code, Developed by Argonne National Laboratory, Environmental Assessment Division, Argonne, IL under sponsorship by the U.S. Department of Energy, July 3, 1996.

Yu 2001 Yu, C., et. al., 2001. *Users Manual For RESRAD Version 6.0,* ANL/EAD-4, Argonne National Laboratory, Environmental Assessment Division, Argonne, IL., July 2001.

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MALCOLM PIRNIE

C

APPENDIX C

RESRAD

Thorium Baseline Case

Table of Contents

Part I: Mixture Sums and Single Radionuclide Guidelines

Dose Conversion Factor (and Related) Parameter Summary
File: FGR 13 Morbidity

Menu	Parameter	Current Value	Default	Parameter Name
B-1	Dose conversion factors for inhalation, mrem/pCi:			
B-1	Ra-228+D	5.080E-03	5.080E-03	DCF2(1)
B-1	Th-228+D	3.450E-01	3.450E-01	DCF2(2)
B-1	Th-232	1.640E+00	1.640E+00	DCF2(3)
D-1	Dose conversion factors for ingestion, mrem/pCi:			
D-1	Ra-228+D	1.440E-03	1.440E-03	DCF3(1)
D-1	Th-228+D	8.080E-04	8.080E-04	DCF3(2)
D-1	Th-232	2.730E-03	2.730E-03	DCF3(3)
D-34	Food transfer factors:			
D-34	Ra-228+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(1,1)
D-34	Ra-228+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(1,2)
D-34	Ra-228+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(1,3)
D-34				
D-34	Th-228+D , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(2,1)
D-34	Th-228+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(2,2)
D-34	Th-228+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(2,3)
D-34				
D-34	Th-232 , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(3,1)
D-34	Th-232 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(3,2)
D-34	Th-232 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(3,3)
D-5	Bioaccumulation factors, fresh water, L/kg:			
D-5	Ra-228+D , fish	5.000E+01	5.000E+01	BIOFAC(1,1)
D-5	Ra-228+D , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(1,2)
D-5				
D-5	Th-228+D , fish	1.000E+02	1.000E+02	BIOFAC(2,1)
D-5	Th-228+D , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(2,2)
D-5				
D-5	Th-232 , fish	1.000E+02	1.000E+02	BIOFAC(3,1)
D-5	Th-232 , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(3,2)

Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R011	Area of contaminated zone (m**2)	1.000E+04	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	3.000E-01	2.000E+00	---	THICK0
R011	Length parallel to aquifer flow (m)	1.000E+02	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	3.000E+01	2.500E+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): Ra-228	5.000E+00	0.000E+00	---	S1(1)
R012	Initial principal radionuclide (pCi/g): Th-228	5.000E+00	0.000E+00	---	S1(2)
R012	Initial principal radionuclide (pCi/g): Th-232	5.000E+00	0.000E+00	---	S1(3)
R012	Concentration in groundwater (pCi/L): Ra-228	not used	0.000E+00	---	W1(1)
R012	Concentration in groundwater (pCi/L): Th-228	not used	0.000E+00	---	W1(2)
R012	Concentration in groundwater (pCi/L): Th-232	not used	0.000E+00	---	W1(3)
R013	Cover depth (m)	0.000E+00	0.000E+00	---	COVER0
R013	Density of cover material (g/cm**3)	not used	1.500E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	not used	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.630E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	1.000E-03	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	3.000E-01	4.000E-01	---	TPCZ
R013	Contaminated zone field capacity	2.000E-01	2.000E-01	---	FCCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	1.000E+01	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter	5.300E+00	5.300E+00	---	BCZ
R013	Average annual wind speed (m/sec)	2.000E+00	2.000E+00	---	WIND
R013	Humidity in air (g/m**3)	not used	8.000E+00	---	HUMID
R013	Evapotranspiration coefficient	5.000E-01	5.000E-01	---	EVAPTR
R013	Precipitation (m/yr)	1.000E+00	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	7.600E-01	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	2.000E-01	2.000E-01	---	RUNOFF
R013	Watershed area for nearby stream or pond (m**2)	1.000E+06	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)	1.630E+00	1.500E+00	---	DENSAQ
R014	Saturated zone total porosity	3.000E-01	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	2.000E-01	2.000E-01	---	EPSZ
R014	Saturated zone field capacity	2.000E-01	2.000E-01	---	FCSZ
R014	Saturated zone hydraulic conductivity (m/yr)	1.000E+02	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	2.000E-02	2.000E-02	---	HGWT
R014	Saturated zone b parameter	5.300E+00	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	1.000E-03	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	1.000E+01	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	ND	ND	---	MODEL

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R014	Well pumping rate (m**3/yr)	2.500E+02	2.500E+02	---	UW
R015	Number of unsaturated zone strata	1	1	---	NS
R015	Unsat. zone 1, thickness (m)	1.000E+00	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	1.630E+00	1.500E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	3.000E-01	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	2.000E-01	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, field capacity	2.000E-01	2.000E-01	---	FCUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	5.300E+00	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	1.000E+01	1.000E+01	---	HCUZ(1)
R016	Distribution coefficients for Ra-228				
R016	Contaminated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCC(1)
R016	Unsaturated zone 1 (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCU(1,1)
R016	Saturated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCS(1)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.274E-02	ALEACH(1)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(1)
R016	Distribution coefficients for Th-228				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(2)
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCU(2,1)
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCS(2)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.658E-05	ALEACH(2)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(2)
R016	Distribution coefficients for Th-232				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(3)
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCU(3,1)
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCS(3)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.658E-05	ALEACH(3)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(3)
R017	Inhalation rate (m**3/yr)	1.051E+04	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	2.000E-04	1.000E-04	---	MLINH
R017	Exposure duration	3.000E+01	3.000E+01	---	ED
R017	Shielding factor, inhalation	5.000E-01	4.000E-01	---	SHF3
R017	Shielding factor, external gamma	3.300E-01	7.000E-01	---	SHF1
R017	Fraction of time spent indoors	5.500E-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

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
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)
017	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)
017	Outer annular radius (m), ring 5:	not used	0.000E+00	---	RAD_SHAPE(5)
017	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)
017	Outer annular radius (m), ring 8:	not used	0.000E+00	---	RAD_SHAPE(8)
017	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)
017	Outer annular radius (m), ring 12:	not used	0.000E+00	---	RAD_SHAPE(12)
R017	Fractions of annular areas within AREA:				
017	Ring 1	not used	1.000E+00	---	FRACA(1)
017	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)
017	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)
017	Ring 8	not used	0.000E+00	---	FRACA(8)
017	Ring 9	not used	0.000E+00	---	FRACA(9)
R017	Ring 10	not used	0.000E+00	---	FRACA(10)
017	Ring 11	not used	0.000E+00	---	FRACA(11)
017	Ring 12	not used	0.000E+00	---	FRACA(12)
R018	Fruits, vegetables and grain consumption (kg/yr)	1.660E+02	1.600E+02	---	DIET(1)
018	Leafy vegetable consumption (kg/yr)	1.100E+01	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	1.000E+02	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	6.300E+01	6.300E+01	---	DIET(4)
018	Fish consumption (kg/yr)	5.400E+00	5.400E+00	---	DIET(5)
018	Other seafood consumption (kg/yr)	9.000E-01	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	1.825E+01	3.650E+01	---	SOIL
018	Drinking water intake (L/yr)	7.300E+02	5.100E+02	---	DWI
018	Contamination fraction of drinking water	1.000E+00	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
018	Contamination fraction of irrigation water	1.000E+00	1.000E+00	---	FIRW
018	Contamination fraction of aquatic food	5.000E-01	5.000E-01	---	FR9
R018	Contamination fraction of plant food	-1	-1	0.500E+00	FPLANT
018	Contamination fraction of meat	-1	-1	0.500E+00	FMEAT
018	Contamination fraction of milk	-1	-1	0.500E+00	FMILK
019	Livestock fodder intake for meat (kg/day)	6.800E+01	6.800E+01	---	LFI5
019	Livestock fodder intake for milk (kg/day)	5.500E+01	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)	1.600E+02	1.600E+02	---	LWI6
019	Livestock soil intake (kg/day)	5.000E-01	5.000E-01	---	LSI
019	Mass loading for foliar deposition (g/m**3)	1.000E-04	1.000E-04	---	MLFD

Site-Specific Parameter Summary (continued)

nu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	9.000E-01	9.000E-01	---	DROOT
19	Drinking water fraction from ground water	1.000E+00	1.000E+00	---	FGWDW
R019	Household water fraction from ground water	not used	1.000E+00	---	FGWHH
R019	Livestock water fraction from ground water	1.000E+00	1.000E+00	---	FGWLW
19	Irrigation fraction from ground water	1.000E+00	1.000E+00	---	FGWIR
R19B	Wet weight crop yield for Non-Leafy (kg/m**2)	7.000E-01	7.000E-01	---	YV(1)
9B	Wet weight crop yield for Leafy (kg/m**2)	1.500E+00	1.500E+00	---	YV(2)
9B	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)
19B	Growing Season for Fodder (years)	8.000E-02	8.000E-02	---	TE(3)
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)
19B	Translocation Factor for Fodder	1.000E+00	1.000E+00	---	TIV(3)
19B	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)
19B	Dry Foliar Interception Fraction for Fodder	2.500E-01	2.500E-01	---	RDRY(3)
19B	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)
19B	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
14	C-12 concentration in contaminated soil (g/g)	not used	3.000E-02	---	C12CZ
14	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
14	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
14	Fraction of grain in milk cow feed	not used	2.000E-01	---	AVFG5
14	DCF correction factor for gaseous forms of C14	not used	8.894E+01	---	CO2F
TOR	Storage times of contaminated foodstuffs (days):				
TOR	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)
TOR	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)
TOR	Well water	1.000E+00	1.000E+00	---	STOR_T(7)
TOR	Surface water	1.000E+00	1.000E+00	---	STOR_T(8)
STOR	Livestock fodder	4.500E+01	4.500E+01	---	STOR_T(9)
:021	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
:021	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

Site-Specific Parameter Summary (continued)

enu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R021	Volumetric water content of the foundation	not used	3.000E-02	---	PH2OFL
R021	Diffusion coefficient for radon gas (m/sec):				
021	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
021	Radon vertical dimension of mixing (m)	not used	2.000E+00	---	HMIX
021	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
021	Building interior area factor	not used	0.000E+00	---	FAI
021	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
TITL	Maximum number of integration points for dose	17	---	---	LYMAX
ITL	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	active
6 -- aquatic foods	active
7 -- drinking water	active
8 -- soil ingestion	active
9 -- radon	suppressed
Find peak pathway doses	active

