APPENDIX A

GROUNDWATER AT THE ST. LOUIS DOWNTOWN SITE

Mallinckrodt Inc.

C-T Phase II Decommissioning Plan

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APPENDIX A

GROUNDWATER AT THE ST. LOUIS DOWNTOWN SITE

1.1. INTRODUCTION

The hydrogeology of the Mallinckrodt site has been extensively studied by Mallinckrodt, Inc. (Mallinckrodt, 2001), and by the U.S. Department of Energy (DOE) and U.S. Army Corps of Engineers (USACE) under FUSRAP. The site hydrogeology is described in Section 1.2. Section 1.3 describes historical groundwater sampling events and analytical results. Section 1.4 presents a groundwater exposure assessment.

1.2. SITE HYDROGEOLOGY

1.2.1. Surface Water

The site is adjacent to the Mississippi River (**Figure A1**). A man-made levee constructed by the USACE along the riverfront protects the site from floodwater. According to flood insurance rate maps, the site is not located in a floodplain. The buildings and the concrete and asphalt pavement that cover most of the site have altered natural runoff and recharge. As a result, groundwater recharge via infiltration of precipitation is judged to be minimal. Surface water runoff from the site is collected and discharged to the St. Louis Metropolitan Sewer District.

1.2.2. Groundwater

The historical development of the riverfront in St. Louis involved the placement of man-made fill over the alluvial soils of the Mississippi River floodplain. The alluvial deposits beneath the fill material consist of a fining-upward sequence that thickens eastward towards the river. A generalized subsurface geologic profile is shown in **Figure A2**.

Four stratigraphic units have been identified beneath the Mallinckrodt site. These are, from top down: 1) man-made fill, 7 to 30 ft thick, consisting of bricks, coal, slag, cinder, concrete, construction rubble, and glass in a matrix of sand and clay; 2) a relatively lower permeability fine-grained alluvial silt and clay unit, 20 to 30 ft thick; with isolated lenses of fine sand 3) a lower alluvial unit, 0 to 60 ft thick, consisting of relatively permeable sandy sediments; and, 4) limestone bedrock. The bedrock is Mississipian-aged limestone of the St. Genevieve Formation. Bedrock is exposed in highway cuts west of the site, and the bedrock surface slopes eastward to a depth of over 100 ft beneath the Mississippi River (DOE, 1990).

A generalized diagram of the hydrostratigraphic units at the site is shown in **Figure A3**. Two hydrostratigraphic units are recognized above the bedrock. The Upper Hydrostratigraphic Unit (upper zone) consists of the man-made fill and the underlying layers of low-permeability alluvial silt and clay. The second or Lower Hydrostratigraphic Zone (lower zone) is composed of relatively permeable sandy silt, sand, and fine gravel. The groundwater in the upper zone occurs within man-made fill and is perched upon the low-permeability silt and clay layers. The perched

groundwater is intermittent in nature and limited in its lateral continuity, saturated thickness, and transmissivity. The perched groundwater is not hydraulically connected to the lower zone or to the Mississippi River. Groundwater in the lower zone is hydraulically connected to the Mississippi River and, as such, is influenced by changing river stage. The direction of groundwater flow in the lower zone is generally towards the river during low river stage and away from the river during high river stage. Recharge of groundwater in the lower zone is thought to occur through riverbed infiltration (bank storage) from the Mississippi River and upward seepage of groundwater from bedrock.

Detailed hydrogeologic profiles were prepared from boring logs provided by the DOE and USACE. A well/piezometer location map is shown in **Figure A4**, and the detailed profiles are presented in **Figure A5**.

It should be noted that the boundary between the upper and lower zones is gradational in certain areas. Although the lower zone consists generally of high-permeability alluvial sediments, the top of the lower zone includes local regions of relatively low permeability silty sediments.

Representative hydraulic and geotechnical properties of the alluvial silt and clay were evaluated by U.S. DOE under FUSRAP. An in-situ, changing head test performed in this unit in Plant 7 yielded a horizontal hydraulic conductivity of 9.9 x 10-6 cm/s. DOE also collected fourteen undisturbed samples of this unit from various boreholes across the St. Louis Plant and tested them for laboratory permeability, cation exchange, and geotechnical parameters. The vertical hydraulic conductivity ranged from 4 x 10-4 to 1 x 10-6 cm/s with a geometric mean of 1 x 10-5 cm/s. Cation exchange capacities ranged from 70 to 200 meq/100 g, with an average value of 39 meq/100 g (DOE, 1990; 1993).

Time series plots of hydraulic head measurements in the upper zone, lower zone, and Mississippi River are shown in **Figure A6**. A strong correlation exists between hydraulic head fluctuations in the lower zone and those in the Mississippi River, indicating good hydraulic communication between the lower zone and the river. Hydraulic head fluctuations in the upper zone, however, do not correlate well with those in the lower zone and the river. This indicates a low degree of hydraulic communication between the upper and lower zones and between the upper zone and the river.

1.2.3. History of Well and Piezometer Installation

The network of monitoring wells and piezometers at the site was installed by Bechtel National Incorporated (BNI) on behalf of the DOE and by IT Corporation (IT) and SAIC on behalf of the USACE. **Table A1** lists well and piezometer construction details and screened hydrostratigraphic zones.

Between February 1988 and April 1988, BNI installed eight monitoring wells at the site. The wells installed were designated B16W01S, B16W02S, B16W03S, B16W04S, B16W05D, B16W06D, B16W07D, and B16W08D. Two of the wells were installed in the upper zone and four in the lower zone. Monitoring well B16W03S was screened across both the upper and lower zones, and well B16W01S was screened across both the upper zone and bedrock. These two wells (B16W03S and B16W01S) were later decommissioned because of the potential for

vertical cross contamination.

Monitoring well B16W09D was added to the lower zone in June 1989 by BNI to provide an additional data collection point.

In the Fall of 1992 eight additional monitoring wells were installed at the site by BNI (DOE, 1993). These monitoring wells were designated B16W05S, B16W06S, B16W07S, B16W08S, B16W10S, B16W11S, B16W12S, and B16W13SR. Five of the wells were installed in the upper zone and three in the lower zone. Although monitoring wells B16W06S, B16W08S, and B16W11S are denoted with an "S" at the end of the well designation, the wells are actually screened in the lower zone. The letters at the end of the well designations were provided for initial project planning and should not be used to differentiate between shallow (upper zone) and deep (lower zone) monitoring wells (DOE, 1990). Five of the eight wells were installed adjacent to existing deep monitoring wells. The remaining three wells were installed downgradient of Plant 1 and Plant 5.

During the winter of 1998, eight new monitoring wells were installed at the site under SAIC's FUSRAP contract with the USACE. These monitoring wells were designated: MW3 (DW14), MW4 (DW15), MW5 (DW16), MW6 (DW17), MW7 (DW18), MW8 (DW19), MW9 (DW20), and MW10 (DW21). Two of the monitoring wells (MW9 and MW10) were installed in the upper zone and the remaining six monitoring wells were installed in the lower zone.

In September of 2000, IT, in connection with the FUSRAP activities, installed three piezometers (PZ-1, PZ-2, and PZ-3) in the upper zone in the west half of Plant 6. Based on subsequently collected water level data, IT concluded that monitoring well B16W11S is screened in the lower zone since its observed water levels are greater than 20 feet below the elevation of the perched water table in the upper zone.

1.2.4. Groundwater Flow Directions

Groundwater elevation data from three recent events are presented in **Table A2** and on the cross sections in **Figure A5**.

Groundwater elevation contour maps for the perched water table in the upper zone are not presented because of the lack of systematic spatial trends and high variability in water levels. As stated in Section 1.2.1, the perched groundwater is intermittent in nature and limited in its lateral continuity, saturated thickness, and transmissivity. In addition, the flow of perched groundwater in the fill may be locally influenced by man-made features such as dewatered excavations.

Groundwater level contour maps were created for the lower zone from water level measurements gathered on March 9, 1999 since this event provides the most complete set of data. For the purposes of contouring, wells screened in the lower zone were placed into two groups based on their relative depth in the lower zone. Monitoring wells B16W09D, MW3 (DW14), MW4 (DW15), MW5 (DW16), MW6 (DW17), MW7 (DW18), and MW8 (DW19) represent the shallow part of the lower zone, and wells B16W05D, B16W06D, B16W07D, B16W08D represent the deep part of the lower zone. These groups are contoured on **Figures A7** and **A8**, respectively. Monitoring wells B16W06S, B16W08S, and B16W11S were not used for contouring of the potentiometric surface in the shallow part of the lower zone since they are

screened in a lower permeability silty material at the top of the lower zone. This lower permeability material causes the water levels in these three wells to equilibrate more slowly than those in the other lower zone wells during periods of rising and falling hydraulic head.

Conventional hydrologic models of groundwater flow in alluvial settings predict that the river stage greatly affects groundwater flow directions. Groundwater flow is generally towards the river during periods of low river stage (e.g. base flow conditions during which the river is recharged by groundwater discharge) as shown on **Figure A9**. Conversely, groundwater flows away from the river during periods of high river stage in association with bank recharge, as shown on **Figure A10**. A potentiometric low ("trough") will develop landward of the zone of bank recharge where riverward groundwater flow is juxtaposed by landward groundwater flow, as shown on **Figure A11**. The potentiometric contours for the lower zone on March 9, 1999 are interpreted to indicate groundwater flow away from the river during a period of bank recharge associated with high river stage (**Figure A7** and **A8**). The deflection of the 394 foot contour in the vicinity of monitoring well MW8 (DW19) on **Figure A7** from what is otherwise generally a river-parallel trend may be caused by a localized zone of low permeability material around the well.

1.3. GROUNDWATER SAMPLING AND ANALYTICAL RESULTS

Total uranium, radium-226, and thorium-230 were analyzed in samples collected from eight monitoring wells during four quarterly sampling events between July 1988 and April 1989 (USACE, 1998). The groundwater was sampled again by BNI in during a single event in late 1997/early 1998 that included 17 monitoring wells. Samples were analyzed for actinium-227, lead-210, protactinium-231, radium-226, radium-228, thorium-228, thorium-230, thorium-232, and total uranium (USACE, 1998). **Table A3** presents statistical summary results (min, max, average) from the four sampling events performed in 1988 thru 1989. **Table A4** presents total uranium results from the 1997/1998 sampling event.

Total uranium was the only radionuclide detected in filtered samples at elevated concentrations. The elevated concentrations have been detected in only a single well, B16W02S, which is screened in perched groundwater in the upper zone. The total uranium concentrations in this well have ranged from a 1988/1989 average of 228 ug/l to a 1997/1998 value of 1,187 ug/l. These detections do not present a groundwater ingestion hazard since the perched groundwater in the upper zone is not a drinking water source.

Although Protactinium-231 was detected at concentrations up to 45 pCi/l in unfiltered groundwater samples from three wells, it was not detected in filtered samples from these three wells. USACE has concluded that the protactinium is bound to sediment particles and that the unfiltered results are not representative of groundwater quality at the site (USACE, 1998).

No radionuclides were detected above US EPA MCLs in filtered groundwater samples from the lower zone. This finding suggests that the low-permeability silt and clay layers between the upper and lower zones retard contaminant migration between the two zones.

1.4. GROUNDWATER EXPOSURE ASSESSMENT

The groundwater beneath the site is not a current source of drinking water, nor will it be a source of drinking water in the future for the following reasons:

1. All of the drinking water for the City of St. Louis is derived from the Mississippi and/or Missouri Rivers, and all of the drinking water intakes for the City of St. Louis are located upstream of the site.
2. St. Louis City Ordinance 13,272, Section 3 (dated March 25, 1885), states that drinking water supply wells are prohibited within the City of St. Louis. The ordinance has restricted drinking water supply well installation in the City of St. Louis for over 100 years and will continue to restrict well installation for the foreseeable future.
3. There is no known drinking water well in the vicinity of the plant (DOE, 1990). According to information obtained from the Missouri Department of Natural Resources Division of Geology and Land Survey, two wells are located within a ½-mile radius of the site (EPA, 1993). Neither of the wells is a drinking water well. Well No. 2798 is located in the SE¼ of Township 45N Range 7E. It was installed in 1933 to a depth of 185 feet and produced 30 gallons per minute. Fisher Chemical Company is listed as the well owner. Well No. 19835 is located in the SE¼ NE½ Township 45 N Range 7E and was installed in 1961. It is 180 feet deep and screened in the Mississippian alluvium. Well No. 19835 has produced 260 gallons per minute, but is located at an abandoned site.
4. The quality of perched groundwater in fill historically placed along the riverfront in the St. Louis area is naturally poor due to the presence of brick, glass, concrete rubble, coal cinder, and slag, and associated metals and PAH compounds (DOE, 1990). The perched zone is intermittent in nature and limited in its lateral continuity, saturated thickness, and transmissivity, which results in low water producing quality. For these reasons, the perched zone is not a realistic source of potable groundwater even in the absence of any contamination derived from the Mallinckrodt site.
5. Groundwater in the lower zone (sandy alluvial unit) is locally saline and generally very hard, with high iron and manganese content. Groundwater in the underlying bedrock is generally saline and non-potable. Groundwater in the site area is not withdrawn for potable, industrial, or agricultural purposes, and groundwater use is not anticipated to change in the future. Considering these unfavorable groundwater characteristics and that St. Louis has a municipal water system that serves this region, installation of a domestic water well is not reasonably foreseeable. Since the land is unsuitable for agriculture because the surficial soil is man-made fill, withdrawal of groundwater for agricultural irrigation also is not a reasonable expectation.
6. Groundwater in the St. Louis area is generally of poor quality and does not meet drinking water standards without treatment. The expected future use of groundwater at the site is minimal since the Mississippi and Missouri Rivers constitute high-quality, large-quantity, readily available sources (USACE ROD, p.6).

1.5. REFERENCES

1. DOE. *Radiological, Chemical, and Hydrogeological Characterization Report for the St. Louis Downtown Site in St. Louis, Missouri.* Sept. 1990.

2. DOE. Remedial Investigation Addendum Report for the St. Louis Site, DOE/OR/21950-132. Prepared by SAIC, May 1993.

3. Mallinckrodt. *RCRA Facility Investigation Report for AOC I (Site-Wide Groundwater)*, Mallinckrodt, Inc., St. Louis Facility, April 6, 2001; prepared by URS Corporation.

4. USACE. *Groundwater Characterization Report of 1997/1998 Baseline Data for the St. Louis Downtown Site.* St. Louis, MO. July 1998.

5. USACE ROD. *Record of Decision for the St. Louis Downtown Site.* St. Louis, MO. July 1998.

TABLE A1
Well and Piezometer Construction Details
Mallinckrodt Inc. - St. Louis Downtown Site

Monitoring Well No.	Installation Date	Surface Elevation (ft. MSL)	Top of Casing Elevation (ft. MSL)	Bottom of Boring (ft. bgs)	Borehole Diameter (in.)	Well Diameter (in.)	Screen Interval (ft. bgs)	Hydrologic Zone Monitored by Screen Interval
B16W02S	4/1/1988	420.2	419.4	33.1	8.25	2	20.4 to 30.7	upper zone
B16W04S	3/28/1988	425.5	424.6	31.3	8.25	2	22.2 to 27.2	upper zone
B16W05S	9/30/1992	423.1	422.8	20.0	9.75	4	9.7 to 19.7	upper zone
B16W05D	4/14/1988	423.0	422.2	74.8	8.25	2	57.3 to 67.7	lower zone
B16W06S	9/30/1992	424.1	423.8	43.0	9.75	4	32.5 to 42.5	lower zone
B16W06D	3/17/1988	423.5	422.7	94.2	8.25	2	70.2 to 80.2	lower zone
B16W07S	9/11/1992	422.1	421.8	21.2	8	4	10.6 to 20.6	upper zone
B16W07D	3/18/1988	421.9	421.4	94.1	8.25	2	66.5 to 76.8	lower zone
B16W08S	9/30/1992	422.4	422.1	38.0	9.75	4	27.7 to 37.7	lower zone
B16W08D	3/25/1988	423.5	422	80.7	8.25	2	59.7 to 70.1	lower zone
B16W09D	6/7/1989	421.9	421.1	61.7	7.00	2	44.8 to 54.8	lower zone
B16W10S	9/30/1992	420.6	420.4	25.0	8.75	4	14.2 to 24.2	upper zone
B16W11S	9/30/1992	424.2	423.9	39.0	9.75	4	29.7 to 39.7	lower zone
B16W12S	9/30/1992	427.2	426.9	20.0	10.75	4	9.7 to 19.7	upper zone
B16W13SR	9/30/1992	420.5	420.3	19.0	6.75	4	8.7 to 18.7	upper zone
MW3 (DW14)	11/16/1998	417.8	417.5	40.0	9.00	2	26.6 to 36.6	lower zone
MW4 (DW15)	11/24/1998	427.1	426.8	64.5	9.00	2	53 to 63	lower zone
MW5 (DW16)	12/1/1998	422.6	422.3	50.0	9.00	2	39 to 49	lower zone
MW6 (DW17)	11/20/1998	420.9	421.2	44.5	9.00	2	33.6 to 43.6	lower zone
MW7 (DW18)	11/16/1998	423.2	423.5	55.0	9.00	2	43.7 to 53.7	lower zone
MW8 (DW19)	11/20/1998	424.2	424.4	54.8	9.00	2	44.3 to 54.3	lower zone
MW9 (DW20)	11/9/1998	418.0	417.7	21.0	9.00	2	10 to 20	upper zone
MW10 (DW21)	11/16/1998	422.8	422.6	22.7	9	2	17.3 to 22.3	upper zone

Note: 1. MSL = Mean Sea Level, bgs = below ground surface, ft. = feet, and in. = inches

Table A2
Groundwater Elevation Data
Mallinckrodt Inc. - St. Louis Downtown Site

Monitoring Well No.	Top of Casing Elevation (ft. MSL)	Depth to Water (ft.)	Water Elevation (ft. MSL)	Depth to Water (ft.)	Water Elevation (ft. MSL)	Depth to Water (ft.)	Water Elevation (ft. MSL)
		March 9, 1999		May 17, 1999		February 5, 2001	
B16W02S	419.4	4.56	414.9	4.45	415.0	NT	NT
B16W04S	424.6	5.09	419.6	5.21	419.4	6.25	418.4
B16W05S	422.8	10.8	412.0	10.3	412.5	NT	NT
B16W05D	422.2	28.48	393.8	15.09	407.1	NT	NT
B16W06S	423.8	27.64	396.2	NT	NT	31.71	392.1
B16W06D	422.7	29.06	393.7	NT	NT	33.86	388.9
B16W07S	421.8	10.34	411.5	9.6	412.2	10.28	411.5
B16W07D	421.4	27.71	393.7	14.2	407.2	32.9	388.5
B16W08S	422.1	24.72	397.4	NT	NT	31.13	391.0
B16W08D	422.0	27.45	394.6	13.93	408.1	30.83	391.2
B16W09D	421.1	27.23	393.9	14.01	407.1	32.8	388.3
B16W10S	420.4	17.34	403.1	11.46	408.9	NT	NT
B16W11S	423.9	28.05	395.9	21.71	402.2	35.9	388.0
B16W12S	426.9	15.09	411.8	13.07	413.9	17.97	409.0
B16W13SR	420.3	7.3	413.0	6.01	414.3	NT	NT
MW3 (DW14)	417.5	22.32	395.2	10.27	407.2	NT	NT
MW4 (DW15)	426.8	32.83	394.0	19.6	407.2	38.92	387.9
MW5 (DW16)	422.3	28.49	393.8	14.96	407.4	34.29	388.0
MW6 (DW17)	421.2	27.12	394.1	13.45	407.7	33.95	387.2
MW7 (DW18)	423.5	29.25	394.2	16.02	407.4	34.2	389.3
MW8 (DW19)	424.4	30.29	394.2	17.0	407.4	NT	NT
MW9 (DW20)	417.7	17.95	399.8	10.57	407.1	19.87	397.8
MW10 (DW21)	422.6	10.95	411.6	9.7	412.9	13.46	409.1

Notes:
1. All measurements from top of casing (MSL = Mean Sea Level and ft. = feet).
2. NT= measurements not taken
3. The water level for Monitoring Well DW17 (MW6) during the February 5, 2001 event is questionable due to a bubbling sound coming from the well and sporadic beeping of the water level indicator.

Table A3
Statistical Summary Data from 1988-1989 Quarterly Sampling Events
Mallinckrodt Inc. - St. Louis Downtown Site

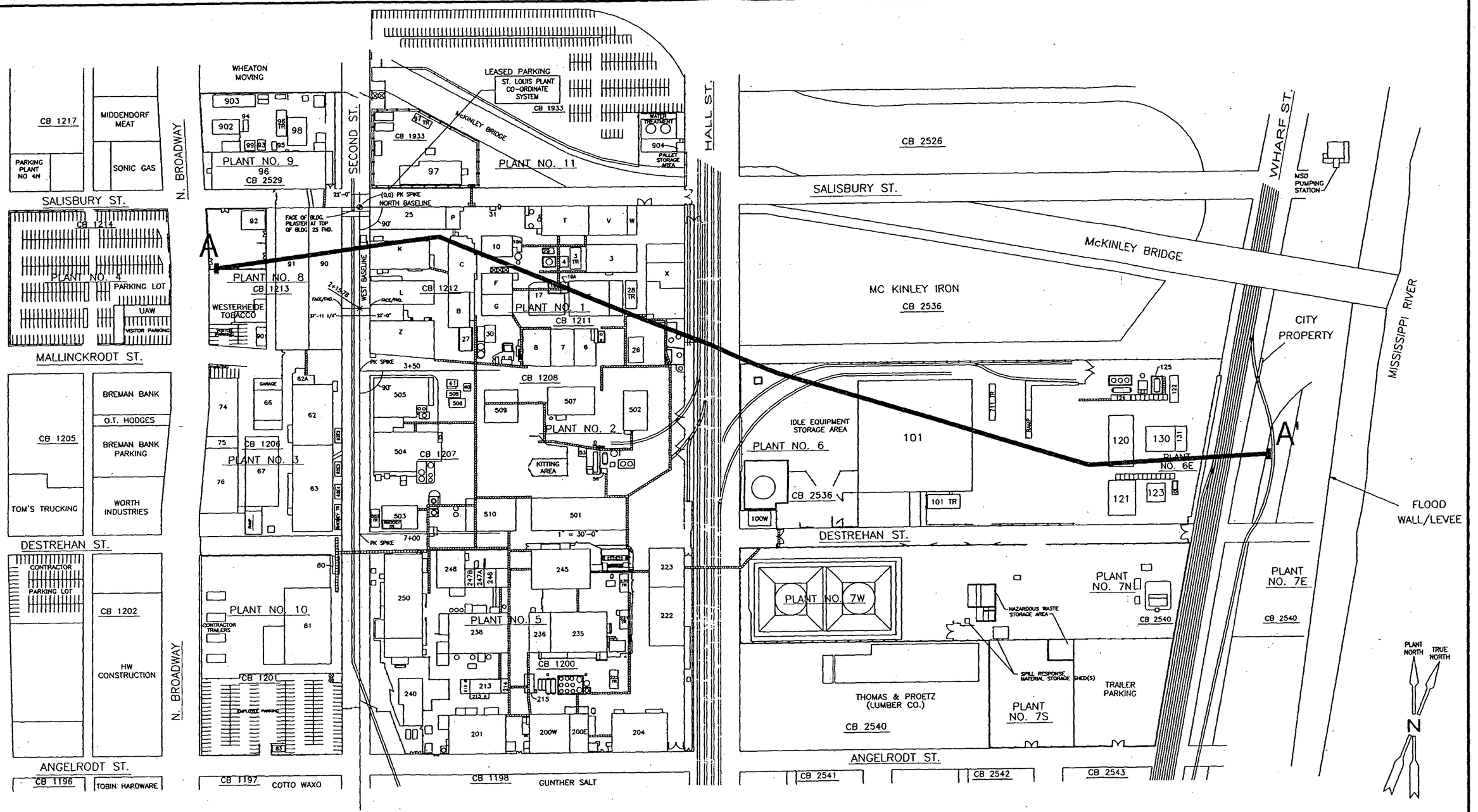
Sampling Location	Number of Samples	Statistical Minimum (10^{-9} µCi/ml)	Statistical Maximum (10^{-9} µCi/ml)	Statistical Average (10^{-9} µCi/ml)
Total Uranium				
B16W01S	4	< 3	5	4
B16W02S	4	107	193	162
B16W03S	4	< 3	< 3	< 3
B16W04S	4	< 3	< 3	< 3
B16W05D	4	< 3	3	< 3
B16W06D	4	< 3	3	< 3
B16W07D	4	< 3	< 3	< 3
B16W08D	4	< 3	< 3	< 3
Radium-226				
B16W01S	4	0.7	3.2	2.3
B16W02S	4	0.3	2.7	1.2
B16W03S	4	0.3	0.6	0.5
B16W04S	4	0.3	1.3	0.8
B16W05D	4	0.9	1.1	1
B16W06D	4	0.5	1.8	1.3
B16W07D	4	0.3	0.9	0.6
B16W08D	4	0.3	0.8	0.6
Thorium-230				
B16W01S	4	0.3	3.7	1.9
B16W02S	4	< 0.1	2.7	0.9
B16W03S	4	0.2	0.6	0.3
B16W04S	4	< 0.1	0.8	0.4
B16W05D	4	< 0.1	0.2	0.1
B16W06D	4	< 0.1	0.2	0.2
B16W07D	4	< 0.2	0.3	0.3
B16W08D	4	< 0.1	< 0.3	< 0.2

Reference: Table 6-9 of DOE (1990) (DOE/OR/20722-258)

Table A4
Total Uranium Results from the 1997/1998 Sampling Event
Mallinckrodt Inc. - St. Louis Downtown Site

Monitoring Well No.	Total Uranium (unfiltered) (µg/l)	Total Uranium (filtered) (µg/l)
B16W01S	4.22	5.42
B16W02S	1,175	1,187
B16W03S	7.39	4.84
B16W04S	7.48	1.74
B16W05S	1.62	1.60
B16W05D	0.22	< 0.03
B16W06S	< 0.03	< 0.03
B16W06D	0.30	< 0.03
B16W07S	0.24	0.33
B16W07D	2.45	2
B16W08S	1.62	1.56
B16W08D	0.38	0.34
B16W09D	< 0.03	< 0.03
B16W10S	3.69	4.12
B16W11S	49.90	71.70
B16W12S	6.29	6.23
B16W13SR	121	137

Reference: Table 4-4 of USACE (1998); (USACE/OR/DACW45-1050)



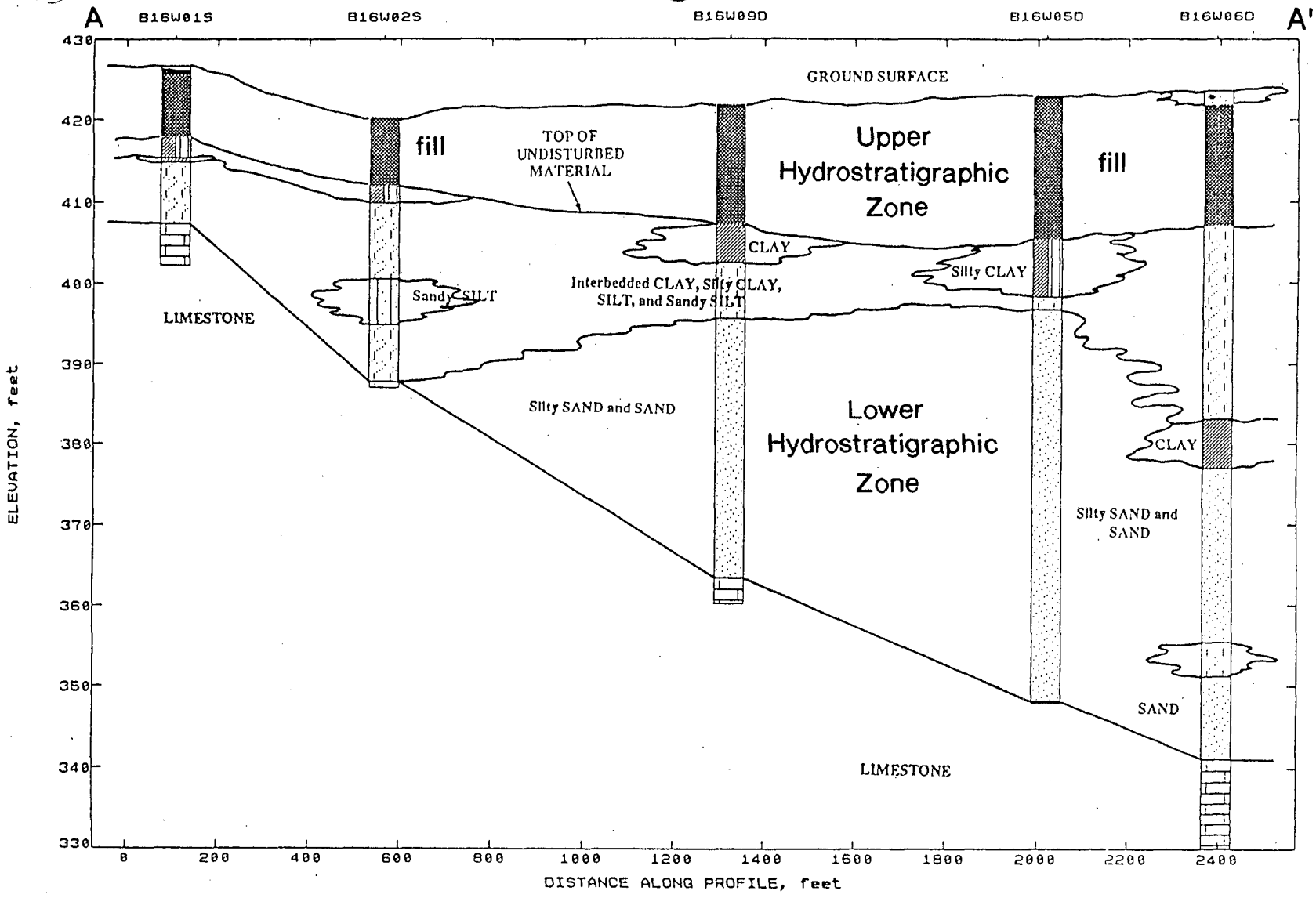
NOTE: PROFILE A–A' IS SHOWN ON FIGURE A2

0 200
SCALE FEET

REFERENCE: MALLINCKRODT DRAWING NO. 5000, ST. LOUIS PLANT MAP, 1990

MALLINCKRODT INC ST. LOUIS, MISSOURI	PROJECT NO. 21560918
URS	
DRN. BY: djd 11/6/02 DSGN. BY: ret CHKD. BY: RET 11/6/2002	Site Map — FIG. NO. A1

File: E:\0918.00000\11-4-02\FIG_A1.DWG Last edited: 11/06/02 @ p.m. @ WCC-ST.LOUIS



Reference: Figure 6-40; (DOE, 1990)

MALLINCKRODT, INC ST. LOUIS, MISSOURI	PROJECT NO. 21560918
URS	
DRN. BY:rt 11/6/02 DSGN. BY: RZT CHKD. BY: RZT 11/6/2002	Generalized Subsurface Geologic Profile
	FIG. NO. A2