Contaminated Zone Dimensions		Initial Soil Concentrations, pCi/g	
Area:	10000.00 square meters	Ra-228	5.000E+00
Thickness:	0.30 meters	Th-228	5.000E+00
Cover Depth:	0.00 meters	Th-232	5.000E+00

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 3.000E+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):	4.152E+01	4.096E+01	3.982E+01	3.693E+01	3.457E+01	3.163E+01	2.652E-05	1.090E-12
M(t):	1.384E+00	1.365E+00	1.327E+00	1.231E+00	1.152E+00	1.054E+00	8.841E-07	3.634E-14

Maximum TDOSE(t): 4.152E+01 mrem/yr   at t = 0.000E+00 years

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

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
uclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	1.324E+01	0.3188	4.978E-02	0.0012	0.000E+00	0.0000	7.975E+00	0.1921	3.019E-01	0.0073	4.143E-01	0.0100	1.016E-01	0.0024
-228	1.574E+01	0.3790	2.498E-01	0.0060	0.000E+00	0.0000	1.002E-01	0.0024	5.583E-03	0.0001	4.394E-04	0.0000	4.701E-02	0.0011
-232	7.608E-01	0.0183	1.417E+00	0.0341	0.000E+00	0.0000	8.645E-01	0.0208	3.684E-02	0.0009	2.397E-02	0.0006	1.954E-01	0.0047
otal	2.973E+01	0.7162	1.717E+00	0.0414	0.000E+00	0.0000	8.940E+00	0.2153	3.444E-01	0.0083	4.387E-01	0.0106	3.441E-01	0.0083

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

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
uclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	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	2.208E+01	0.5318
Th-228	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	1.614E+01	0.3887
h-232	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	3.299E+00	0.0795
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	4.152E+01	1.0000

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-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
iclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	1.590E+01	0.3883	1.136E-01	0.0028	0.000E+00	0.0000	6.924E+00	0.1690	2.633E-01	0.0064	3.586E-01	0.0088	1.013E-01	0.0025
-228	1.095E+01	0.2673	1.738E-01	0.0042	0.000E+00	0.0000	6.949E-02	0.0017	3.885E-03	0.0001	3.058E-04	0.0000	3.272E-02	0.0008
-232	2.538E+00	0.0620	1.428E+00	0.0349	0.000E+00	0.0000	1.752E+00	0.0428	7.010E-02	0.0017	6.983E-02	0.0017	2.077E-01	0.0051
otal	2.939E+01	0.7176	1.715E+00	0.0419	0.000E+00	0.0000	8.746E+00	0.2135	3.373E-01	0.0082	4.287E-01	0.0105	3.417E-01	0.0083

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-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
uclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	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	2.367E+01	0.5777
Th-228	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	1.123E+01	0.2742
h-232	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	6.066E+00	0.1481
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	4.096E+01	1.0000

*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

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
uclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	1.676E+01	0.4209	1.618E-01	0.0041	0.000E+00	0.0000	5.195E+00	0.1304	1.985E-01	0.0050	2.683E-01	0.0067	9.049E-02	0.0023
h-228	5.303E+00	0.1332	8.422E-02	0.0021	0.000E+00	0.0000	3.344E-02	0.0008	1.882E-03	0.0000	1.481E-04	0.0000	1.585E-02	0.0004
h-232	6.560E+00	0.1647	1.462E+00	0.0367	0.000E+00	0.0000	3.186E+00	0.0800	1.251E-01	0.0031	1.444E-01	0.0036	2.310E-01	0.0058
otal	2.862E+01	0.7188	1.708E+00	0.0429	0.000E+00	0.0000	8.415E+00	0.2113	3.255E-01	0.0082	4.129E-01	0.0104	3.373E-01	0.0085

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

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
uclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	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	2.267E+01	0.5694
Th-228	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	5.439E+00	0.1366
h-232	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	1.171E+01	0.2940
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	3.982E+01	1.0000

*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

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
uclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	8.659E+00	0.2345	9.943E-02	0.0027	0.000E+00	0.0000	1.876E+00	0.0508	7.263E-02	0.0020	9.710E-02	0.0026	4.073E-02	0.0011
h-228	4.191E-01	0.0113	6.666E-03	0.0002	0.000E+00	0.0000	2.585E-03	0.0001	1.468E-04	0.0000	1.171E-05	0.0000	1.255E-03	0.0000
h-232	1.745E+01	0.4726	1.580E+00	0.0428	0.000E+00	0.0000	5.825E+00	0.1577	2.284E-01	0.0062	2.834E-01	0.0077	2.851E-01	0.0077
otal	2.653E+01	0.7184	1.686E+00	0.0457	0.000E+00	0.0000	7.703E+00	0.2086	3.012E-01	0.0082	3.806E-01	0.0103	3.271E-01	0.0089

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

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.
Ra-228	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	1.084E+01	0.2937
Th-228	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	4.298E-01	0.0116
h-232	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	2.565E+01	0.6947
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	3.693E+01	1.0000

*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

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
ıclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	5.295E-01	0.0153	6.282E-03	0.0002	0.000E+00	0.0000	9.967E-02	0.0029	3.972E-03	0.0001	5.307E-03	0.0002	2.436E-03	0.0001
ı-228	2.969E-04	0.0000	4.749E-06	0.0000	0.000E+00	0.0000	1.715E-06	0.0000	1.057E-07	0.0000	8.325E-09	0.0000	8.938E-07	0.0000
ı-232	2.452E+01	0.7091	1.663E+00	0.0481	0.000E+00	0.0000	6.806E+00	0.1969	2.746E-01	0.0079	3.459E-01	0.0100	3.182E-01	0.0092
otal	2.505E+01	0.7245	1.669E+00	0.0483	0.000E+00	0.0000	6.906E+00	0.1998	2.786E-01	0.0081	3.512E-01	0.0102	3.206E-01	0.0093

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

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
uclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	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	6.471E-01	0.0187
Th-228	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	3.044E-04	0.0000
h-232	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	3.392E+01	0.9813
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	3.457E+01	1.0000

*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

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
uclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	2.247E-05	0.0000	2.771E-07	0.0000	0.000E+00	0.0000	3.251E-06	0.0000	1.477E-07	0.0000	1.993E-07	0.0000	1.074E-07	0.0000
h-228	2.747E-15	0.0000	4.583E-17	0.0000	0.000E+00	0.0000	1.227E-17	0.0000	1.010E-18	0.0000	7.968E-20	0.0000	8.626E-18	0.0000
h-232	2.402E+01	0.7593	1.665E+00	0.0526	0.000E+00	0.0000	5.092E+00	0.1610	2.372E-01	0.0075	2.987E-01	0.0094	3.197E-01	0.0101
otal	2.402E+01	0.7593	1.665E+00	0.0526	0.000E+00	0.0000	5.092E+00	0.1610	2.372E-01	0.0075	2.987E-01	0.0094	3.197E-01	0.0101

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

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.
Ra-228	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	2.645E-05	0.0000
Th-228	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	2.814E-15	0.0000
h-232	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	3.163E+01	1.0000
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	3.163E+01	1.0000

*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

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
ıclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.710E-24	0.0000	2.501E-24	0.0000	1.503E-24	0.0000	0.000E+00	0.0000
ı-228	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	0.000E+00	0.0000
ı-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.093E-05	0.4123	9.741E-06	0.3672	5.779E-06	0.2179	0.000E+00	0.0000
otal	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.093E-05	0.4123	9.741E-06	0.3672	5.779E-06	0.2179	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 = 3.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
"uclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	5.308E-16	0.0000	1.807E-18	0.0000	0.000E+00	0.0000	1.061E-16	0.0000	1.203E-17	0.0000	1.960E-17	0.0000	6.703E-16	0.0000
Th-228	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	0.000E+00	0.0000
h-232	5.573E-08	0.0021	1.893E-10	0.0000	0.000E+00	0.0000	1.110E-08	0.0004	1.240E-09	0.0000	2.037E-09	0.0001	2.652E-05	1.0000
Total	5.573E-08	0.0021	1.893E-10	0.0000	0.000E+00	0.0000	1.110E-08	0.0004	1.240E-09	0.0000	2.037E-09	0.0001	2.652E-05	1.0000

*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

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
uclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	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	0.000E+00	0.0000
h-228	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	0.000E+00	0.0000
h-232	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	0.000E+00	0.0000
otal	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	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+03 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
uclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	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	0.000E+00	0.0000
Th-228	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	0.000E+00	0.0000
h-232	8.643E-13	0.7928	2.936E-15	0.0027	0.000E+00	0.0000	1.721E-13	0.1579	1.921E-14	0.0176	3.158E-14	0.0290	1.090E-12	1.0000
Total	8.643E-13	0.7928	2.936E-15	0.0027	0.000E+00	0.0000	1.721E-13	0.1579	1.921E-14	0.0176	3.158E-14	0.0290	1.090E-12	1.0000

*Sum of all water independent and dependent pathways.

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

Parent (i)	Product (j)	Branch Fraction*	DSR(j,t) (mrem/yr)/(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
Ra-228	Ra-228	1.000E+00	3.815E+00	3.301E+00	2.471E+00	8.967E-01	4.947E-02	1.912E-06	1.337E-16	0.000E+00
Ra-228	Th-228	1.000E+00	6.007E-01	1.432E+00	2.064E+00	1.272E+00	7.995E-02	3.378E-06	3.584E-19	0.000E+00
Ra-228	∑DSR(j)		4.416E+00	4.733E+00	4.535E+00	2.169E+00	1.294E-01	5.291E-06	1.341E-16	0.000E+00
Th-228	Th-228	1.000E+00	3.228E+00	2.246E+00	1.088E+00	8.595E-02	6.087E-05	5.629E-16	0.000E+00	0.000E+00
Th-232	Th-232	1.000E+00	4.066E-01	4.064E-01	4.058E-01	4.039E-01	3.983E-01	3.787E-01	1.561E-07	0.000E+00
Th-232	Ra-228	1.000E+00	2.277E-01	6.540E-01	1.342E+00	2.630E+00	3.236E+00	2.871E+00	5.069E-06	2.175E-13
Th-232	Th-228	1.000E+00	2.540E-02	1.528E-01	5.942E-01	2.097E+00	3.151E+00	3.076E+00	7.964E-08	5.138E-16
Th-232	∑DSR(j)		6.598E-01	1.213E+00	2.342E+00	5.131E+00	6.785E+00	6.326E+00	5.305E-06	2.180E-13

*Branch Fraction is the cumulative factor for the j't principal radionuclide daughter: CUMBRF(j) = BRF(1)*BRF(2)* ... BRF(j).
The DSR includes contributions from associated (half-life ≤ 0.5 yr) daughters.

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 3.000E+01 mrem/yr

Nuclide (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
Ra-228	6.794E+00	6.338E+00	6.615E+00	1.383E+01	2.318E+02	5.670E+06	*2.726E+14	*2.726E+14
Th-228	9.294E+00	1.336E+01	2.758E+01	3.490E+02	4.928E+05	*8.192E+14	*8.192E+14	*8.192E+14
Th-232	4.547E+01	2.473E+01	1.281E+01	5.847E+00	4.422E+00	4.742E+00	*1.096E+05	*1.096E+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 = 0.000E+00 years

Nuclide (i)	Initial (pCi/g)	tmin (years)	DSR(i,tmin)	G(i,tmin) (pCi/g)	DSR(i,tmax)	G(i,tmax) (pCi/g)
Ra-228	5.000E+00	1.466 ± 0.003	4.762E+00	6.300E+00	4.416E+00	6.794E+00
Th-228	5.000E+00	0.000E+00	3.228E+00	9.294E+00	3.228E+00	9.294E+00
Th-232	5.000E+00	35.53 ± 0.07	6.806E+00	4.408E+00	6.598E-01	4.547E+01

Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated

clide (j)	Parent (i)	BRF(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
-228	Ra-228	1.000E+00	1.908E+01	1.651E+01	1.236E+01	4.484E+00	2.473E-01	9.562E-06	6.685E-16	0.000E+00
-228	Th-232	1.000E+00	1.139E+00	3.270E+00	6.709E+00	1.315E+01	1.618E+01	1.436E+01	2.535E-05	1.088E-12
Ra-228	∑DOSE(j)		2.021E+01	1.978E+01	1.907E+01	1.763E+01	1.643E+01	1.436E+01	2.535E-05	1.088E-12
-228	Ra-228	1.000E+00	3.004E+00	7.159E+00	1.032E+01	6.361E+00	3.998E-01	1.689E-05	1.792E-18	0.000E+00
-228	Th-228	1.000E+00	1.614E+01	1.123E+01	5.439E+00	4.298E-01	3.044E-04	2.814E-15	0.000E+00	0.000E+00
Th-228	Th-232	1.000E+00	1.270E-01	7.638E-01	2.971E+00	1.049E+01	1.576E+01	1.538E+01	3.982E-07	2.569E-15
-228	∑DOSE(j)		1.927E+01	1.915E+01	1.873E+01	1.728E+01	1.616E+01	1.538E+01	3.982E-07	2.569E-15
Th-232	Th-232	1.000E+00	2.033E+00	2.032E+00	2.029E+00	2.019E+00	1.991E+00	1.894E+00	7.806E-07	0.000E+00

RF(i) is the branch fraction of the parent nuclide.

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

uclide (j)	Parent (i)	BRF(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
a-228	Ra-228	1.000E+00	5.000E+00	4.333E+00	3.253E+00	1.193E+00	6.794E-02	2.994E-06	1.073E-18	0.000E+00
a-228	Th-232	1.000E+00	0.000E+00	5.615E-01	1.470E+00	3.202E+00	4.147E+00	4.196E+00	4.174E+00	4.097E+00
Ra-228	∑S(j):		5.000E+00	4.894E+00	4.723E+00	4.395E+00	4.215E+00	4.196E+00	4.174E+00	4.097E+00
h-228	Ra-228	1.000E+00	0.000E+00	1.410E+00	2.592E+00	1.753E+00	1.122E-01	4.951E-06	1.775E-18	0.000E+00
Th-228	Th-228	1.000E+00	5.000E+00	3.480E+00	1.686E+00	1.335E-01	9.507E-05	9.175E-16	0.000E+00	0.000E+00
h-228	Th-232	1.000E+00	0.000E+00	9.251E-02	6.074E-01	2.619E+00	4.109E+00	4.196E+00	4.174E+00	4.097E+00
h-228	∑S(j):		5.000E+00	4.982E+00	4.885E+00	4.505E+00	4.222E+00	4.196E+00	4.174E+00	4.097E+00
Th-232	Th-232	1.000E+00	5.000E+00	5.000E+00	5.000E+00	4.999E+00	4.996E+00	4.987E+00	4.960E+00	4.869E+00

RF(i) is the branch fraction of the parent nuclide.

ESCALC.EXE execution time = 3.23 seconds

Radium Baseline Case

Table of Contents

Part I: Mixture Sums and Single Radionuclide Guidelines

Dose Conversion Factor (and Related) Parameter Summary
File: FGR 13 Morbidity

enu	Parameter	Current Value	Default	Parameter Name
B-1	Dose conversion factors for inhalation, mrem/pCi:			
-1	Pb-210+D	2.320E-02	2.320E-02	DCF2(1)
-1	Ra-226+D	8.600E-03	8.600E-03	DCF2(2)
-1	Dose conversion factors for ingestion, mrem/pCi:			
-1	Pb-210+D	7.270E-03	7.270E-03	DCF3(1)
D-1	Ra-226+D	1.330E-03	1.330E-03	DCF3(2)
-34	Food transfer factors:			
D-34	Pb-210+D , plant/soil concentration ratio, dimensionless	1.000E-02	1.000E-02	RTF(1,1)
D-34	Pb-210+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	8.000E-04	8.000E-04	RTF(1,2)
-34	Pb-210+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	3.000E-04	3.000E-04	RTF(1,3)
-34				
D-34	Ra-226+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(2,1)
-34	Ra-226+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(2,2)
-34	Ra-226+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(2,3)
D-5	Bioaccumulation factors, fresh water, L/kg:			
-5	Pb-210+D , fish	3.000E+02	3.000E+02	BIOFAC(1,1)
-5	Pb-210+D , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC(1,2)
D-5				
-5	Ra-226+D , fish	5.000E+01	5.000E+01	BIOFAC(2,1)
-5	Ra-226+D , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(2,2)

Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R011	Area of contaminated zone (m**2)	1.000E+04	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	3.000E-01	2.000E+00	---	THICK0
011	Length parallel to aquifer flow (m)	1.000E+02	1.000E+02	---	LCZPAQ
011	Basic radiation dose limit (mrem/yr)	3.000E+01	2.500E+01	---	BRDL
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
011	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)
011	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)
011	Times for calculations (yr)	not used	0.000E+00	---	T(9)
011	Times for calculations (yr)	not used	0.000E+00	---	T(10)
012	Initial principal radionuclide (pCi/g): Ra-226	5.000E+00	0.000E+00	---	S1(2)
012	Concentration in groundwater (pCi/L): Ra-226	not used	0.000E+00	---	W1(2)
R013	Cover depth (m)	0.000E+00	0.000E+00	---	COVER0
013	Density of cover material (g/cm**3)	not used	1.500E+00	---	DENSCV
013	Cover depth erosion rate (m/yr)	not used	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.630E+00	1.500E+00	---	DENSCZ
013	Contaminated zone erosion rate (m/yr)	1.000E-03	1.000E-03	---	VCZ
013	Contaminated zone total porosity	3.000E-01	4.000E-01	---	TPCZ
R013	Contaminated zone field capacity	2.000E-01	2.000E-01	---	FCCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	1.000E+01	1.000E+01	---	HCCZ
013	Contaminated zone b parameter	5.300E+00	5.300E+00	---	BCZ
R013	Average annual wind speed (m/sec)	2.000E+00	2.000E+00	---	WIND
R013	Humidity in air (g/m**3)	not used	8.000E+00	---	HUMID
013	Evapotranspiration coefficient	5.000E-01	5.000E-01	---	EVAPTR
013	Precipitation (m/yr)	1.000E+00	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	7.600E-01	2.000E-01	---	RI
013	Irrigation mode	overhead	overhead	---	IDITCH
013	Runoff coefficient	2.000E-01	2.000E-01	---	RUNOFF
R013	Watershed area for nearby stream or pond (m**2)	1.000E+06	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)	1.630E+00	1.500E+00	---	DENSAQ
R014	Saturated zone total porosity	3.000E-01	4.000E-01	---	TPSZ
014	Saturated zone effective porosity	2.000E-01	2.000E-01	---	EPSZ
014	Saturated zone field capacity	2.000E-01	2.000E-01	---	FCSZ
R014	Saturated zone hydraulic conductivity (m/yr)	1.000E+02	1.000E+02	---	HCSZ
014	Saturated zone hydraulic gradient	2.000E-02	2.000E-02	---	HGWT
014	Saturated zone b parameter	5.300E+00	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	1.000E-03	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	1.000E+01	1.000E+01	---	DWIBWT
014	Model: Nondispersion (ND) or Mass-Balance (MB)	ND	ND	---	MODEL
R014	Well pumping rate (m**3/yr)	2.500E+02	2.500E+02	---	UW
015	Number of unsaturated zone strata	1	1	---	NS