Unit Designation	Graphic Column	Approximate Thickness (ft)	Description
Upper Hydro Stratigraphic Unit		0-25	**RUBBLE and FILL** Grayish black (N2) to brownish black (5YR2/1). Dry to slightly moist, generally becoming moist at 5-6 ft and saturated at 10-12 ft. Slight cohesion, variable with depth, moisture content and percentage of fines present. Consistency of relative density is unrepresentative, due to large rubble fragments. Rubble is concrete, brick, glass, and coal slag. Percentage of fines as silt or clay increases with depth from 5 to 30 percent. Some weakly cemented aggregations of soil particles. Adhesion of fines to rubble increases with depth and higher moisture content. Degree of compaction is slight to moderate with frequent large voids.
		0-10	**Silty CLAY (ML-CL)** Layers are mostly olive gray (5Y2/1), with some olive black (5Y2/1). Predominantly occurs at contact of undisturbed material, or at boundary of material with elevated activity. Abundant dark, decomposed organics. Variable percentages of silt and clay composition.
		0-5	**CLAY (CL)** Layers are light olive gray (5Y5/2), or dark greenish gray (5GY4/1). Slightly moist to moist, moderate cohesion, medium stiff consistency. Tends to have lowest moisture content. Slight to moderate plasticity.
		0-2.5	**Interbedded CLAY, silty CLAY, SILT and Sandy SILT (CL, CL-ML, ML)** Dark greenish gray (5GY4/1) to Light olive gray (5Y6/1). Moist to saturated, dependent on percentage of particle size. Contacts are sharp, with structure normal to sampler axis to less than 15 degrees downdip. Layer thicknesses are variable, random in alternation with no predictable vertical gradiation or lateral continuity. Some very fine-grained, rounded silica sand as stringers. Silt in dark mafic, biotite flakes. Some decomposed organics.
Lower Hydro Stratigraphic Unit		0-10	**Sandy SILT (ML)** Olive gray (5Y4/1). Moist with zones of higher sand content saturated. Slight to moderate cohesion, moderate compaction. Stiff to very stiff consistency, rapid dilatancy, nonplastic. Sand is well sorted, very fine and fine-grained rounded quartz particles.
		0-50	**Silty SAND and SAND (SM, SP, SW)** Olive gray (5Y4/1). Saturated, slight cohesion, becoming noncohesive with decrease of silt particles with depth. Dense, moderate compaction. Moderate to well-graded, mostly fine- and medium-grained, with some fine- and coarse-grained particles. Mostly rounded with coarse grains slightly subrounded. Gradual gradation from upper unit, silty sand has abundant dark mafic/biotite flakes. Sand is well-graded, fine gravel to fine sand. Mostly medium-grained, with some fine-grained and few coarse-grained and fine gravel.
Bedrock Unit		Total thickness not penetrated during drilling	**LIMESTONE** Light olive gray (5Y4/1) with interbedded chert nodules. Generally hard to very hard; difficult to scratch with knife. Slightly weathered, moderately fresh with little to no discoloration or staining. Top 5 ft is moderately fractured, with 99 percent of joints normal to the core axis. Joints are open, planar, and smooth. Some are slightly discolored with trace of hematite staining.

Reference: Figure 6-38; (DOE, 1990)

MALLINCKRODT, INC ST. LOUIS, MISSOURI	PROJECT NO. 21560918
URS	
DRN. BY:rt 11/6/02 DSGN. BY:RET CHKD. BY:RET 11/6/2002	Generalized Diagram of Hydrostratigraphic Units — FIG. NO. A3

NOTES:
UPPER ZONE WELLS
LOWER ZONE WELLS

MALLINCKRODT INC. ST. LOUIS, MISSOURI	PROJECT NO. 21560918
URS	
DRN. BY: djd 11/6/02 DSGN. BY: tja CHKD. BY: RET 11/6/2002	Monitoring Well Location Plan
	FIG. NO. A4

File: E:\21560918.00000\11-4-02\FIG A4.DWG Last edited: NOV. 06, 02 @ 1:18 p.m. URS Corp.

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Figure Number: A5

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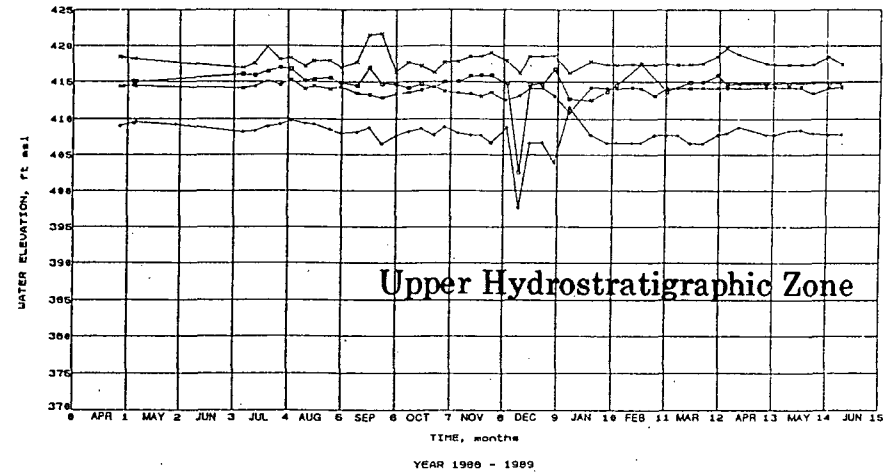

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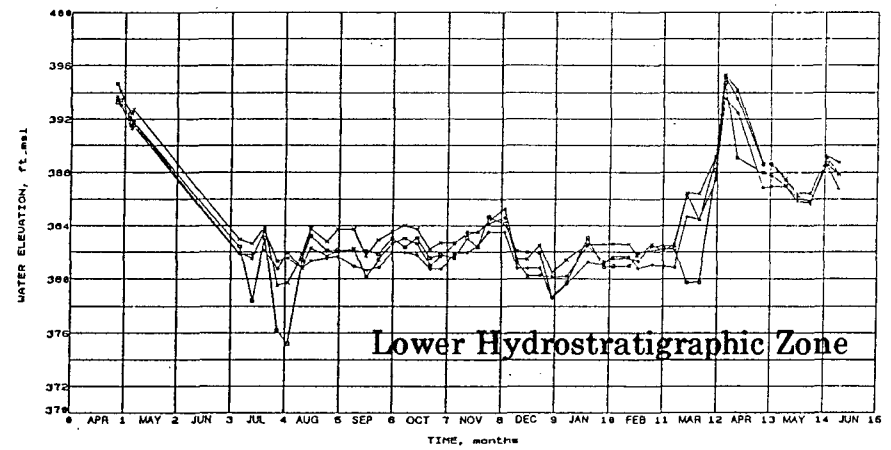

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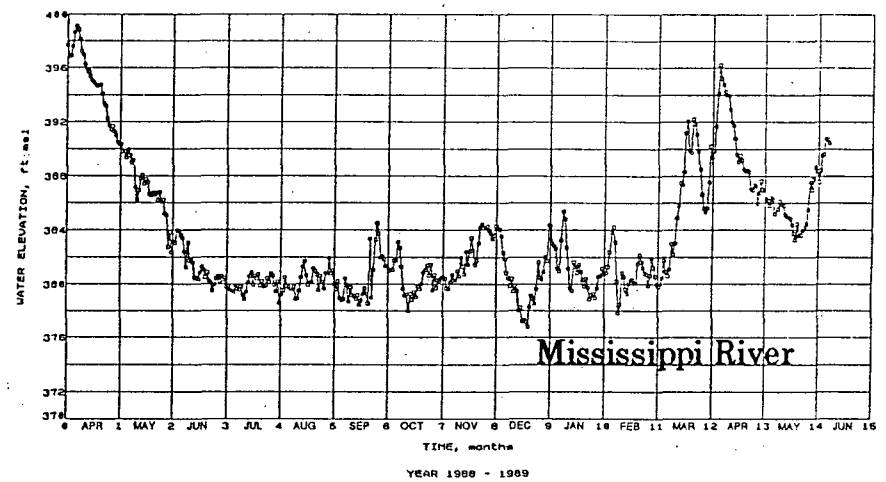
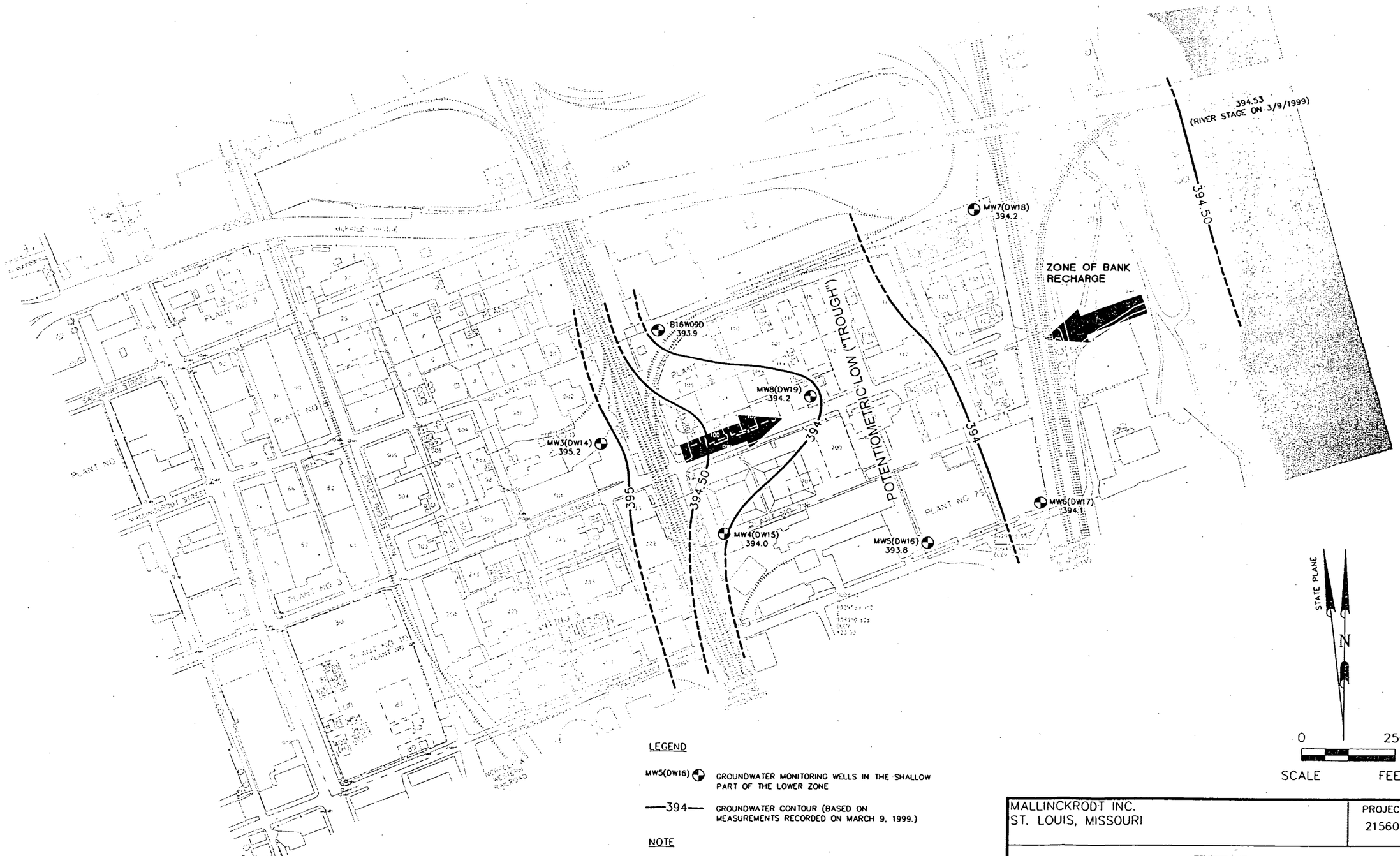
■ POINT ID 816W060
◇ POINT ID 816W070
× POINT ID 816W080



Reference:
Figures 6-44, 6-45, 6-46; (DOE, 1990)

MALLINCKRODT, INC ST. LOUIS, MISSOURI	PROJECT NO. 21560918
URS	
DRN. BY: rt 11/6/02 DSGN. BY: RET CHKD. BY: RET 11/6/2002	Time Series Plots of Water Level Measurements — FIG. NO. A6



LEGEND

MW5(DW16) GROUNDWATER MONITORING WELLS IN THE SHALLOW PART OF THE LOWER ZONE

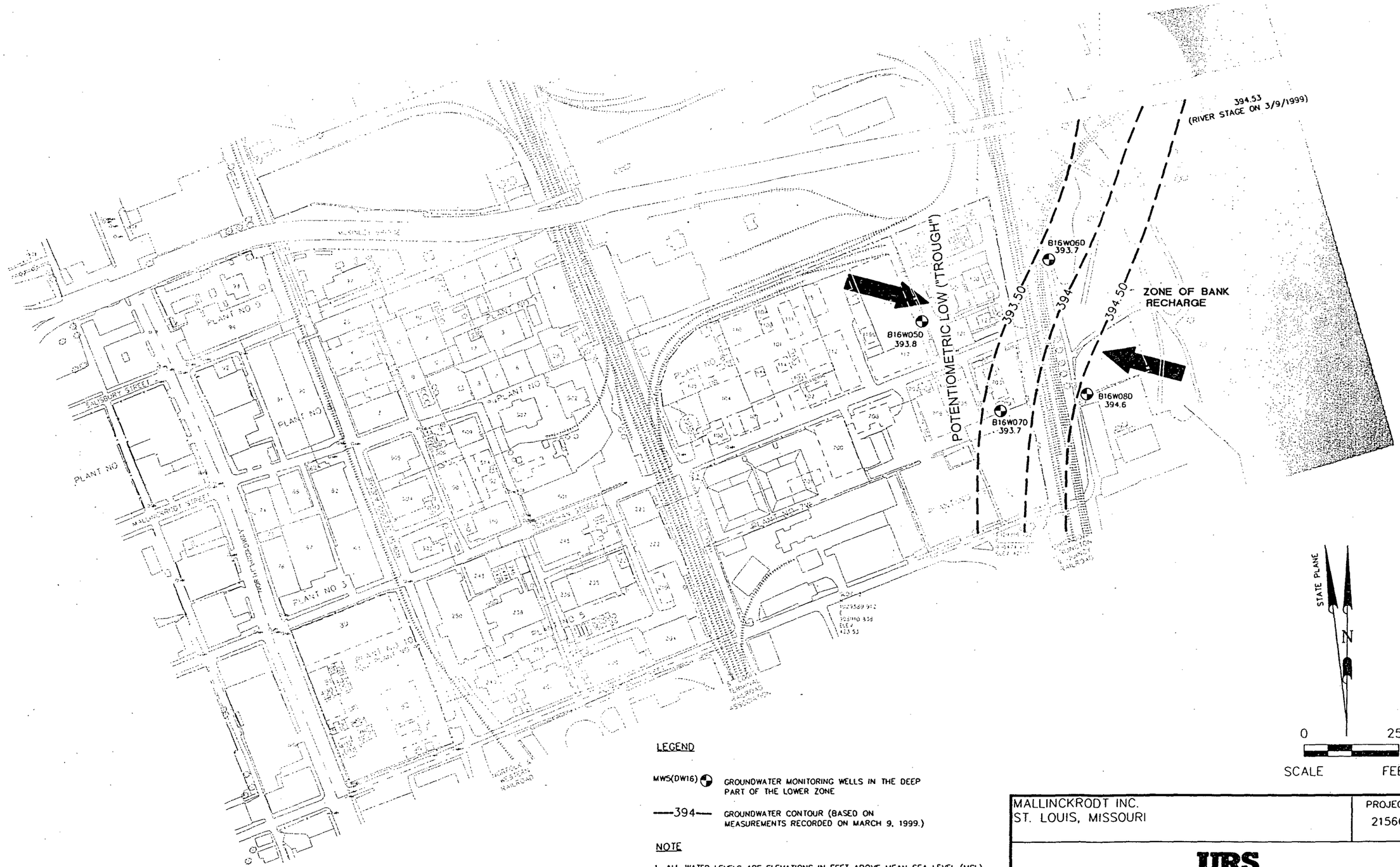
—394— GROUNDWATER CONTOUR (BASED ON MEASUREMENTS RECORDED ON MARCH 9, 1999.)