Site-Specific Parameter Summary (continued)

nu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R015	Unsat. zone 1, thickness (m)	1.000E+00	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	1.630E+00	1.500E+00	---	DENSUZ(1)
·15	Unsat. zone 1, total porosity	3.000E-01	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	2.000E-01	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, field capacity	2.000E-01	2.000E-01	---	FCUZ(1)
15	Unsat. zone 1, soil-specific b parameter	5.300E+00	5.300E+00	---	BUZ(1)
15	Unsat. zone 1, hydraulic conductivity (m/yr)	1.000E+01	1.000E+01	---	HCUZ(1)
016	Distribution coefficients for Ra-226				
016	Contaminated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCC(2)
R016	Unsaturated zone 1 (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCU(2,1)
R016	Saturated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCS(2)
016	Leach rate (/yr)	0.000E+00	0.000E+00	2.274E-02	ALEACH(2)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(2)
016	Distribution coefficients for daughter Pb-210				
016	Contaminated zone (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCC(1)
R016	Unsaturated zone 1 (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCU(1,1)
016	Saturated zone (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCS(1)
016	Leach rate (/yr)	0.000E+00	0.000E+00	1.593E-02	ALEACH(1)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(1)
017	Inhalation rate (m**3/yr)	1.051E+04	8.400E+03	---	INHALR
017	Mass loading for inhalation (g/m**3)	2.000E-04	1.000E-04	---	MLINH
R017	Exposure duration	3.000E+01	3.000E+01	---	ED
017	Shielding factor, inhalation	5.000E-01	4.000E-01	---	SHF3
017	Shielding factor, external gamma	3.300E-01	7.000E-01	---	SHF1
R017	Fraction of time spent indoors	5.500E-01	5.000E-01	---	FIND
R017	Fraction of time spent outdoors (on site)	2.100E-01	2.500E-01	---	FOTD
017	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)
017	Outer annular radius (m), ring 2:	not used	7.071E+01	---	RAD_SHAPE(2)
017	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)
017	Outer annular radius (m), ring 5:	not used	0.000E+00	---	RAD_SHAPE(5)
017	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)
017	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)
017	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)
017	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)
017	Ring 5	not used	0.000E+00	---	FRACA(5)
017	Ring 6	not used	0.000E+00	---	FRACA(6)
R017	Ring 7	not used	0.000E+00	---	FRACA(7)
017	Ring 8	not used	0.000E+00	---	FRACA(8)
017	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)
017	Ring 12	not used	0.000E+00	---	FRACA(12)
R018	Fruits, vegetables and grain consumption (kg/yr)	1.660E+02	1.600E+02	---	DIET(1)
018	Leafy vegetable consumption (kg/yr)	1.100E+01	1.400E+01	---	DIET(2)
018	Milk consumption (L/yr)	1.000E+02	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	6.300E+01	6.300E+01	---	DIET(4)
018	Fish consumption (kg/yr)	5.400E+00	5.400E+00	---	DIET(5)
018	Other seafood consumption (kg/yr)	9.000E-01	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	1.825E+01	3.650E+01	---	SOIL
R018	Drinking water intake (L/yr)	7.300E+02	5.100E+02	---	DWI
018	Contamination fraction of drinking water	1.000E+00	1.000E+00	---	FDW
018	Contamination fraction of household water	not used	1.000E+00	---	FHHW
R018	Contamination fraction of livestock water	1.000E+00	1.000E+00	---	FLW
018	Contamination fraction of irrigation water	1.000E+00	1.000E+00	---	FIRW
018	Contamination fraction of aquatic food	5.000E-01	5.000E-01	---	FR9
R018	Contamination fraction of plant food	-1	-1	0.500E+00	FPLANT
R018	Contamination fraction of meat	-1	-1	0.500E+00	FMEAT
018	Contamination fraction of milk	-1	-1	0.500E+00	FMILK
R019	Livestock fodder intake for meat (kg/day)	6.800E+01	6.800E+01	---	LFI5
019	Livestock fodder intake for milk (kg/day)	5.500E+01	5.500E+01	---	LFI6
019	Livestock water intake for meat (L/day)	5.000E+01	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	1.600E+02	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)	9.000E-01	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	1.000E+00	1.000E+00	---	FGWDW
R019	Household water fraction from ground water	not used	1.000E+00	---	FGWHH
R019	Livestock water fraction from ground water	1.000E+00	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	1.000E+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)
R19B	Translocation Factor for Non-Leafy	1.000E-01	1.000E-01	---	TIV(1)

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
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
C14	DCF correction factor for gaseous forms of C14	not used	8.894E+01	---	CO2F
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
TITL	Maximum number of integration points for dose	17	---	---	LYMAX

Site-Specific Parameter Summary (continued)

enu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
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	active
6 -- aquatic foods	active
7 -- drinking water	active
8 -- soil ingestion	active
9 -- radon	suppressed
Find peak pathway doses	active

Contaminated Zone Dimensions		Initial Soil Concentrations, pCi/g	
Area:	10000.00 square meters	Ra-226	5.000E+00
Thickness:	0.30 meters		
over Depth:	0.00 meters		

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 3.000E+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):	2.928E+01	2.894E+01	2.823E+01	2.554E+01	1.778E+01	3.517E+00	1.403E+01	1.045E+01
M(t):	9.760E-01	9.648E-01	9.411E-01	8.513E-01	5.925E-01	1.172E-01	4.677E-01	3.484E-01

Maximum TDOSE(t): 2.928E+01 mrem/yr at t = 0.000E+00 years

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

Water Independent Pathways (Inhalation excludes radon)

adio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
uclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	2.051E+01	0.7005	7.640E-03	0.0003	0.000E+00	0.0000	7.944E+00	0.2713	3.054E-01	0.0104	4.125E-01	0.0141	9.883E-02	0.0034
Total	2.051E+01	0.7005	7.640E-03	0.0003	0.000E+00	0.0000	7.944E+00	0.2713	3.054E-01	0.0104	4.125E-01	0.0141	9.883E-02	0.0034

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

Water Dependent Pathways

adio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
uclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
a-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	2.928E+01	1.0000
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	2.928E+01	1.0000

*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-	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.
Ra-226	2.004E+01	0.6923	8.052E-03	0.0003	0.000E+00	0.0000	8.055E+00	0.2783	3.180E-01	0.0110	4.135E-01	0.0143	1.113E-01	0.0038
Total	2.004E+01	0.6923	8.052E-03	0.0003	0.000E+00	0.0000	8.055E+00	0.2783	3.180E-01	0.0110	4.135E-01	0.0143	1.113E-01	0.0038

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-	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.
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	2.894E+01	1.0000
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	2.894E+01	1.0000

*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

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.
Ra-226	1.913E+01	0.6775	8.769E-03	0.0003	0.000E+00	0.0000	8.212E+00	0.2909	3.382E-01	0.0120	4.133E-01	0.0146	1.335E-01	0.0047
Total	1.913E+01	0.6775	8.769E-03	0.0003	0.000E+00	0.0000	8.212E+00	0.2909	3.382E-01	0.0120	4.133E-01	0.0146	1.335E-01	0.0047

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

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.
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	2.823E+01	1.0000
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	2.823E+01	1.0000

*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

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.
Ra-226	1.625E+01	0.6362	1.035E-02	0.0004	0.000E+00	0.0000	8.315E+00	0.3256	3.790E-01	0.0148	4.001E-01	0.0157	1.864E-01	0.0073
Total	1.625E+01	0.6362	1.035E-02	0.0004	0.000E+00	0.0000	8.315E+00	0.3256	3.790E-01	0.0148	4.001E-01	0.0157	1.864E-01	0.0073

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

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.
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	2.554E+01	1.0000
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	2.554E+01	1.0000

*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

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
uclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	1.019E+01	0.5731	1.031E-02	0.0006	0.000E+00	0.0000	6.701E+00	0.3770	3.527E-01	0.0198	3.116E-01	0.0175	2.130E-01	0.0120
Total	1.019E+01	0.5731	1.031E-02	0.0006	0.000E+00	0.0000	6.701E+00	0.3770	3.527E-01	0.0198	3.116E-01	0.0175	2.130E-01	0.0120

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

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.
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	1.778E+01	1.0000
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	1.778E+01	1.0000

*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

Water Independent Pathways (Inhalation excludes radon)

dio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
clide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	1.948E+00	0.5539	3.035E-03	0.0009	0.000E+00	0.0000	1.336E+00	0.3798	9.182E-02	0.0261	7.134E-02	0.0203	6.720E-02	0.0191
Total	1.948E+00	0.5539	3.035E-03	0.0009	0.000E+00	0.0000	1.336E+00	0.3798	9.182E-02	0.0261	7.134E-02	0.0203	6.720E-02	0.0191

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

Water Dependent Pathways

adio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
uclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
a-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	3.517E+00	1.0000
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	3.517E+00	1.0000

*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

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
uclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.102E-07	0.0000	4.254E-08	0.0000	1.339E-08	0.0000	0.000E+00	0.0000
otal	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.102E-07	0.0000	4.254E-08	0.0000	1.339E-08	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 = 3.000E+02 years

Water Dependent Pathways

adio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
uclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
a-226	1.129E+01	0.8047	1.129E-01	0.0080	0.000E+00	0.0000	2.229E+00	0.1589	2.131E-01	0.0152	1.852E-01	0.0132	1.403E+01	1.0000
Total	1.129E+01	0.8047	1.129E-01	0.0080	0.000E+00	0.0000	2.229E+00	0.1589	2.131E-01	0.0152	1.852E-01	0.0132	1.403E+01	1.0000

*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

Water Independent Pathways (Inhalation excludes radon)

adio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
uclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
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	0.000E+00	0.0000
otal	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	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+03 years

Water Dependent Pathways

adio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
uclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
a-226	8.411E+00	0.8047	8.415E-02	0.0081	0.000E+00	0.0000	1.661E+00	0.1589	1.587E-01	0.0152	1.379E-01	0.0132	1.045E+01	1.0000
Total	8.411E+00	0.8047	8.415E-02	0.0081	0.000E+00	0.0000	1.661E+00	0.1589	1.587E-01	0.0152	1.379E-01	0.0132	1.045E+01	1.0000

Sum of all water independent and dependent pathways.

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

rent	Product	Branch		DSR(j,t) (mrem/yr)/(pCi/g)							
i)	(j)	Fraction*	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
Ra-226	Ra-226	1.000E+00		5.811E+00	5.673E+00	5.405E+00	4.562E+00	2.808E+00	5.040E-01	5.847E-01	4.345E-01
-226	Pb-210	1.000E+00		4.428E-02	1.162E-01	2.418E-01	5.460E-01	7.472E-01	1.994E-01	2.221E+00	1.656E+00
Ra-226	∑DSR(j)			5.856E+00	5.789E+00	5.647E+00	5.108E+00	3.555E+00	7.034E-01	2.806E+00	2.091E+00

ranch Fraction is the cumulative factor for the j't principal radionuclide daughter: CUMBRF(j) = BRF(1)*BRF(2)* ... BRF(j).
e DSR includes contributions from associated (half-life ≤ 0.5 yr) daughters.

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 3.000E+01 mrem/yr

iclide (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
a-226	5.123E+00	5.162E+00	5.313E+00	5.873E+00	8.438E+00	4.265E+01	1.069E+01	1.435E+01

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 = 0.000E+00 years

Nuclide (i)	Initial (pCi/g)	tmin (years)	DSR(i,tmin)	G(i,tmin) (pCi/g)	DSR(i,tmax)	G(i,tmax) (pCi/g)
Ra-226	5.000E+00	0.000E+00	5.856E+00	5.123E+00	5.856E+00	5.123E+00

Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated

clide (j)	Parent (i)	BRF(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
Ra-226	Ra-226	1.000E+00	2.906E+01	2.836E+01	2.702E+01	2.281E+01	1.404E+01	2.520E+00	2.923E+00	2.173E+00
Pb-210	Ra-226	1.000E+00	2.214E-01	5.808E-01	1.209E+00	2.730E+00	3.736E+00	9.971E-01	1.111E+01	8.280E+00

BRF(i) is the branch fraction of the parent nuclide.

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

clide (j)	Parent (i)	BRF(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
Ra-226	Ra-226	1.000E+00	5.000E+00	4.885E+00	4.664E+00	3.966E+00	2.495E+00	4.928E-01	4.787E-03	4.326E-10
Pb-210	Ra-226	1.000E+00	0.000E+00	1.501E-01	4.197E-01	1.097E+00	1.662E+00	5.833E-01	6.237E-03	5.640E-10

BRF(i) is the branch fraction of the parent nuclide.

RESCALC.EXE execution time = 1.17 seconds

Uranium Baseline Case

Table of Contents

Part I: Mixture Sums and Single Radionuclide Guidelines

Dose Conversion Factor (and Related) Parameter Summary
File: FGR 13 Morbidity

Menu	Parameter	Current Value	Default	Parameter Name
-1	Dose conversion factors for inhalation, mrem/pCi:			
B-1	Pb-210+D	2.320E-02	2.320E-02	DCF2(1)
B-1	Ra-226+D	8.600E-03	8.600E-03	DCF2(2)
-1	Th-230	3.260E-01	3.260E-01	DCF2(3)
-1	U-234	1.320E-01	1.320E-01	DCF2(4)
B-1	U-238+D	1.180E-01	1.180E-01	DCF2(5)
-1	Dose conversion factors for ingestion, mrem/pCi:			
D-1	Pb-210+D	7.270E-03	7.270E-03	DCF3(1)
D-1	Ra-226+D	1.330E-03	1.330E-03	DCF3(2)
-1	Th-230	5.480E-04	5.480E-04	DCF3(3)
D-1	U-234	2.830E-04	2.830E-04	DCF3(4)
D-1	U-238+D	2.690E-04	2.690E-04	DCF3(5)
-34	Food transfer factors:			
D-34	Pb-210+D , plant/soil concentration ratio, dimensionless	1.000E-02	1.000E-02	RTF(1,1)
-34	Pb-210+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	8.000E-04	8.000E-04	RTF(1,2)
-34	Pb-210+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	3.000E-04	3.000E-04	RTF(1,3)
D-34				
D-34	Ra-226+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(2,1)
-34	Ra-226+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(2,2)
-34	Ra-226+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(2,3)
D-34				
-34	Th-230 , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(3,1)
-34	Th-230 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(3,2)
D-34	Th-230 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(3,3)
D-34				
-34	U-234 , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(4,1)
D-34	U-234 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(4,2)
D-34	U-234 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(4,3)
-34				
-34	U-238+D , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(5,1)
D-34	U-238+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(5,2)
-34	U-238+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(5,3)
D-5	Bioaccumulation factors, fresh water, L/kg:			
D-5	Pb-210+D , fish	3.000E+02	3.000E+02	BIOFAC(1,1)
D-5	Pb-210+D , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC(1,2)
D-5				
D-5	Ra-226+D , fish	5.000E+01	5.000E+01	BIOFAC(2,1)
D-5	Ra-226+D , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(2,2)
D-5				
D-5	Th-230 , fish	1.000E+02	1.000E+02	BIOFAC(3,1)
D-5	Th-230 , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(3,2)
D-5				
D-5	U-234 , fish	1.000E+01	1.000E+01	BIOFAC(4,1)
D-5	U-234 , crustacea and mollusks	6.000E+01	6.000E+01	BIOFAC(4,2)
D-5				

Dose Conversion Factor (and Related) Parameter Summary (continued)
File: FGR 13 Morbidity

Menu	Parameter	Current Value	Default	Parameter Name
D-5	U-238+D , fish	1.000E+01	1.000E+01	BIOFAC(5,1)
D-5	U-238+D , crustacea and mollusks	6.000E+01	6.000E+01	BIOFAC(5,2)

Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R011	Area of contaminated zone (m**2)	1.000E+04	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	3.000E-01	2.000E+00	---	THICK0
R011	Length parallel to aquifer flow (m)	1.000E+02	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	3.000E+01	2.500E+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	5.000E+00	0.000E+00	---	S1(1)
R012	Initial principal radionuclide (pCi/g): Ra-226	5.000E+00	0.000E+00	---	S1(2)
R012	Initial principal radionuclide (pCi/g): Th-230	5.000E+00	0.000E+00	---	S1(3)
R012	Initial principal radionuclide (pCi/g): U-234	5.000E+00	0.000E+00	---	S1(4)
R012	Initial principal radionuclide (pCi/g): U-238	5.000E+00	0.000E+00	---	S1(5)
R012	Concentration in groundwater (pCi/L): Pb-210	not used	0.000E+00	---	W1(1)
R012	Concentration in groundwater (pCi/L): Ra-226	not used	0.000E+00	---	W1(2)
R012	Concentration in groundwater (pCi/L): Th-230	not used	0.000E+00	---	W1(3)
R012	Concentration in groundwater (pCi/L): U-234	not used	0.000E+00	---	W1(4)
R012	Concentration in groundwater (pCi/L): U-238	not used	0.000E+00	---	W1(5)
R013	Cover depth (m)	0.000E+00	0.000E+00	---	COVER0
R013	Density of cover material (g/cm**3)	not used	1.500E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	not used	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.630E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	1.000E-03	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	3.000E-01	4.000E-01	---	TPCZ
R013	Contaminated zone field capacity	2.000E-01	2.000E-01	---	FCCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	1.000E+01	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter	5.300E+00	5.300E+00	---	BCZ
R013	Average annual wind speed (m/sec)	2.000E+00	2.000E+00	---	WIND
R013	Humidity in air (g/m**3)	not used	8.000E+00	---	HUMID
R013	Evapotranspiration coefficient	5.000E-01	5.000E-01	---	EVAPTR
R013	Precipitation (m/yr)	1.000E+00	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	7.600E-01	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	2.000E-01	2.000E-01	---	RUNOFF
R013	Watershed area for nearby stream or pond (m**2)	1.000E+06	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)	1.630E+00	1.500E+00	---	DENSAQ
R014	Saturated zone total porosity	3.000E-01	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	2.000E-01	2.000E-01	---	EPSZ
R014	Saturated zone field capacity	2.000E-01	2.000E-01	---	FCSZ
R014	Saturated zone hydraulic conductivity (m/yr)	1.000E+02	1.000E+02	---	HCSZ

Site-Specific Parameter Summary (continued)

nu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
014	Saturated zone hydraulic gradient	2.000E-02	2.000E-02	---	HGWT
014	Saturated zone b parameter	not used	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	0.000E+00	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	1.000E+01	1.000E+01	---	DWIBWT
014	Model: Nondispersion (ND) or Mass-Balance (MB)	ND	ND	---	MODEL
014	Well pumping rate (m**3/yr)	2.500E+02	2.500E+02	---	UW
015	Number of unsaturated zone strata	1	1	---	NS
015	Unsat. zone 1, thickness (m)	1.000E+00	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	1.630E+00	1.500E+00	---	DENSUZ(1)
015	Unsat. zone 1, total porosity	3.000E-01	4.000E-01	---	TPUZ(1)
015	Unsat. zone 1, effective porosity	2.000E-01	2.000E-01	---	EPUZ(1)
015	Unsat. zone 1, field capacity	2.000E-01	2.000E-01	---	FCUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	5.300E+00	5.300E+00	---	BUZ(1)
015	Unsat. zone 1, hydraulic conductivity (m/yr)	1.000E+01	1.000E+01	---	HCUZ(1)
R016	Distribution coefficients for Pb-210				
016	Contaminated zone (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCC(1)
016	Unsaturated zone 1 (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCU(1,1)
R016	Saturated zone (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCS(1)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.593E-02	ALEACH(1)
016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(1)
R016	Distribution coefficients for Ra-226				
016	Contaminated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCC(2)
016	Unsaturated zone 1 (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCU(2,1)
R016	Saturated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCS(2)
016	Leach rate (/yr)	0.000E+00	0.000E+00	2.274E-02	ALEACH(2)
016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(2)
R016	Distribution coefficients for Th-230				
016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(3)
016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCU(3,1)
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCS(3)
016	Leach rate (/yr)	0.000E+00	0.000E+00	2.658E-05	ALEACH(3)
016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(3)
R016	Distribution coefficients for U-234				
016	Contaminated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCC(4)
R016	Unsaturated zone 1 (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCU(4,1)
R016	Saturated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCS(4)
016	Leach rate (/yr)	0.000E+00	0.000E+00	3.180E-02	ALEACH(4)
016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(4)
016	Distribution coefficients for U-238				
016	Contaminated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCC(5)
R016	Unsaturated zone 1 (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCU(5,1)
R016	Saturated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCS(5)
016	Leach rate (/yr)	0.000E+00	0.000E+00	3.180E-02	ALEACH(5)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(5)

Site-Specific Parameter Summary (continued)

mu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R017	Inhalation rate (m**3/yr)	1.051E+04	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	2.000E-04	1.000E-04	---	MLINH
R017	Exposure duration	3.000E+01	3.000E+01	---	ED
R017	Shielding factor, inhalation	5.000E-01	4.000E-01	---	SHF3
R017	Shielding factor, external gamma	3.300E-01	7.000E-01	---	SHF1
R017	Fraction of time spent indoors	5.500E-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)
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)	1.660E+02	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	1.100E+01	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	1.000E+02	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)	5.400E+00	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	9.000E-01	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	1.825E+01	3.650E+01	---	SOIL
R018	Drinking water intake (L/yr)	7.300E+02	5.100E+02	---	DWI
R018	Contamination fraction of drinking water	1.000E+00	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	1.000E+00	1.000E+00	---	FIRW
R018	Contamination fraction of aquatic food	5.000E-01	5.000E-01	---	FR9
R018	Contamination fraction of plant food	-1	-1	0.500E+00	FPLANT