NOTE

1. ALL WATER LEVELS ARE ELEVATIONS IN FEET ABOVE MEAN SEA LEVEL (MSL)
2. THE RIVER STAGE DEPICTED ON THE FIGURE WAS INTERPOLATED BETWEEN USACE GAGING STATIONS AT CHAIN OF ROCKS, ST. LOUIS, MISSOURI AND THE FOOT OF MARKET STREET, ST. LOUIS, MISSOURI.

MALLINCKRODT INC. ST. LOUIS, MISSOURI		PROJECT NO. 21560918
URS		
DRN. BY: djd 11/6/02 DSGN. BY: tjo CHKD. BY: RET 11/6/2002	Generalized Groundwater Contours of the Shallow Part of the Lower Zone	FIG. NO. A-7

File: F:\21560918.00000\11-4-02\FIG_A7.DWG Last edited: NOV. 06, 02 @ 1:24 p.m. URS (Cop)



LEGEND

MW5(DW16) GROUNDWATER MONITORING WELLS IN THE DEEP PART OF THE LOWER ZONE

—394— GROUNDWATER CONTOUR (BASED ON MEASUREMENTS RECORDED ON MARCH 9, 1999.)

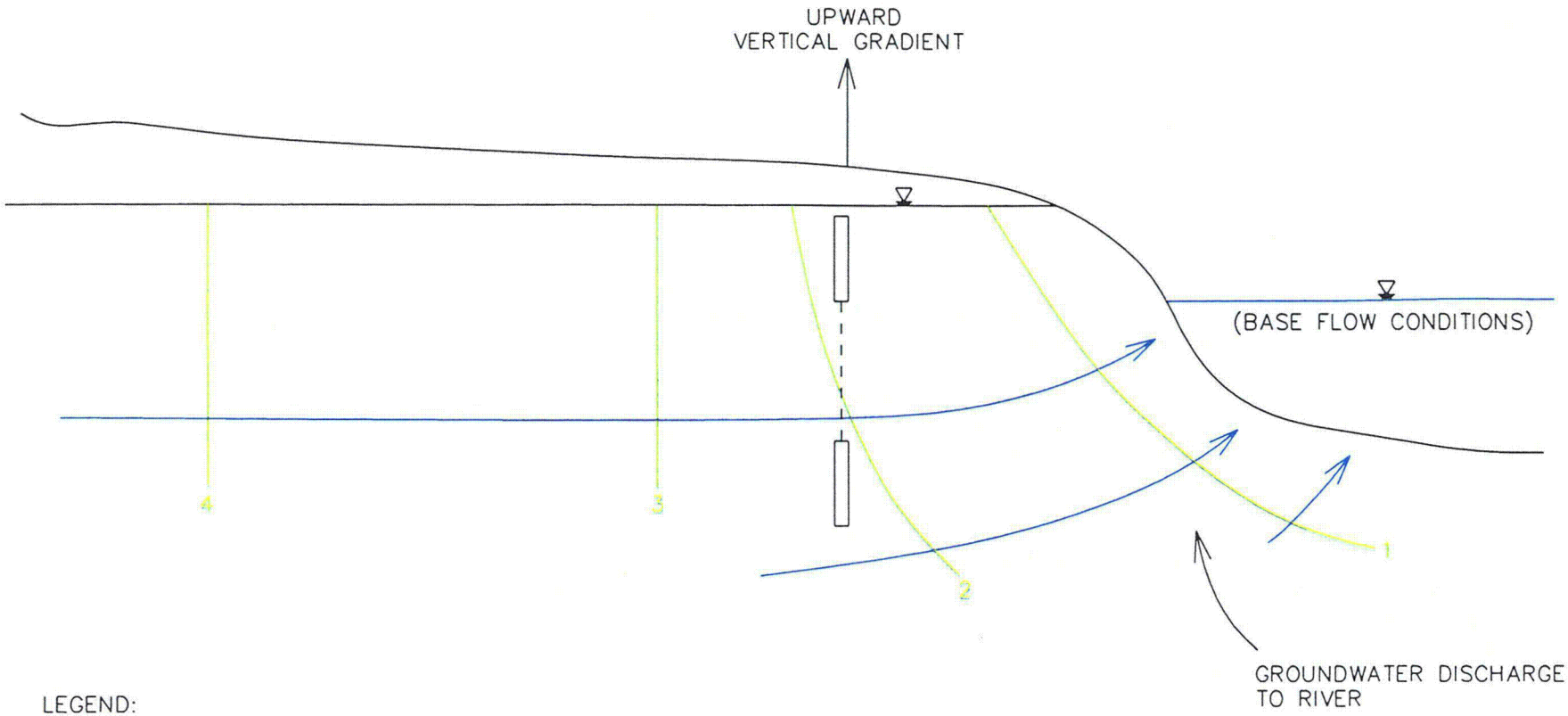
NOTE

1. ALL WATER LEVELS ARE ELEVATIONS IN FEET ABOVE MEAN SEA LEVEL (MSL)
2. THE RIVER STAGE DEPICTED ON THE FIGURE WAS INTERPOLATED BETWEEN USACE GAGING STATIONS AT CHAIN OF ROCKS, ST. LOUIS, MISSOURI AND THE FOOT OF MARKET STREET, ST. LOUIS, MISSOURI.

MALLINCKRODT INC. ST. LOUIS, MISSOURI	PROJECT NO. 21560918
URS	
DRN. BY: chs 4/5/01 DSGN. BY: tja CHKD. BY: RET 11/6/2002	Generalized Groundwater Contours of the Deep Part of the Lower Zone
FIG. NO. A-8	

FILE: F:\21560918\Acad\11-4-02\FIG_A8.DWG Last edited: NOV 06, 02 @ 2:07 p.m. URS Corp.

RIVER RECHARGE



LEGEND:

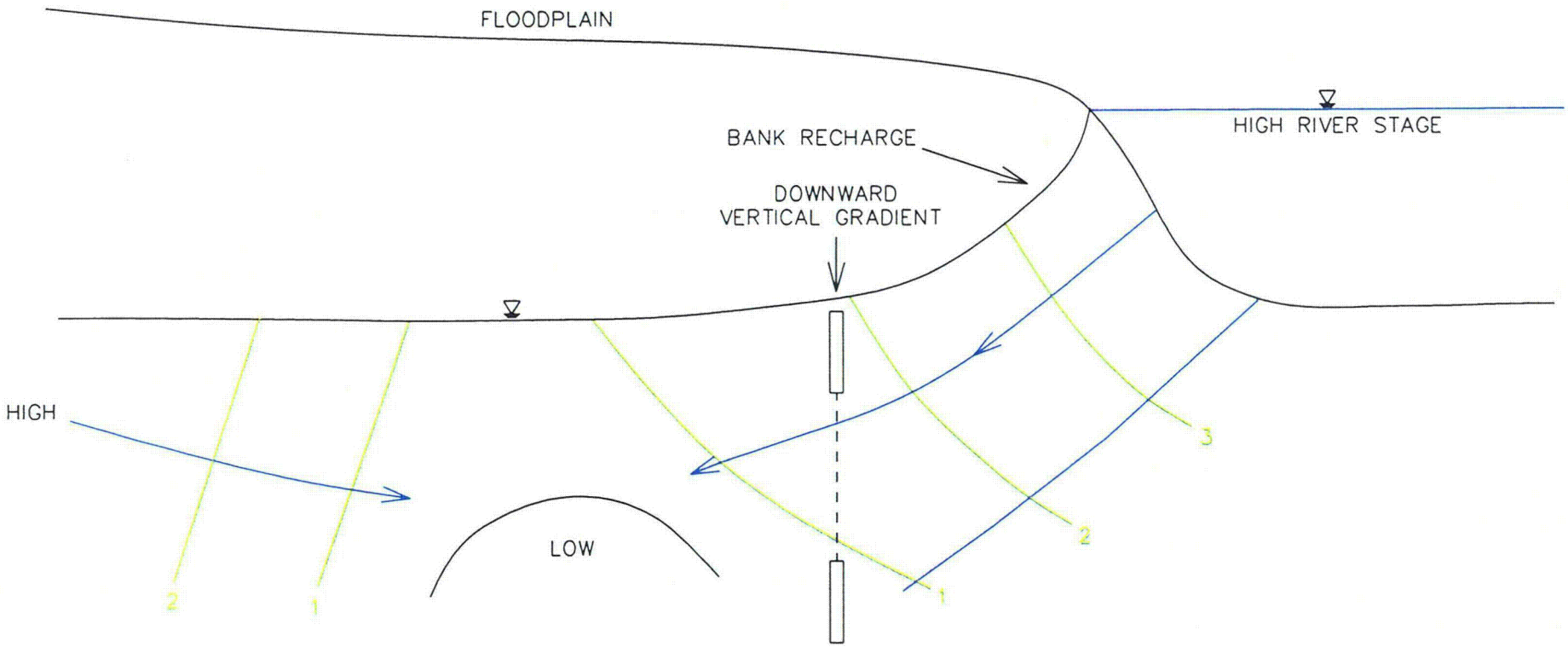
4 EQUIPOTENTIAL LINES
(NUMBERS ARE EQUAL TO RELATIVE
HYDRAULIC HEAD VALUES)

FLOW LINES

NOTE: DURING GROUNDWATER DISCHARGE TO THE RIVER
AN UPWARD VERTICAL GRADIENT WOULD BE NOTICED
AT THE WELL CLUSTER.

MALLINCKRODT INC. ST. LOUIS, MISSOURI	PROJECT NO. 21560918
URS	
DRN. BY: djd 11/6/02 DSGN. BY: ret CHKD. BY: RET 11/6/2002	Conventional Hydrologic Model of River Recharge in an Alluvial Setting
	FIG. NO. A9

BANK RECHARGE



LEGEND:

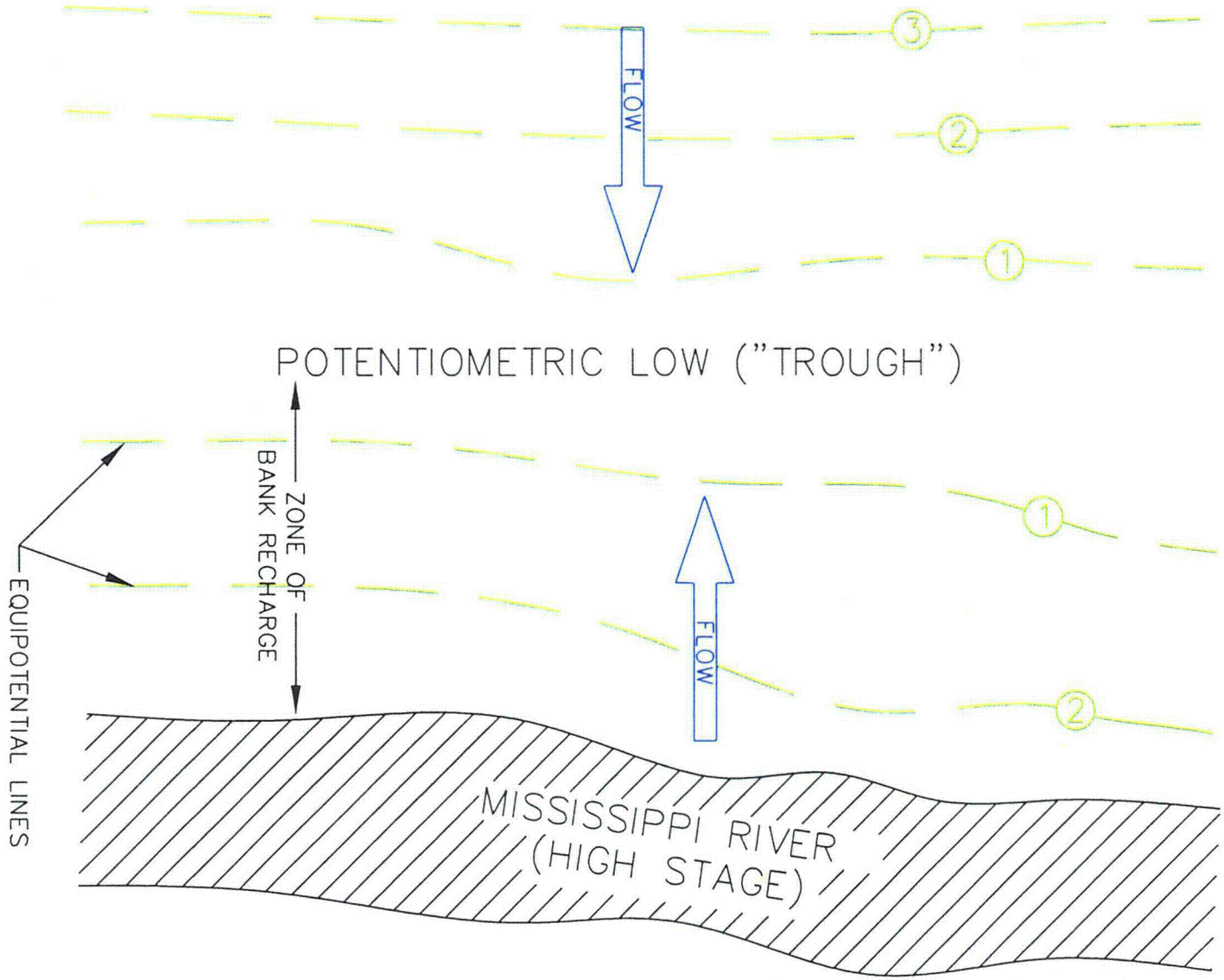
4 EQUIPOTENTIAL LINES (NUMBERS ARE EQUAL TO RELATIVE HYDRAULIC HEAD VALUES)

FLOW LINES

NOTE: DURING BANK RECHARGE TO THE FLOODPLAIN A DOWNWARD VERTICAL GRADIENT WOULD BE NOTICED AT THE WELL CLUSTER.

MALLINCKRODT INC. ST. LOUIS, MISSOURI	PROJECT NO. 21560918
URS	
DRN. BY: djd 11/6/02 DSGN. BY: ret CHKD. BY: RET 11/6/2002	Conventional Hydrologic Model of Bank Recharge in an Alluvial Setting — FIG. NO. A10

File: E:\21560918.000\ 1-02\FIG_A11.DWG Last edited: NOV. 06, 02 @ 1:54 p.m. by: DJDEGUIO



NOTE: THE DASHED LINE REPRESENT POINTS OF EQUAL HYDRAULIC HEAD.

MALLINCKRODT INC. ST. LOUIS, MISSOURI	PROJECT NO. 21560918
URS	
DRN. BY: djd 4/5/01 DSGN. BY: ret CHKD. BY: RET 11/6/2002	Idealized 2-D Model (Plan View) of Bank Recharge During High River Stage
	FIG. NO. A11

APPENDIX B

INTERPRETATION OF NATURAL BACKGROUND RADIONUCLIDE CONCENTRATION IN CINDER/FILL FOR THE MALLINCKRODT COLUMBIUM-TANTALUM DECOMMISSIONING PLAN

Mallinckrodt Inc.

C-T Phase II Decommissioning Plan

March 10, 2003

NRC Docket: 40-06563

NRC License: STB-401

Appendix B

B. INTERPRETATION OF NATURAL BACKGROUND RADIONUCLIDE CONCENTRATION IN CINDER/FILL FOR THE MALLINCKRODT COLUMBIUM-TANTALUM DECOMMISSIONING PLAN

A large number of subsurface soil (cinder/fill) samples were collected in the Mallinckrodt Columbium-Tantalum (C-T) Plant 5 area. An assumption was made that not all of the subsurface soils were contaminated with uranium-series or thorium-series radionuclides from historical process operations. Then those uncontaminated samples can be used to interpret the natural background concentration of uranium-series and thorium-series radionuclides in the subsurface soil.