Site-Specific Parameter Summary (continued)

nu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
018	Contamination fraction of meat	-1	-1	0.500E+00	FMEAT
118	Contamination fraction of milk	-1	-1	0.500E+00	FMILK
R019	Livestock fodder intake for meat (kg/day)	6.800E+01	6.800E+01	---	LFI5
119	Livestock fodder intake for milk (kg/day)	5.500E+01	5.500E+01	---	LFI6
019	Livestock water intake for meat (L/day)	5.000E+01	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	1.600E+02	1.600E+02	---	LWI6
019	Livestock soil intake (kg/day)	5.000E-01	5.000E-01	---	LSI
019	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
019	Depth of roots (m)	9.000E-01	9.000E-01	---	DROOT
019	Drinking water fraction from ground water	1.000E+00	1.000E+00	---	FGWDW
R019	Household water fraction from ground water	not used	1.000E+00	---	FGWHH
R019	Livestock water fraction from ground water	1.000E+00	1.000E+00	---	FGWLW
019	Irrigation fraction from ground water	1.000E+00	1.000E+00	---	FGWIR
R19B	Wet weight crop yield for Non-Leafy (kg/m**2)	7.000E-01	7.000E-01	---	YV(1)
19B	Wet weight crop yield for Leafy (kg/m**2)	1.500E+00	1.500E+00	---	YV(2)
19B	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)
19B	Growing Season for Fodder (years)	8.000E-02	8.000E-02	---	TE(3)
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)
19B	Translocation Factor for Fodder	1.000E+00	1.000E+00	---	TIV(3)
19B	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)
19B	Dry Foliar Interception Fraction for Fodder	2.500E-01	2.500E-01	---	RDRY(3)
19B	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)
19B	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
14	C-12 concentration in contaminated soil (g/g)	not used	3.000E-02	---	C12CZ
14	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
14	C-14 evasion layer thickness in soil (m)	not used	3.000E-01	---	DMC
14	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
14	Fraction of grain in milk cow feed	not used	2.000E-01	---	AVFG5
14	DCF correction factor for gaseous forms of C14	not used	8.894E+01	---	CO2F
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)

Site-Specific Parameter Summary (continued)

:enu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
STOR	Crustacea and mollusks	7.000E+00	7.000E+00	---	STOR_T(6)
TOR	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)
021	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
021	Total porosity of the cover material	not used	4.000E-01	---	TPCV
021	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
021	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
021	in contaminated zone soil	not used	2.000E-06	---	DIFCZ
021	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
.021	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)
:021	Emanating power of Rn-220 gas	not used	1.500E-01	---	EMANA(2)
TITL	Number of graphical time points	32	---	---	NPTS
:ITL	Maximum number of integration points for dose	17	---	---	LYMAX
:ITL	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	active
6 -- aquatic foods	active
7 -- drinking water	active
8 -- soil ingestion	active
9 -- radon	suppressed
Find peak pathway doses	active

Summary : Washington AAR 3000-m3 Resident Gardener
File : Wash AAR Uranium .RAD

Contaminated Zone Dimensions	
Area:	10000.00 square meters
Thickness:	0.30 meters
Cover Depth:	0.00 meters

Initial Soil Concentrations, pCi/g	
Pb-210	5.000E+00
Ra-226	5.000E+00
Th-230	5.000E+00
U-234	5.000E+00
U-238	5.000E+00

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 3.000E+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):	4.249E+01	4.156E+01	3.973E+01	3.392E+01	2.144E+01	6.187E+00	1.679E+01	1.111E+01
M(t):	1.416E+00	1.385E+00	1.324E+00	1.131E+00	7.148E-01	2.062E-01	5.598E-01	3.705E-01

Maximum TDOSE(t): 4.249E+01 mrem/yr at t = 0.000E+00 years

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

Water Independent Pathways (Inhalation excludes radon)

adio-	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.
b-210	1.147E-02	0.0003	1.956E-02	0.0005	0.000E+00	0.0000	1.047E+01	0.2464	6.511E-01	0.0153	3.642E-01	0.0086	4.925E-01	0.0116
a-226	2.051E+01	0.4827	7.640E-03	0.0002	0.000E+00	0.0000	7.944E+00	0.1870	3.054E-01	0.0072	4.125E-01	0.0097	9.883E-02	0.0023
Th-230	6.751E-03	0.0002	2.813E-01	0.0066	0.000E+00	0.0000	8.259E-02	0.0019	4.565E-03	0.0001	4.332E-04	0.0000	3.802E-02	0.0009
-234	7.511E-04	0.0000	1.121E-01	0.0026	0.000E+00	0.0000	1.028E-01	0.0024	8.322E-03	0.0002	2.282E-02	0.0005	1.932E-02	0.0005
-238	2.790E-01	0.0066	1.002E-01	0.0024	0.000E+00	0.0000	9.771E-02	0.0023	7.911E-03	0.0002	2.169E-02	0.0005	1.836E-02	0.0004
Total	2.081E+01	0.4897	5.209E-01	0.0123	0.000E+00	0.0000	1.869E+01	0.4400	9.773E-01	0.0230	8.216E-01	0.0193	6.670E-01	0.0157

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

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.
b-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	1.201E+01	0.2826
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	2.928E+01	0.6891
h-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	4.137E-01	0.0097
-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	2.661E-01	0.0063
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	5.249E-01	0.0124
otal	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	4.249E+01	1.0000

*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)

dio-	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.
-210	1.095E-02	0.0003	1.866E-02	0.0004	0.000E+00	0.0000	9.955E+00	0.2395	6.207E-01	0.0149	3.472E-01	0.0084	4.699E-01	0.0113
-226	2.004E+01	0.4822	8.052E-03	0.0002	0.000E+00	0.0000	8.055E+00	0.1938	3.180E-01	0.0077	4.135E-01	0.0099	1.113E-01	0.0027
Th-230	1.553E-02	0.0004	2.813E-01	0.0068	0.000E+00	0.0000	8.576E-02	0.0021	4.697E-03	0.0001	6.099E-04	0.0000	3.807E-02	0.0009
-234	7.277E-04	0.0000	1.086E-01	0.0026	0.000E+00	0.0000	9.927E-02	0.0024	8.062E-03	0.0002	2.210E-02	0.0005	1.871E-02	0.0005
-238	2.703E-01	0.0065	9.709E-02	0.0023	0.000E+00	0.0000	9.435E-02	0.0023	7.663E-03	0.0002	2.101E-02	0.0005	1.779E-02	0.0004
Total	2.034E+01	0.4893	5.137E-01	0.0124	0.000E+00	0.0000	1.829E+01	0.4401	9.591E-01	0.0231	8.044E-01	0.0194	6.558E-01	0.0158

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-	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.
b-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	1.142E+01	0.2748
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	2.894E+01	0.6965
h-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	4.260E-01	0.0103
-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	2.575E-01	0.0062
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	5.082E-01	0.0122
otal	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	4.156E+01	1.0000

*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

Water Independent Pathways (Inhalation excludes radon)

dio-	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.
-210	9.963E-03	0.0003	1.699E-02	0.0004	0.000E+00	0.0000	9.001E+00	0.2265	5.639E-01	0.0142	3.154E-01	0.0079	4.277E-01	0.0108
a-226	1.913E+01	0.4814	8.769E-03	0.0002	0.000E+00	0.0000	8.212E+00	0.2067	3.382E-01	0.0085	4.133E-01	0.0104	1.335E-01	0.0034
Th-230	3.249E-02	0.0008	2.813E-01	0.0071	0.000E+00	0.0000	9.221E-02	0.0023	4.978E-03	0.0001	9.664E-04	0.0000	3.817E-02	0.0010
-234	6.833E-04	0.0000	1.019E-01	0.0026	0.000E+00	0.0000	9.253E-02	0.0023	7.560E-03	0.0002	2.073E-02	0.0005	1.756E-02	0.0004
-238	2.536E-01	0.0064	9.111E-02	0.0023	0.000E+00	0.0000	8.795E-02	0.0022	7.186E-03	0.0002	1.970E-02	0.0005	1.669E-02	0.0004
otal	1.942E+01	0.4888	5.001E-01	0.0126	0.000E+00	0.0000	1.749E+01	0.4400	9.218E-01	0.0232	7.701E-01	0.0194	6.337E-01	0.0159

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

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.
b-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	1.033E+01	0.2601
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	2.823E+01	0.7105
h-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	4.501E-01	0.0113
-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	2.410E-01	0.0061
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	4.762E-01	0.0120
otal	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	3.973E+01	1.0000

*Sum of all water independent and dependent pathways.

Summary : Washington AAR 3000-m3 Resident Gardener
File : Wash AAR Uranium .RAD

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

Water Independent Pathways (Inhalation excludes radon)

dio-	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.
-210	7.170E-03	0.0002	1.222E-02	0.0004	0.000E+00	0.0000	6.324E+00	0.1864	4.028E-01	0.0119	2.256E-01	0.0066	3.078E-01	0.0091
-226	1.625E+01	0.4791	1.035E-02	0.0003	0.000E+00	0.0000	8.315E+00	0.2451	3.790E-01	0.0112	4.001E-01	0.0118	1.864E-01	0.0055
Th-230	8.594E-02	0.0025	2.813E-01	0.0083	0.000E+00	0.0000	1.149E-01	0.0034	6.057E-03	0.0002	2.187E-03	0.0001	3.866E-02	0.0011
-234	5.503E-04	0.0000	8.160E-02	0.0024	0.000E+00	0.0000	7.232E-02	0.0021	6.037E-03	0.0002	1.656E-02	0.0005	1.406E-02	0.0004
-238	2.029E-01	0.0060	7.293E-02	0.0021	0.000E+00	0.0000	6.874E-02	0.0020	5.738E-03	0.0002	1.574E-02	0.0005	1.336E-02	0.0004
Total	1.655E+01	0.4878	4.584E-01	0.0135	0.000E+00	0.0000	1.490E+01	0.4391	7.996E-01	0.0236	6.602E-01	0.0195	5.603E-01	0.0165

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

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.
b-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	7.280E+00	0.2146
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	2.554E+01	0.7530
h-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	5.290E-01	0.0156
-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	1.911E-01	0.0056
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	3.794E-01	0.0112
otal	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	3.392E+01	1.0000

*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

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.
-210	2.800E-03	0.0001	4.774E-03	0.0002	0.000E+00	0.0000	2.299E+00	0.1072	1.540E-01	0.0072	8.650E-02	0.0040	1.202E-01	0.0056
Ra-226	1.019E+01	0.4750	1.031E-02	0.0005	0.000E+00	0.0000	6.701E+00	0.3125	3.527E-01	0.0164	3.116E-01	0.0145	2.130E-01	0.0099
Th-230	1.978E-01	0.0092	2.812E-01	0.0131	0.000E+00	0.0000	1.707E-01	0.0080	9.192E-03	0.0004	5.170E-03	0.0002	4.045E-02	0.0019
234	3.115E-04	0.0000	4.323E-02	0.0020	0.000E+00	0.0000	3.566E-02	0.0017	3.175E-03	0.0001	8.716E-03	0.0004	7.446E-03	0.0003
-238	1.072E-01	0.0050	3.861E-02	0.0018	0.000E+00	0.0000	3.388E-02	0.0016	3.017E-03	0.0001	8.286E-03	0.0004	7.072E-03	0.0003
tal	1.049E+01	0.4894	3.781E-01	0.0176	0.000E+00	0.0000	9.241E+00	0.4309	5.221E-01	0.0243	4.203E-01	0.0196	3.882E-01	0.0181

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

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	2.668E+00	0.1244
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	1.778E+01	0.8289
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	7.045E-01	0.0329
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	9.853E-02	0.0046
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	1.980E-01	0.0092
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	2.144E+01	1.0000

*Sum of all water independent and dependent pathways.

Summary : Washington AAR 3000-m3 Resident Gardener
File : Wash AAR Uranium .RAD

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

Water Independent Pathways (Inhalation excludes radon)

dio-	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.
-210	1.040E-04	0.0000	1.777E-04	0.0000	0.000E+00	0.0000	6.338E-02	0.0102	5.302E-03	0.0009	3.013E-03	0.0005	4.475E-03	0.0007
Ra-226	1.948E+00	0.3149	3.035E-03	0.0005	0.000E+00	0.0000	1.336E+00	0.2159	9.182E-02	0.0148	7.134E-02	0.0115	6.720E-02	0.0109
Th-230	3.388E-01	0.0548	2.807E-01	0.0454	0.000E+00	0.0000	2.140E-01	0.0346	1.439E-02	0.0023	9.315E-03	0.0015	4.450E-02	0.0072
-234	1.111E-04	0.0000	4.735E-03	0.0008	0.000E+00	0.0000	2.899E-03	0.0005	3.376E-04	0.0001	9.239E-04	0.0001	8.144E-04	0.0001
-238	1.131E-02	0.0018	4.167E-03	0.0007	0.000E+00	0.0000	2.709E-03	0.0004	3.178E-04	0.0001	8.767E-04	0.0001	7.634E-04	0.0001
otal	2.298E+00	0.3715	2.928E-01	0.0473	0.000E+00	0.0000	1.619E+00	0.2616	1.122E-01	0.0181	8.547E-02	0.0138	1.178E-01	0.0190

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

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
uclide	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	7.645E-02	0.0124
Ra-226	2.729E-01	0.0441	1.679E-03	0.0003	0.000E+00	0.0000	5.351E-02	0.0086	5.370E-03	0.0009	7.456E-03	0.0012	3.858E+00	0.6236
h-230	1.491E-04	0.0000	8.164E-07	0.0000	0.000E+00	0.0000	2.898E-05	0.0000	2.824E-06	0.0000	4.236E-06	0.0000	9.019E-01	0.1458
-234	5.517E-01	0.0892	4.081E-04	0.0001	0.000E+00	0.0000	1.084E-01	0.0175	4.186E-03	0.0007	1.220E-02	0.0020	6.867E-01	0.1110
U-238	5.247E-01	0.0848	3.880E-04	0.0001	0.000E+00	0.0000	1.031E-01	0.0167	3.981E-03	0.0006	1.161E-02	0.0019	6.639E-01	0.1073
otal	1.349E+00	0.2181	2.476E-03	0.0004	0.000E+00	0.0000	2.651E-01	0.0429	1.354E-02	0.0022	3.127E-02	0.0051	6.187E+00	1.0000

*Sum of all water independent and dependent pathways.

Summary : Washington AAR 3000-m3 Resident Gardener
File : Wash AAR Uranium .RAD

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

Water Independent Pathways (Inhalation excludes radon)

idio-	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.
-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.158E-11	0.0000	1.051E-11	0.0000	2.012E-12	0.0000	0.000E+00	0.0000
a-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.009E-08	0.0000	2.783E-08	0.0000	9.597E-09	0.0000	0.000E+00	0.0000
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.136E-07	0.0000	4.115E-07	0.0000	1.538E-07	0.0000	0.000E+00	0.0000
-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.559E-10	0.0000	1.233E-10	0.0000	4.735E-11	0.0000	0.000E+00	0.0000
-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.029E-11	0.0000	6.754E-12	0.0000	3.707E-12	0.0000	0.000E+00	0.0000
otal	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.439E-07	0.0000	4.395E-07	0.0000	1.635E-07	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 = 3.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
uclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	8.071E-04	0.0000	9.452E-06	0.0000	0.000E+00	0.0000	1.591E-04	0.0000	1.445E-05	0.0000	8.941E-06	0.0000	9.990E-04	0.0001
Ra-226	1.135E+01	0.6760	1.136E-01	0.0068	0.000E+00	0.0000	2.242E+00	0.1335	2.142E-01	0.0128	1.861E-01	0.0111	1.411E+01	0.8401
h-230	5.614E-01	0.0334	5.586E-03	0.0003	0.000E+00	0.0000	1.109E-01	0.0066	1.060E-02	0.0006	9.291E-03	0.0006	6.977E-01	0.0415
-234	8.300E-01	0.0494	6.281E-04	0.0000	0.000E+00	0.0000	1.632E-01	0.0097	6.335E-03	0.0004	1.838E-02	0.0011	1.019E+00	0.0607
U-238	7.868E-01	0.0470	5.835E-04	0.0000	0.000E+00	0.0000	1.551E-01	0.0092	6.003E-03	0.0004	1.748E-02	0.0010	9.680E-01	0.0576
otal	1.353E+01	0.8059	1.204E-01	0.0072	0.000E+00	0.0000	2.671E+00	0.1591	2.372E-01	0.0141	2.313E-01	0.0138	1.679E+01	1.0000

*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

Water Independent Pathways (Inhalation excludes radon)

adio-	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.
b-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	0.000E+00	0.0000
a-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	0.000E+00	0.0000
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	0.000E+00	0.0000
-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	0.000E+00	0.0000
-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	0.000E+00	0.0000
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	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+03 years

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.
b-210	2.947E-13	0.0000	3.452E-15	0.0000	0.000E+00	0.0000	5.808E-14	0.0000	5.278E-15	0.0000	3.265E-15	0.0000	3.648E-13	0.0000
Ra-226	8.411E+00	0.7568	8.415E-02	0.0076	0.000E+00	0.0000	1.661E+00	0.1495	1.587E-01	0.0143	1.379E-01	0.0124	1.045E+01	0.9405
h-230	5.144E-01	0.0463	5.146E-03	0.0005	0.000E+00	0.0000	1.016E-01	0.0091	9.707E-03	0.0009	8.432E-03	0.0008	6.392E-01	0.0575
-234	1.754E-02	0.0016	1.733E-04	0.0000	0.000E+00	0.0000	3.464E-03	0.0003	3.307E-04	0.0000	2.920E-04	0.0000	2.180E-02	0.0020
U-238	9.046E-05	0.0000	1.999E-07	0.0000	0.000E+00	0.0000	1.783E-05	0.0000	8.578E-07	0.0000	1.933E-06	0.0000	1.113E-04	0.0000
otal	8.943E+00	0.8047	8.947E-02	0.0081	0.000E+00	0.0000	1.766E+00	0.1589	1.688E-01	0.0152	1.466E-01	0.0132	1.111E+01	1.0000

*Sum of all water independent and dependent pathways.

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

Parent (i)	Product (j)	Branch Fraction*	DSR(j,t) (mrem/yr)/(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	2.401E+00	2.284E+00	2.067E+00	1.456E+00	5.335E-01	1.529E-02	1.998E-04	7.296E-14
Ra-226	Ra-226	1.000E+00	5.811E+00	5.673E+00	5.405E+00	4.562E+00	2.808E+00	5.494E-01	5.871E-01	4.345E-01
Ra-226	Pb-210	1.000E+00	4.428E-02	1.162E-01	2.418E-01	5.460E-01	7.472E-01	2.222E-01	2.235E+00	1.656E+00
Ra-226	∑DSR(j)		5.856E+00	5.789E+00	5.647E+00	5.108E+00	3.555E+00	7.716E-01	2.822E+00	2.091E+00
Th-230	Th-230	1.000E+00	8.149E-02	8.144E-02	8.132E-02	8.092E-02	7.979E-02	7.582E-02	3.125E-08	0.000E+00
Th-230	Ra-226	1.000E+00	1.238E-03	3.719E-03	8.504E-03	2.346E-02	5.387E-02	8.709E-02	2.989E-02	2.658E-02
Th-230	Pb-210	1.000E+00	6.971E-06	4.212E-05	1.980E-04	1.424E-03	7.232E-03	1.746E-02	1.096E-01	1.013E-01
Th-230	∑DSR(j)		8.274E-02	8.520E-02	9.002E-02	1.058E-01	1.409E-01	1.804E-01	1.395E-01	1.278E-01
U-234	U-234	1.000E+00	5.323E-02	5.150E-02	4.819E-02	3.822E-02	1.969E-02	1.373E-01	2.033E-01	1.950E-05
U-234	Th-230	1.000E+00	3.707E-07	1.082E-06	2.432E-06	6.510E-06	1.403E-05	2.065E-05	6.196E-07	2.027E-06
U-234	Ra-226	1.000E+00	3.646E-09	2.556E-08	1.312E-07	1.033E-06	6.025E-06	2.177E-05	9.614E-05	9.427E-04
U-234	Pb-210	1.000E+00	1.657E-11	2.116E-10	2.145E-09	4.428E-08	6.134E-07	5.395E-06	2.973E-04	3.395E-03
U-234	∑DSR(j)		5.323E-02	5.150E-02	4.820E-02	3.822E-02	1.971E-02	1.373E-01	2.037E-01	4.359E-03
U-238	U-238	1.000E+00	1.050E-01	1.016E-01	9.524E-02	7.587E-02	3.960E-02	1.327E-01	1.934E-01	1.859E-05
U-238	U-234	1.000E+00	7.504E-08	2.186E-07	4.778E-07	1.137E-06	1.702E-06	3.913E-05	1.733E-04	5.539E-08
U-238	Th-230	1.000E+00	3.534E-13	2.381E-12	1.196E-11	9.166E-11	5.103E-10	1.602E-09	3.534E-10	2.570E-09
U-238	Ra-226	1.000E+00	2.548E-15	3.833E-14	4.331E-13	9.886E-12	1.559E-10	7.230E-09	3.402E-08	7.962E-07
U-238	Pb-210	1.000E+00	9.829E-18	2.569E-16	5.530E-15	3.286E-13	1.270E-11	2.211E-08	1.008E-07	2.812E-06
U-238	∑DSR(j)		1.050E-01	1.016E-01	9.524E-02	7.587E-02	3.961E-02	1.328E-01	1.936E-01	2.225E-05