B.1 PROBLEM

The Nuclear Regulatory Commission (NRC) provides criteria for release of a licensed facility for unrestricted use. A radionuclide concentration may be derived for soils corresponding to the release criterion; e.g. a derived concentration guideline level (DCGL). The DCGL is established as a net activity concentration; i.e. a concentration of a radionuclide in soil above the concentration of that radionuclide which occurs naturally in the soil. The naturally occurring concentration of a radionuclide in soil is also known as the respective radionuclide's background concentration. The DCGL and the background concentration may be similar in value. It is then essential to make an accurate estimate of the background concentration.

The natural background concentrations of uranium-series and thorium-series radionuclides vary in the environment, even on a local scale. An area that has similar physical, chemical, and radiological, and biological characteristics as the site area being remediated, but which has not been contaminated by licensed activities is desired in order to estimate background concentrations. The distribution and concentration of background radiation in such a reference area would be expected to be the same as that at the site. If such a reference area is not available, an alternate method of interpreting natural background concentrations is necessary.

The Mallinckrodt Plant 5 area, where the C-T process occurred, has an undisturbed clay layer 15 to 20 feet below the present ground surface. As long as 150 years ago, fill material comprised of cinders from coal burned in the area and other material was deposited on top of the clay, raising the ground level a few to as many as 20 feet. Various other fill materials are found among the cinders, but there is no homogeneity to these materials.

It has not been possible to find near Plant 5 cinder/fill for which the natural radioactivity concentration is assumedly similar to that in Plant 5. Figure B-1 shows the Mallinckrodt site and surrounding areas. It is likely not reasonable or feasible to complete drilling activities on the non-Mallinckrodt properties north and south of the Plant 5 area. The Mark Twain expressway marks a limit toward the west where cinder fill was not used. The Mississippi River is a natural boundary to the east. Areas of the site north and east of Plant 5 are additionally limited by the condition that they were used to process radioactive materials for the Atomic Energy Commission and the Manhattan Engineering District (AEC-MED).

An attempt was made to find a reference area on Mallinckrodt property north of Plant 5. Figure B-1 shows borehole locations from which samples were collected to develop background concentrations for radionuclides of the uranium-series and thorium-series. This area is known as the "Coal Yard". In the Coal Yard, the cinder fill was in layers two to four feet thick and at variable depths. Variability in the sample results indicated that extensive additional sample collection would be necessary to provide requisite statistical confidence.

Several areas were further considered for additional sampling. Further north, the suspicion was the cinder fill layer(s) would also be shallow and variable. There might also be a time difference in placement that would contribute additional variability in the concentrations of radionuclides. It was not possible to go east due to AEC and MED activities, and then the Mississippi River. It was not possible to go west due to lack of cinders as fill material. Access to the south was hindered by industrial development of streets and structures.

It then seemed reasonable to attempt to extract a background data set from samples collected in the Plant 5 area. In other words, a reference area would be developed from the total site characterization data set. Specifically, it was presumed that the whole of the Plant 5 subsurface soils was not contaminated by C-T or MED-AEC activities. Then those uncontaminated samples could be used as the reference area data set from which background concentrations could be interpreted for radionuclides of the uranium-series and the thorium-series. Such presumption is consistent with NRC guidance.[1,2], which states:

> A derived reference area may be used when it is necessary to extract background information from the survey unit because a suitable reference area is not readily available. For example, it may be possible to derive a background distribution based on an area of the survey unit where residual distribution based on area of the survey unit where residual radioactivity is not present.

B.2 OBJECTIVE

The objective of this appendix is to interpret background concentrations by analysis of the site characterization data for the primary radionuclides in each of the uranium series and the thorium series. The scope of this objective is limited to three long-lived radionuclides from each series: the three from the uranium series are U-238, Th-230, and Ra-226; the three from the thorium series are Th-232, Ra-228, and Th-228.

Specifically, a set of measurements will be selected to represent the distribution of background concentration of the key radionuclides of the uranium series and the thorium series. The set of measurements will be selected from the larger data set of characterization samples. A best single-valued estimate of background for each key radionuclide will be derived to support remediation efforts in which a decision is made on a single measurement. Also, the set of background measurements will be used as the background data set for performance of Wilcoxon Rank Sum tests of final status survey data sets.

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[1] USNRC. "Demonstrating Compliance with the Radiological Criteria for License Termination". Draft Regulatory Guide DG-4006. Section 2.3.1. August 1998.

[2] USNRC. "Consolidated NMSS Decommissioning Guidance." NUREG-1757, 2, §A.3.1, p. A-5. Sept. 2002.

B.3 SOLUTION

Several statistical methods were evaluated as means to achieve the objective. Application of these methods has been presented to the NRC elsewhere.[3,4] The presentations described each method, compared advantages and disadvantages, and demonstrated the validity of each method to achieve the objective. Background concentration of each key radionuclide was interpreted by a combination of differential and integral curve fits. A histogram, or differential curve, of measurements of each key radionuclide was constructed to interpret where a rational distinction occurs between natural background data and data that likely include licensed source material residue. The mean and standard deviation were then interpreted by constructing a cumulative probability plot, or integral curve, of the background data. This method of interpretation of background has the following advantages:

- Minimizes assumptions.
- Uses all of the data cumulatively.
- Enables visual interpretation of the data.
- Tests and illustrates nearness to the distribution assumed.
- Provides the desired results directly.
- Is practical to implement using curve fitting software.

B.3.1 Description

The application of this method to the C-T site characterization data first required choice of an upper bound radioactivity concentration for each of the uranium-series and the thorium-series. The upper bound was chosen by constructing a frequency histogram from all characterization data for the respective key radionuclide. The histogram was interpreted by acknowledging that the lowest peak must be a representation of background. Then the upper tail of this peak may also represent an upper bound of background radioactivity concentration.

The histogram for each of the six key radionuclides is shown in figures B-2 through B-7. The histograms of figures B-2 through B-7 were constructed of the entire set of characterization samples for the respective key radionuclide. However, in order to clearly show the lower end of the histogram, only that portion of the histogram between 0 and 20 pCi/g is shown. In the case of the uranium series (U-238, Th-230, and Ra-226), figures B-2 through B-4 reflect that the background peak must be below 10 pCi/g. In the case of the thorium series (Th-232,Ra-228, and Th-228), figures B-5 through B-7 reflect that the background peak must be below 5 pCi/g.

The set of characterization samples was reduced to that set of samples for which each of the six key radionuclides was less than or equal to its' respective upper bound. In other words, the set of background samples are those samples for which each of U-238, Th-230, and Ra-226 is less than 10 pCi/g, and each of Th-232, Ra-228, and Th-228 is less than 5 pCi/g. The resulting data set is

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[3] Mallinckrodt Chemical Company. "Interpretation of Natural Background Radionuclide Concentration in Soil in an Area Where Contamination by Regulated Materials May Occur". Sol Guber. July 9, 1997.

[4] Henry W. Morton. "Methods of Interpreting Background Radioactivity Concentration in Soil". Presentation to USNRC Staff. January 23, 2002.

presented in Table B-1. Since each radionuclide in each sample is less than its' respective upper bound, it is reasonable to assume each sample may be a background sample. Then any manipulation of this data set may be considered equivalent to manipulation of a background data set. The location of the boreholes represented by the samples in Table B-1 are shown in Figure B-8.

A cumulative probability graph was constructed from the data in Table B-1for each of the six key radionuclides. A best-fit distribution was determined for each probability graph. In each case, the Weibull distribution provided the best fit compared to the normal and the lognormal. Gilbert has synopsized works of others supporting representation of some environmental pollution data, including background.[5] Figures B-9 through B-14 show the probability graph developed for each of the six key radionuclides. Tables B-2 through B-7 provide particular description of each figure. The graphs and tables were developed from statistical software.[6]

B.3.2 Results

Table B-8 presents the results of the analyses for each key radionuclide: number of measurements, mean, standard deviation, and confidence limits.

B.4 CONCLUSION

The mean values in Table B-8 will be used as the background radioactivity concentrations for the C-T Phase 2 decommissioning. Additionally, the background data set described in Table B-1 will represent background radionuclide concentration in cinder/fill for utilization in population statistical tests of compliance for a final status survey.

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[5] Gilbert, R.O. Statistical Methods for Environmental Pollution Monitoring. Van Nostrand Reinhold. NY. pp. 155-157. 1987.

[6] MINITAB, Inc. MINITAB Statistical Software. Release 13.1. 2000. State College, PA. USA.

Table B-1, Samples With Result For Each Key Radionuclide and all Results Less Than Respective Background Cut-off of 10 pCi/g U-series 5 pCi/g Th-series

Location ID	Sample Matrix	Sample Depth (ft)		Radionuclide Concentration					
		Top	Bottom	U-238 (pCi/g)	Th-230 (pCi/g)	Ra-226 (pCi/g)	Th-232 (pCi/g)	Ra-228 (pCi/g)	Th-228 (pCi/g)
BH-002	Cinder	0.5	2.5	2.5	3.1	2.3	1.8	1.5	1.5
BH-003	Fill	0.5	2.5	7.1	6.1	3.5	1.4	1.5	1.3
BH-008	Fill	0.5	2.5	5.2	3.9	4.2	1.6	1.5	1.4
BH-008	Cinder	5.5	6.5	7.7	3.2	4.4	0.8	1.4	1.4
BH-011	Fill	0	2.5	0.65	0.16	2.12	0.24	1.53	0.23
BH-013	Fill	0	5.5	4.5	2.4	1.1	1.6	1.2	1.3
BH-013	Fill	0	9.5	4.4	1.7	3.4	1.1	1.6	1
BH-016	Fill	0	7.5	5.9	6.3	7.8	3.5	4.5	3.5
BH-019	Fill	0	9.5	4.8	1.5	2.8	1.1	2.9	1.4
BH-020	Fill	0	4.5	3.1	5	2.8	1.8	1.1	2.2
BH-023	Fill	0	9.5	6.6	1.8	0.13	0.61	1.1	0.64
BH-027	Fill	0	5.5	3.6	3.2	1.5	2.1	1.8	2.1
BH-027	Fill	0	8.5	7.1	7.3	4.6	2.9	2.4	2.9
BH-028	Fill	0	10.5	3	2.8	1.7	1	0.81	1.4
BH-029	Fill	0	11	5.5	7.8	4	1.9	1.5	1.5
BH-031	Fill	0	13.5	1.4	1.5	1.7	0.67	1.4	0.72
BH-034	Fill	0	3.5	5.2	6.3	6.9	1.2	1.5	1.3
BH-034	Fill	0	9.5	4.2	5.8	4.6	2.6	1.8	2.9
BH-035	Fill	0	16.5	1.4	1.8	1.5	1.2	1.5	1.6
BH-036	Fill	0	0.5	3	3.6	3.2	0.99	1.6	1.3
BH-036	Fill	0	5.5	3.4	3.9	4.5	1	1.6	1.1
BH-036	Fill	0	16.5	6	3.5	2.4	1.2	1.2	1.2
BH-037	Fill	0	1	9.9	6.5	< 0.44	1.4	< 0.47	1.4
BH-037	Fill	0	7	5.3	6.1	4.3	1.7	< 0.55	1.9
BH-037	Fill	0	11.5	4.4	2.9	6	1.7	1.7	1.4
BH-039	Fill	0	8.5	3	7.7	5	1	1.3	1.2
BH-039	Fill	0	17.5	1.6	1.8	1	1.3	1.5	1.2

Table B-1, Samples With Result For Each Key Radionuclide and all Results Less Than Respective Background Cut-off of 10 pCi/g U-series 5 pCi/g Th-series

Location ID	Sample Matrix	Sample Depth (ft)		Radionuclide Concentration									
		Top	Bottom	U-238 (pCi/g)	Th-230 (pCi/g)	Ra-226 (pCi/g)		Th-232 (pCi/g)		Ra-228 (pCi/g)		Th-228 (pCi/g)
BH-040	Fill	0	3.5	3.3	2.8	2.8		1.3		1.6		1.4
BH-040	Fill	0	11.5	8	4.3	1.7		2.3		2.9		2
BH-041	Fill	0	4.5	6.1	0.3	3.04	<	0.05		1.24		0.17
BH-041	Fill	0	6.5	0.85	0.07	1.37	<	0.03		1.03	<	0.05
BH-041	Fill	0	8.5	3.9	0.095	1.35	<	0.02		1.01	<	0.02
BH-041	Fill	0	12	3.9	2.6	5.6		1		2.8		2.6
BH-041	Cinder	0	16.5	4.2	2.3	3.9		1		1.5		1.2
BH-042	Silt	0	16.5	2.2	2.9	1.9		1.3		1.9		1.4
BH-043	Fill	0	10.5	5.2	7.7	0.91		1		1.2		1.7
BH-044	Fill	0	11	4.8	6	3		3.1		2.8		3.1
BH-045	Fill	0	2	3.1	5.6	1.8		0.89		0.96		1.1
BH-045	Fill	0	9.5	1.5	1.6	1.1		0.81		1		0.71
BH-046	Fill	0	2.5	2	2.2	1.4		1.4		0.67		0.85
BH-046	Fill	0	9.5	6.5	5.4	3.5	<	0.61		1.1		2.3
BH-046	Fill	0	13.5	5.5	3	7.4		2.6		1.6		3.8
BH-047	Fill	0	3.5	6.2	4.6	2.9		1.1		1.7		1.3
BH-047	Fill	0	7.5	5.8	2.5	2.3		1.3		1.6		1.4
BH-048	Fill	0	3.5	1.3	1.5	1.6		1		1.3		1.5
BH-048	Fill	0	9.5	2.6	1.6	2.4		1.1		1		0.94
BH-049	Fill	0	2.5	4.9	3.5	4.8		1.1		1.9		1.1
BH-049	Fill	0	10.5	6.8	3.4	4.8		1.2		1.5		0.85
BH-051	Fill	0	2.5	8.6	4.3	3.6		0.99		1.4		1
BH-051	Fill	0	6.5	1.9	0.18	2.5		0.66		1		0.85
BH-051	Fill	0	13.5	5.8	8.3	7.9		2.2		2.6		1.8
BH-053	Fill	0	2	7.8	7	9.8		1.4		2.2		1.8
BH-053	Fill	0	9.5	5.6	3.2	2.8		1.4		1.2		1.6
BH-054	Fill	0	5.5	4.4	1.8	1.6		0.97		1.6		0.81

Table B-1, Samples With Result For Each Key Radionuclide and all Results Less Than Respective Background Cut-off of 10 pCi/g U-series 5 pCi/g Th-series