*Branch Fraction is the cumulative factor for the j't principal radionuclide daughter: CUMBRF(j) = BRF(1)*BRF(2)* ... BRF(j).
The DSR includes contributions from associated (half-life ≤ 0.5 yr) daughters.

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 3.000E+01 mrem/yr

uclide (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
ͻ-210	1.249E+01	1.313E+01	1.451E+01	2.061E+01	5.623E+01	1.962E+03	1.502E+05	*7.631E+13
Ra-226	5.123E+00	5.182E+00	5.313E+00	5.873E+00	8.438E+00	3.888E+01	1.063E+01	1.435E+01
Th-230	3.626E+02	3.521E+02	3.332E+02	2.835E+02	2.129E+02	1.663E+02	2.150E+02	2.347E+02
-234	5.636E+02	5.826E+02	6.225E+02	7.849E+02	1.522E+03	2.184E+02	1.473E+02	6.882E+03
-238	2.858E+02	2.952E+02	3.150E+02	3.954E+02	7.575E+02	2.259E+02	1.550E+02	*3.360E+05

\t specific activity limit

Summary : Washington AAR 3000-m3 Resident Gardener
File   : Wash AAR Uranium .RAD

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 = 0.000E+00 years

Nuclide (i)	Initial (pCi/g)	tmin (years)	DSR(i,tmin)	G(i,tmin) (pCi/g)	DSR(i,tmax)	G(i,tmax) (pCi/g)
Pb-210	5.000E+00	0.000E+00	2.401E+00	1.249E+01	2.401E+00	1.249E+01
a-226	5.000E+00	0.000E+00	5.856E+00	5.123E+00	5.856E+00	5.123E+00
h-230	5.000E+00	192.3 ± 0.4	1.993E-01	1.505E+02	8.274E-02	3.626E+02
U-234	5.000E+00	767 ± 2	2.061E-01	1.456E+02	5.323E-02	5.636E+02
-238	5.000E+00	767 ± 2	1.939E-01	1.547E+02	1.050E-01	2.858E+02

Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated

uclide (j)	Parent (i)	BRF(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
			DOSE(j,t), mrem/yr							
b-210	Pb-210	1.000E+00	1.201E+01	1.142E+01	1.033E+01	7.280E+00	2.668E+00	7.645E-02	9.990E-04	3.648E-13
Pb-210	Ra-226	1.000E+00	2.214E-01	5.808E-01	1.209E+00	2.730E+00	3.736E+00	1.111E+00	1.117E+01	8.280E+00
Pb-210	Th-230	1.000E+00	3.486E-05	2.106E-04	9.899E-04	7.121E-03	3.616E-02	8.728E-02	5.482E-01	5.063E-01
b-210	U-234	1.000E+00	8.285E-11	1.058E-09	1.072E-08	2.214E-07	3.067E-06	2.697E-05	1.486E-03	1.698E-02
b-210	U-238	1.000E+00	4.914E-17	1.285E-15	2.765E-14	1.643E-12	6.348E-11	1.105E-07	5.041E-07	1.406E-05
Pb-210	∑DOSE(j)		1.223E+01	1.200E+01	1.154E+01	1.002E+01	6.440E+00	1.275E+00	1.172E+01	8.804E+00
a-226	Ra-226	1.000E+00	2.906E+01	2.836E+01	2.702E+01	2.281E+01	1.404E+01	2.747E+00	2.936E+00	2.173E+00
Ra-226	Th-230	1.000E+00	6.190E-03	1.859E-02	4.252E-02	1.173E-01	2.694E-01	4.355E-01	1.495E-01	1.329E-01
a-226	U-234	1.000E+00	1.823E-08	1.278E-07	6.562E-07	5.163E-06	3.013E-05	1.089E-04	4.807E-04	4.714E-03
a-226	U-238	1.000E+00	1.274E-14	1.916E-13	2.165E-12	4.943E-11	7.794E-10	3.615E-08	1.701E-07	3.981E-06
Ra-226	∑DOSE(j)		2.906E+01	2.838E+01	2.707E+01	2.293E+01	1.431E+01	3.183E+00	3.086E+00	2.310E+00
h-230	Th-230	1.000E+00	4.075E-01	4.072E-01	4.066E-01	4.046E-01	3.989E-01	3.791E-01	1.563E-07	0.000E+00
h-230	U-234	1.000E+00	1.854E-06	5.409E-06	1.216E-05	3.255E-05	7.016E-05	1.033E-04	3.098E-06	1.014E-05
Th-230	U-238	1.000E+00	1.767E-12	1.190E-11	5.979E-11	4.583E-10	2.552E-09	8.009E-09	1.767E-09	1.285E-08
h-230	∑DOSE(j)		4.075E-01	4.072E-01	4.066E-01	4.047E-01	3.990E-01	3.792E-01	3.256E-06	1.015E-05
U-234	U-234	1.000E+00	2.661E-01	2.575E-01	2.410E-01	1.911E-01	9.843E-02	6.865E-01	1.017E+00	9.750E-05
U-234	U-238	1.000E+00	3.752E-07	1.093E-06	2.389E-06	5.686E-06	8.511E-06	1.956E-04	8.664E-04	2.770E-07
-234	∑DOSE(j)		2.661E-01	2.575E-01	2.410E-01	1.911E-01	9.844E-02	6.867E-01	1.017E+00	9.778E-05
U-238	U-238	1.000E+00	5.249E-01	5.082E-01	4.762E-01	3.794E-01	1.980E-01	6.637E-01	9.671E-01	9.294E-05

RF(i) is the branch fraction of the parent nuclide.

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	BRF(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	5.000E+00	4.770E+00	4.342E+00	3.125E+00	1.220E+00	4.543E-02	3.751E-06	1.919E-20
Pb-210	Ra-226	1.000E+00	0.000E+00	1.501E-01	4.197E-01	1.097E+00	1.662E+00	5.833E-01	6.237E-03	5.640E-10
Pb-210	Th-230	1.000E+00	0.000E+00	3.289E-05	2.825E-04	2.676E-03	1.564E-02	5.025E-02	6.118E-02	5.979E-02
Pb-210	U-234	1.000E+00	0.000E+00	9.847E-11	2.527E-09	7.850E-08	1.303E-06	1.066E-05	1.726E-05	1.694E-05
Pb-210	U-238	1.000E+00	0.000E+00	6.970E-17	5.352E-15	5.489E-13	2.646E-11	6.107E-10	1.521E-09	1.512E-09
Pb-210	∑S(j):		5.000E+00	4.920E+00	4.762E+00	4.224E+00	2.898E+00	6.790E-01	6.744E-02	5.980E-02
Ra-226	Ra-226	1.000E+00	5.000E+00	4.885E+00	4.664E+00	3.966E+00	2.495E+00	4.928E-01	4.787E-03	4.326E-10
Ra-226	Th-230	1.000E+00	0.000E+00	2.141E-03	6.277E-03	1.933E-02	4.681E-02	8.407E-02	9.254E-02	9.035E-02
Ra-226	U-234	1.000E+00	0.000E+00	9.573E-09	8.307E-08	8.134E-07	5.168E-06	1.977E-05	2.616E-05	2.560E-05
Ra-226	U-238	1.000E+00	0.000E+00	9.015E-15	2.331E-13	7.428E-12	1.318E-10	1.271E-09	2.318E-09	2.284E-09
Ra-226	∑S(j):		5.000E+00	4.888E+00	4.671E+00	3.985E+00	2.542E+00	5.769E-01	9.736E-02	9.038E-02
Th-230	Th-230	1.000E+00	5.000E+00	5.000E+00	4.999E+00	4.998E+00	4.995E+00	4.982E+00	4.947E+00	4.825E+00
Th-230	U-234	1.000E+00	0.000E+00	4.430E-05	1.288E-04	3.855E-04	8.696E-04	1.353E-03	1.401E-03	1.367E-03
Th-230	U-238	1.000E+00	0.000E+00	6.246E-11	5.389E-10	5.175E-09	3.119E-08	1.040E-07	1.250E-07	1.220E-07
Th-230	∑S(j):		5.000E+00	5.000E+00	5.000E+00	4.999E+00	4.996E+00	4.984E+00	4.948E+00	4.827E+00
U-234	U-234	1.000E+00	5.000E+00	4.843E+00	4.545E+00	3.638E+00	1.926E+00	2.078E-01	3.588E-04	7.675E-14
U-234	U-238	1.000E+00	0.000E+00	1.373E-05	3.865E-05	1.031E-04	1.638E-04	5.891E-05	3.053E-07	2.179E-16
U-234	∑S(j):		5.000E+00	4.843E+00	4.545E+00	3.638E+00	1.926E+00	2.078E-01	3.591E-04	7.697E-14
U-238	U-238	1.000E+00	5.000E+00	4.843E+00	4.545E+00	3.638E+00	1.926E+00	2.078E-01	3.591E-04	7.697E-14

BRF(i) is the branch fraction of the parent nuclide.

RESCALC.EXE execution time = 23.15 seconds