Location ID	Sample Matrix	Sample Depth (ft)		Radionuclide Concentration					
		Top	Bottom	U-238 (pCi/g)	Th-230 (pCi/g)	Ra-226 (pCi/g)	Th-232 (pCi/g)	Ra-228 (pCi/g)	Th-228 (pCi/g)
BH-054	Fill	0	15.5	9.2	2	9.8	0.89	1.6	1.2
BH-056	Fill	0	4.5	3.9	2.1	3.1	1.1	2.8	1.5
BH-056	Fill	0	11.5	6.2	4.1	4.8	0.96	1.8	1
BH-056	Fill	0	14.5	8.7	3.8	4.4	0.81	1.7	1
BH-062	Fill	7	8	4.95	4.48	6.15	2.35	3.18	2.22
BH-063	Fill	1	2	7.62	5.25	4.77	1.42	1.46	1.38
BH-063	Fill	4	6	6.45	2.67	2.25	1.26	1.32	1.12
BH-064	Fill	4	5	5.06	3.4	4.07	0.87	1.54	1.03
BH-064	Fill	11	12	3.75	2.42	2.58	1.52	1.36	1.48
BH-065	Fill	0	0.5	5.92	3.78	5.35	1.01	1.98	1.03
BH-065	Fill	0	3.5	1.68	1.93	4.18	1.53	2.36	1.1
BH-066	Fill	0	3.5	5.69	3.8	4.19	1.18	1.4	0.97
BH-067	Fill	1	2	9.81	5.5	4.07	0.85	1.83	1.26
BH-067	Fill	4	6	6.47	4.47	4.66	1.03	1.98	1.19
BH-067	Fill	15	16	3.9	2.51	7.37	0.83	2.14	0.73
BH-068A	Fill	5	6	7.89	5.38	6.45	1.29	1.95	1.15
BH-082	Fill	6	7.5	2.68	1.88	2.06	0.89	0.59	1.04
BH-082	Fill	9	10.5	1	1.46	1.07	0.97	0.68	1.03
BH-082	Fill	12	13.5	2.32	2.6	2.02	0.97	0.23	0.92
BH-083	Fill	10.5	12	1.35	0.94	1.46	0.91	0.85	0.93
BH-083	Fill	13.5	15	1.89	0.86	0.92	0.75	0.79	0.76
BH-084	Fill	0.5	1.5	2.85	2.69	2.1	0.96	0.68	1.08
BH-084	Fill	3	4.5	2.58	2.34	1.14	1.05	0.65	1.05
BH-085	Fill	1	1.5	2.1	1.42	1.48	0.69	0.68	0.72
BH-085	Fill	3	4.5	2.89	2.64	1.6	0.96	0.79	1.16
BH-085	Fill	6	7.5	0.63	0.62	0.54	0.45	0.75	0.52
BH-087	Fill	6	7.5	7.6	1.81	0.047	0.64	-0.17	0.7

Table B-1, Samples With Result For Each Key Radionuclide and all Results Less Than Respective Background Cut-off of 10 pCi/g U-series 5 pCi/g Th-series

Location ID	Sample Matrix	Sample Depth (ft)		Radionuclide Concentration					
		Top	Bottom	U-238 (pCi/g)	Th-230 (pCi/g)	Ra-226 (pCi/g)	Th-232 (pCi/g)	Ra-228 (pCi/g)	Th-228 (pCi/g)
BH-087	Fill	9	10.5	7.5	1.91	1.03	1.12	0.83	1.28
BH-089	Fill	3	4.5	3.13	2.24	9.1	0.96	0.86	1.02
BH-089	Fill	9	10.5	6.2	3.14	5.25	1.45	1.19	1.5
BH-089	Fill	15	16.5	9	7.2	1.04	4.05	1.46	4.53
BH-090	Fill	3	4.5	7.2	2.06	1.7	0.98	1.25	1.3
BH-090	Fill	6	7.5	3.65	1.73	1.52	1.12	0.79	1.16
BH-090	Fill	9	10.5	5.4	0.94	2.4	0.61	0.7	0.86
BH-091	Fill	1	1.5	6.6	4.7	5.08	1.45	1.72	1.41
BH-091	Fill	3	4.5	2.05	2.21	1.86	0.93	1	0.92
BH-091	Fill	6	7.5	1.84	1.34	1.62	0.49	0.89	0.58
BH-091	Fill	9	10.5	2.96	1.5	1.06	0.55	0.17	0.68
BH-092	Fill	1	1.5	5.4	3.51	2.18	0.79	0.68	0.77
BH-092	Fill	3	4.5	3	4.34	3.85	1.07	0.84	1.24
BH-092	Fill	6	7.5	1.37	1.6	1.56	0.67	0.75	0.83
BH-092	Fill	9	10.5	2.23	1.52	1.59	0.59	0.73	0.9
BH-093	Fill	0.5	1.5	6.9	4	3.32	1.3	1.14	1.22
BH-093	Fill	3	4.5	5.4	1.7	1.48	0.96	0.76	0.92
BH-093	Fill	6	7.5	2.14	1.14	0.84	0.48	0.64	0.41
BH-099	Gravel	6	9	1.43	1.26	0.87	4.5	0.88	3.56
BH-100	Gravel	0	3	9.26	8.86	0.86	2.84	1.75	2.84
BH-100	Gravel	6	8.5	7.02	5.61	1.46	2.61	2.21	1.98
BH-101	Silt	3	6	1.9	1.09	1.92	2.61	2	4.27
BH-101	Silt	6	9	1.07	4.39	1.97	4.31	0.9	3.7
BH-102	Sand	3	6	1.2	6.38	2.04	3	0.54	3.19
BH-102	Sand	6	9	1.79	1.34	2.38	3.6	0.49	-1.03
BH-Z-02	Fill	0	1	6.25	4.36	0.27	1.16	0.49	1.42
BH-Z-02	Fill	1	3	7.21	3.48	0.38	1.01	0.76	0.95

Table B-1, Samples With Result For Each Key Radionuclide and all Results Less Than Respective Background Cut-off of 10 pCi/g U-series 5 pCi/g Th-series

Location ID	Sample Matrix	Sample Depth (ft)		Radionuclide Concentration					
		Top	Bottom	U-238 (pCi/g)	Th-230 (pCi/g)	Ra-226 (pCi/g)	Th-232 (pCi/g)	Ra-228 (pCi/g)	Th-228 (pCi/g)
BH-Z-02	Fill	3	6	3.8	5.13	0.21	1.27	0.73	0.98
BH-Z-02	Fill	6	9	4.27	3.66	0.23	1.31	0.76	1.36
BH-Z-02	Fill	9	12	5.36	4.68	0.19	1.65	0.81	1.18
BH-Z-03	Fill	0	1	7.52	3.43	0.25	1.01	0.53	0.76
BH-Z-03	Fill	1	3	7.58	4.49	0.13	1.05	0.65	1.12
BH-Z-03	Fill	3	6	4.36	4.76	0.37	1.08	0.79	1.12
BH-Z-03	Fill	6	9	4.66	4.36	0.41	1.13	0.82	1.03
BH-Z-03	Fill	9	12	3.49	3.3	0.29	0.94	1.13	0.7
BH-Z-08	Fill	0	1	1.99	0.94	0.2	0.27	0.16	0.03
BH-Z-08	Fill	1	3	3.75	3.07	0.54	0.75	0.41	0.79
BH-Z-08	Fill	3	6	5.12	4.24	0.3	1.47	0.64	1.26
BH-Z-08	Fill	6	9	3.89	3.71	0.25	0.9	0.57	1.2
BH-Z-08	Fill	9	12	3.47	3.41	0.15	1.45	0.77	0.88
BH-Z-09	Fill	1	3	7.36	3.99	0.26	1.15	0.66	0.88
BH-Z-09	Fill	3	6	4.59	3.14	0.3	1.07	0.69	1.07
BH-Z-09	Fill	6	9	4.19	2.88	0.45	0.6	0.47	0.73
BH-Z-09	Fill	9	12	4.3	3.33	0.25	0.94	0.69	1.02
BH-Z-10	Fill	0	1	1.45	1.12	0.35	0.48	0.5	0.48
BH-Z-10	Fill	1	3	1.05	1.03	0.42	0.78	0.73	0.73
BH-Z-10	Fill	3	6	1.66	2.71	0.41	1.06	0.62	1
BH-Z-10	Fill	6	9	4.16	3.97	0.32	1.05	0.82	0.75
BH-Z-10	Fill	9	12	4.43	3.51	0.12	0.99	0.87	0.93

Table B-2

Distribution Function Analysis: U-238 background concentration for cinder/fill

Variable: U-238 < 10 pCi/g

Count 130

Estimation Method: Least Squares (X on Y)
Distribution: Weibull

Parameter Estimates

Parameter	Estimate	Standard Error	95% Confidence Interval Lower	Upper
Shape	2.0321	0.1458	1.7655	2.3389
Scale	5.0113	0.2276	4.5845	5.4778

Goodness-of-Fit
Correlation Coefficient = (0.9911 (Pearson correlation coefficient, r)

Characteristics of Distribution

	Estimate	Standard Error	95% Confidence Interval Lower	Upper
Mean	4.4400	0.2002	4.0644	4.8503
Standard Deviation	2.2879	0.1528	2.0071	2.6078
Median	4.1843	0.2135	3.7860	4.6245
First Quartile	2.7144	0.1971	2.3544	3.1296
Third Quartile	5.8851	0.2539	5.4080	6.4044
Interquartile Range	3.1707	0.1965	2.8081	3.5801

Table B-3

Distribution Function Analysis: Th-230 background concentration for cinder/fill

Variable: Th-230 < 10 pCi/g

Count 130

Estimation Method: Least Squares (X on Y)
Distribution: Weibull

Parameter Estimates

Parameter	Estimate	Standard Error	95% Confidence Interval Lower	Upper
Shape	1.5803	0.1219	1.3464	1.8548
Scale	3.7939	0.2216	3.3836	4.2541

Goodness-of-Fit
Correlation Coefficient = (0.9763 (Pearson correlation coefficient, r)

Characteristics of Distribution

	Estimate	Standard Error	95% Confidence Interval Lower	Upper
Mean	3.4055	0.1961	3.0421	3.8124
Standard Deviation	2.2041	0.2046	1.8374	2.6439
Median	3.0086	0.1938	2.6518	3.4134
First Quartile	1.7246	0.1622	1.4343	2.0737
Third Quartile	4.6650	0.2704	4.1641	5.2263
Interquartile Range	2.9404	0.2333	2.5170	3.4351

Table B-4

Distribution Function Analysis: Ra-226 background concentration for cinder/fill

Variable: Ra-226 Value < 10 pCi/g

Count 130

Estimation Method: Least Squares (X on Y)
Distribution: Weibull

Parameter Estimates

Parameter	Estimate	Standard Error	95% Confidence Interval Lower	Upper
Shape	1.1287	0.0791	0.9837	1.2951
Scale	2.6497	0.2167	2.2572	3.1104

Goodness-of-Fit
Correlation Coefficient = (0.9875 (Pearson correlation coefficient, r)

Characteristics of Distribution

	Estimate	Standard Error	95% Confidence Limit Lower	Upper
Mean	2.5358	0.1964	2.1787	2.9515
Standard Deviation	2.2510	0.2240	1.8522	2.7357
Median	1.9150	0.1758	1.5996	2.2926
First Quartile	0.8786	0.1140	0.6813	1.1331
Third Quartile	3.5389	0.2744	3.0399	4.1198
Interquartile Range	2.6603	0.2167	2.2678	3.1207

Table B-5

Distribution Function Analysis: Th-232 background concentration for cinder/fill

Variable: Th-232 Value < 5 pCi/g

Count 130

Estimation Method: Least Squares (X on Y)
Distribution: Weibull

Parameter Estimates

Parameter	Estimate	Standard Error	95% Confidence Interval Lower	Upper
Shape	1.8497	0.1034	1.6577	2.0639
Scale	1.4407	0.0724	1.3057	1.5898

Goodness-of-Fit
Correlation Coefficient = (0.9198 (Pearson correlation coefficient, r)

Characteristics of Distribution

	Estimate	Standard Error	95% Confidence Interval Lower	Upper
Mean	1.2797	0.0632	1.1615	1.4098
Standard Deviation	0.7177	0.0412	0.6414	0.8031
Median	1.1817	0.0654	1.0602	1.3173
First Quartile	0.7346	0.0539	0.6362	0.8482
Third Quartile	1.7190	0.0814	1.5666	1.8862
Interquartile Range	0.9844	0.0525	0.8866	1.0929

Table B-6
Distribution Function Analysis: Ra-228 background concentration for cinder/fill

Variable: Ra-228 Value < 5 pCi/g

Count 129 (one value excluded because less than zero)

Estimation Method: Least Squares (X on Y)
Distribution: Weibull

Parameter Estimates

Parameter	Estimate	Standard Error	95% Confidence Interval Lower	Upper
Shape	2.2898	0.1167	2.0721	2.5303
Scale	1.4042	0.0577	1.2955	1.5220

Goodness-of-Fit
Correlation Coefficient = (0.9802 (Pearson correlation coefficient, r)

Characteristics of Distribution

	Estimate	Standard Error	95% Confidence Interval Lower	Upper
Mean	1.2439	0.0515	1.1470	1.3490
Standard Deviation	0.5758	0.0252	0.5285	0.6275
Median	1.1965	0.0546	1.0941	1.3084
First Quartile	0.8149	0.0487	0.7249	0.9161
Third Quartile	1.6194	0.0617	1.5029	1.7450
Interquartile Range	0.8045	0.0342	0.7403	0.8744

Table B-7

Distribution Function Analysis: Th-228 background concentration for cinder/fill

Variable: Th-228 Value < 5 pCi/g

Count 129 (one value excluded because less than zero)

Estimation Method: Least Squares (X on Y)
Distribution: Weibull

Parameter Estimates

Parameter	Estimate	Standard Error	95% Confidence Interval Lower	Upper
Shape	1.8390	0.1071	1.6406	2.0615
Scale	1.4925	0.0756	1.3515	1.6481

Goodness-of-Fit
Correlation Coefficient = (0.9157 (Pearson correlation coefficient, r)

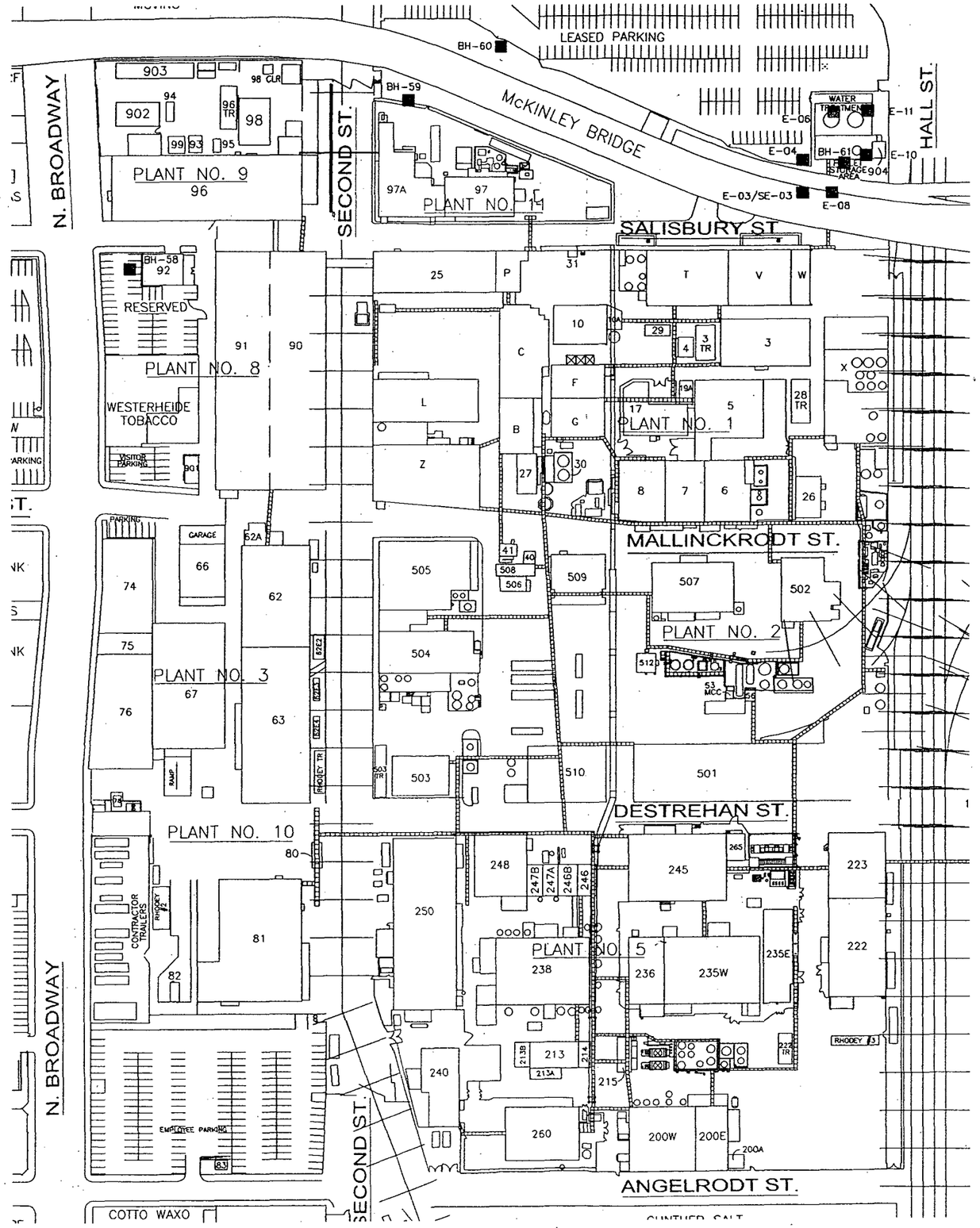
Characteristics of Distribution

	Estimate	Standard Error	95% Confidence Interval Lower	Upper
Mean	1.3259	0.0661	1.2026	1.4619
Standard Deviation	0.7476	0.4510	0.6643	0.8413
Median	1.2228	0.0682	1.0961	1.3641
First Quartile	0.7580	0.0564	0.6552	0.8769
Third Quartile	1.7825	0.0855	1.6226	1.9582
Interquartile Range	1.0245	0.0571	0.9185	1.1428

Table B-8. Estimates of Background Radioactivity Concentration in Cinder/Fill

Radionuclide	Number of Measurements	Mean Concentration[a] (pCi/g)	Standard Deviation[a] (pCi/g)	95% confidence limits[a] (pCi/g)
U-238	130	4.4	2.3	4.1 to 4.9
U-235	n/a	0.2	n/a	n/a
Th-230	130	3.4	2.2	1.8 to 2.6
Ra-226	130	2.5	2.3	1.9 to 2.7
Th-232	130	1.3	0.7	1.2 to 1.4
Ra-228	129	1.2	0.6	1.2 to 1.4
Th-228	129	1.3	0.8	1.2 to 1.5

[a] Derived from the Weibull probability distribution.
The Mean Concentration for U-235 is 0.0455 times U-238; i.e. assumption of natural uranium.



KEY

-Location Identification

TITLE:

Figure B-1
Locations of Background Boreholes
Outside Plant 5

PROJECT C-T Phase 2 DP	DATE: April 2003	DRAWING:	REVISION:
SCALE:	ACAD FILE: BH58_E11.dwg		

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Figure B-2

Characterization Samples of Cinder/Fill

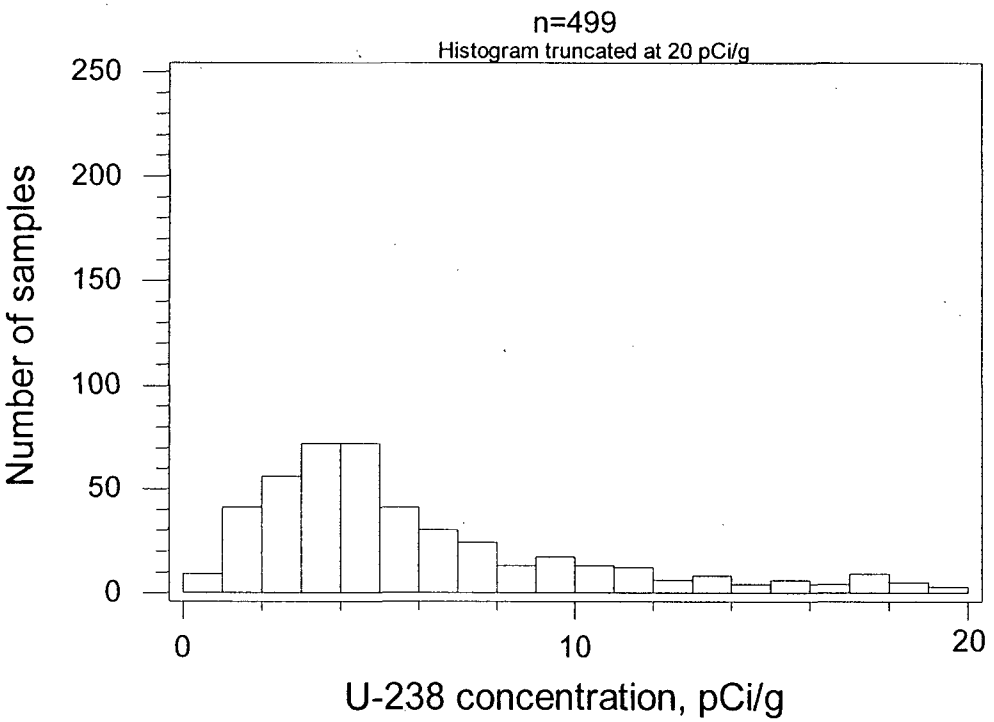


Figure B-3

Characterization Samples of Cinder/Fill

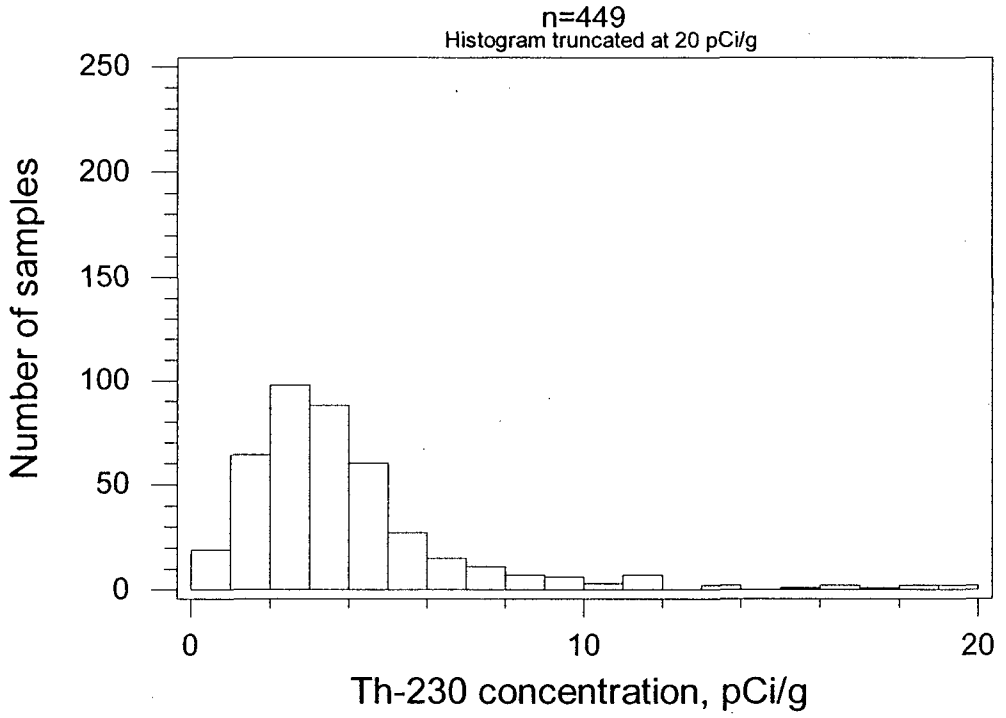


Figure B-4

Characterization Samples of Cinder/Fill

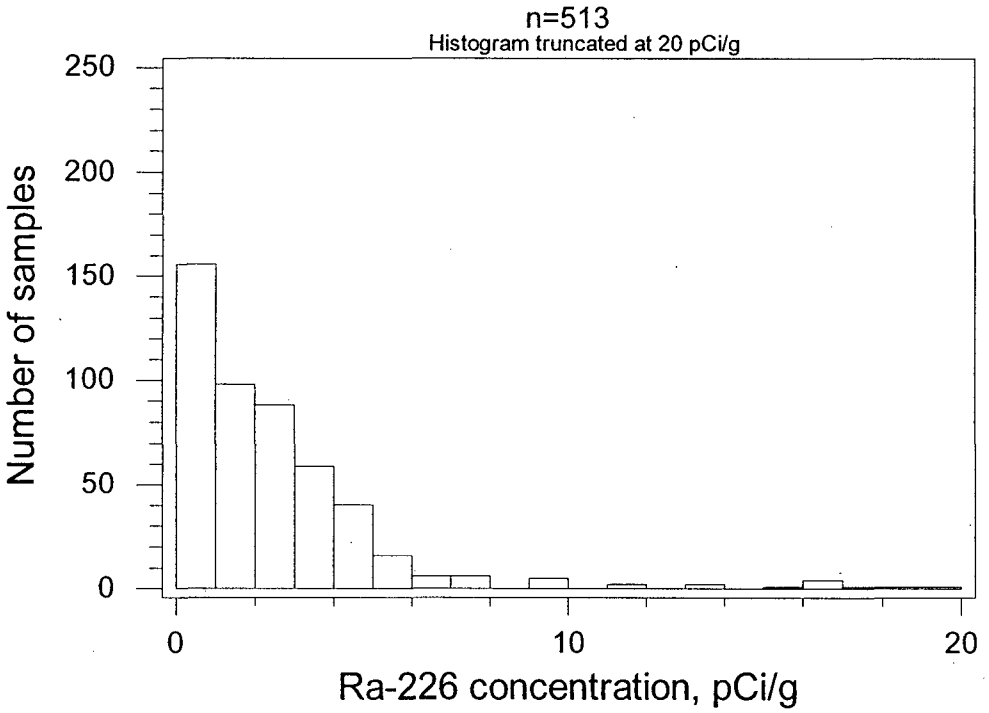


Figure B-5

Characterization Samples of Cinder/Fill

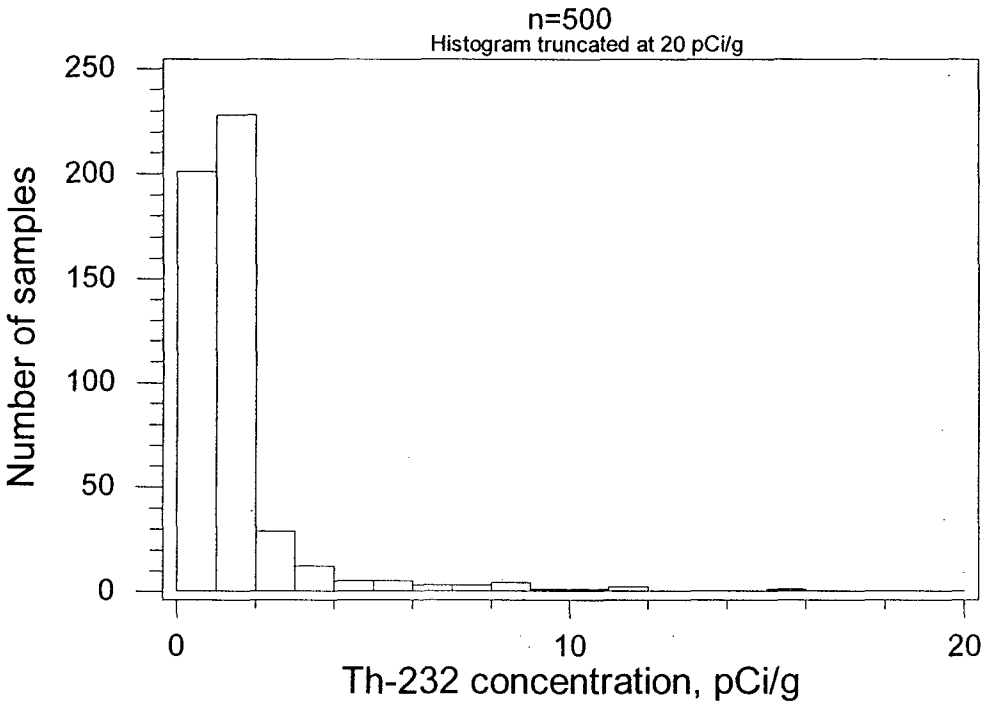


Figure B-6

Characterization Samples of Cinder/Fill

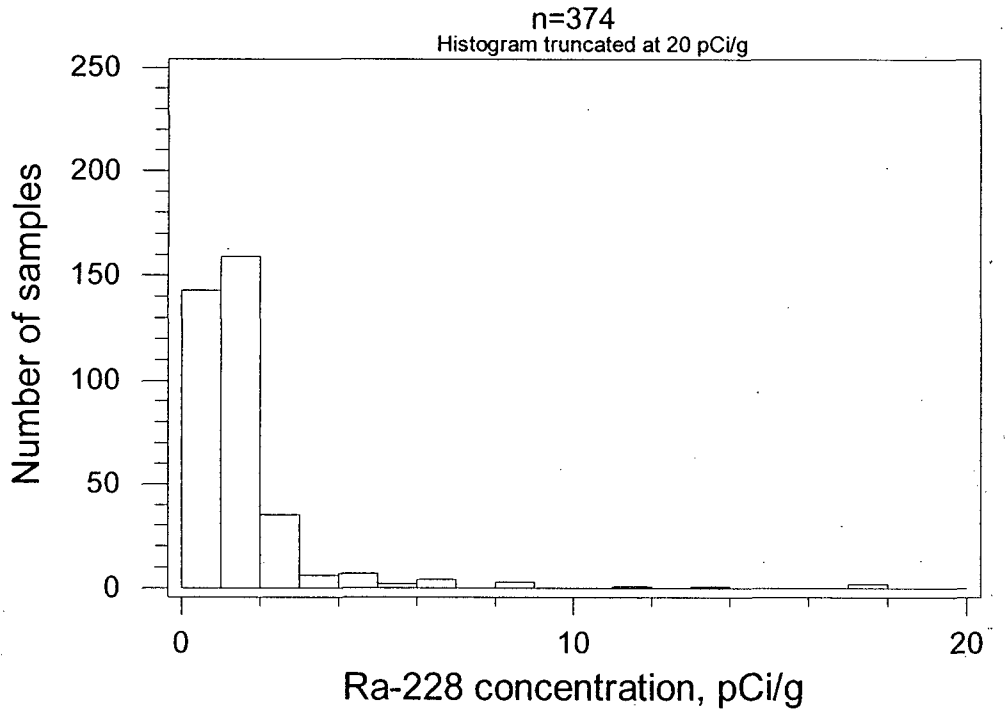
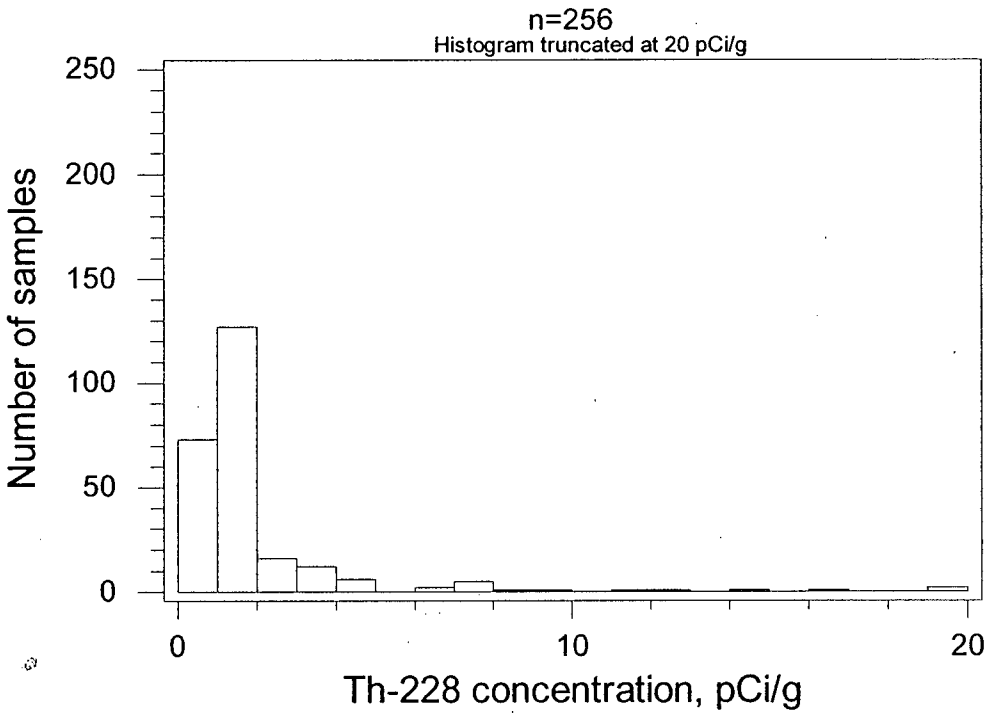
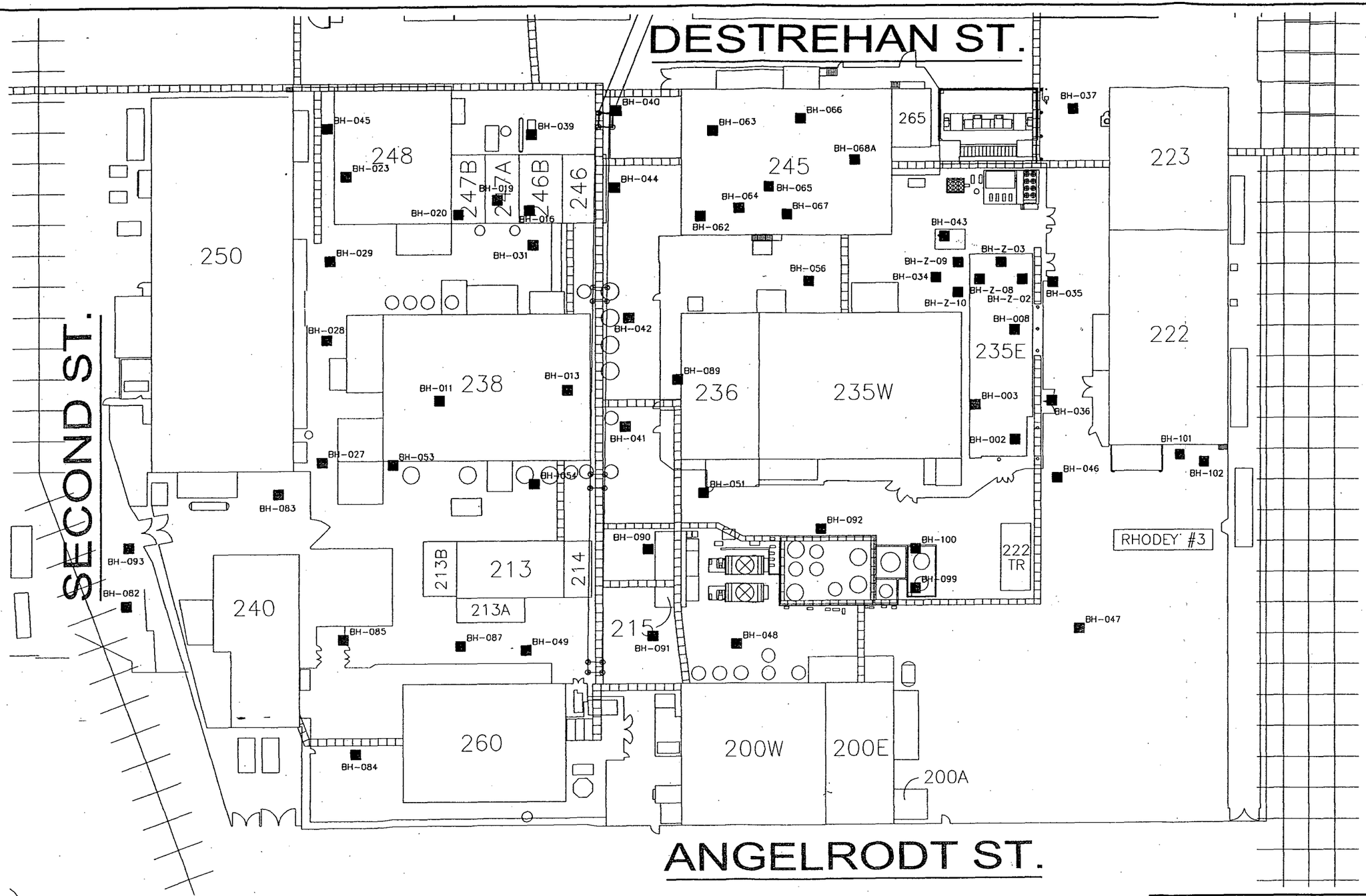


Figure B-7

Characterization Samples of Cinder/Fill





KEY

■ -Location Identification

TITLE:

Figure B-8
Locations of Boreholes Used
in Evaluation of Background

PROJECT: C-T Phase 2 DP	DATE: April 2003	DRAWING:	REVISION:
SCALE:	ACAD FILE: BHPlant5Bkg.dwg		

omega PROJECT SERVICES L.L.C.

Figure B-9

Distribution Analysis: U-238 background concentration for cinder/fill

Weibull Distribution - Least Squares X on Y Estimates - 95% CI

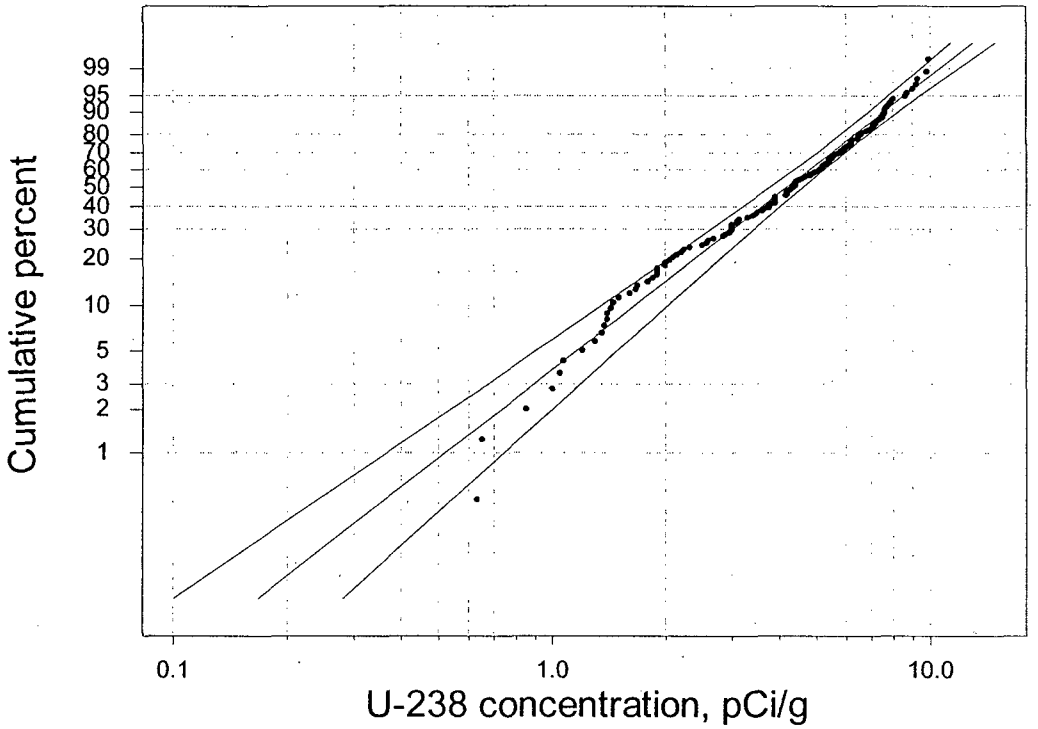


Figure B-10

Distribution Analysis: Th-230 background concentration for cinder/fill

Weibull Distribution - Least Squares X on Y Estimates - 95% CI

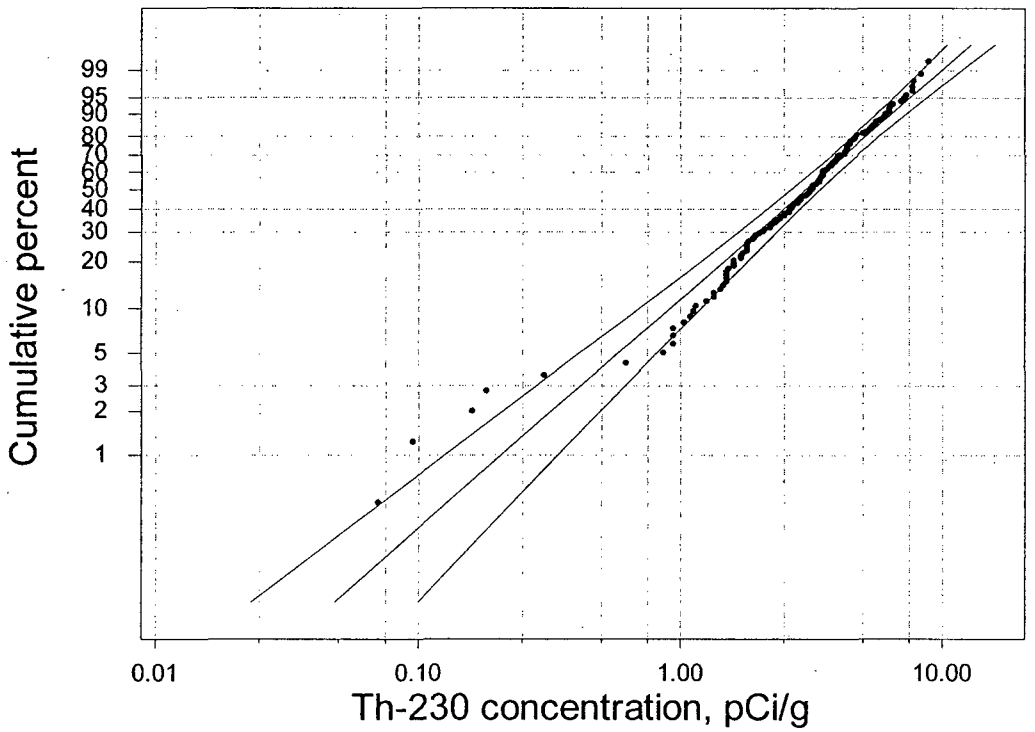


Figure B-11

Distribution Analysis: Ra-226 background concentration for cinder/fill

Weibull Distribution - Least Squares X on Y Estimates - 95% CI

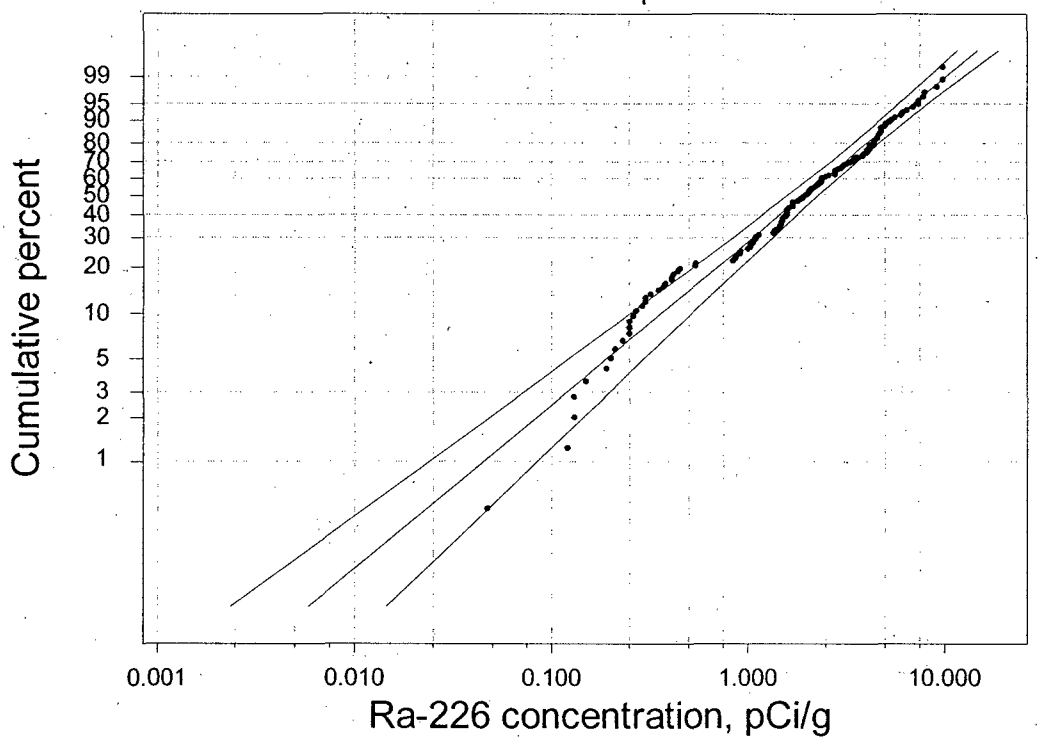


Figure B-12

Distribution Analysis: Th-232 background concentration for cinder/fill

Weibull Distribution - Least Squares X on Y Estimates - 95% CI

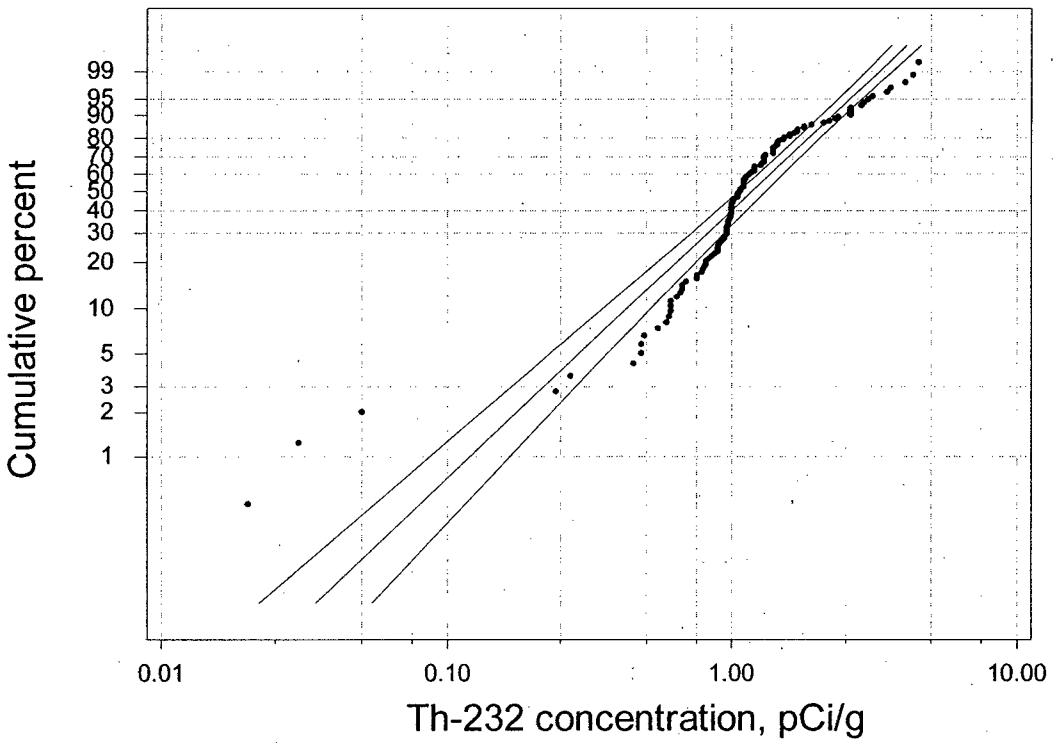


Figure B-13

Distribution Analysis: Ra-228 background concentration for cinder/fill

Weibull Distribution - Least Squares X on Y Estimates - 95% CI

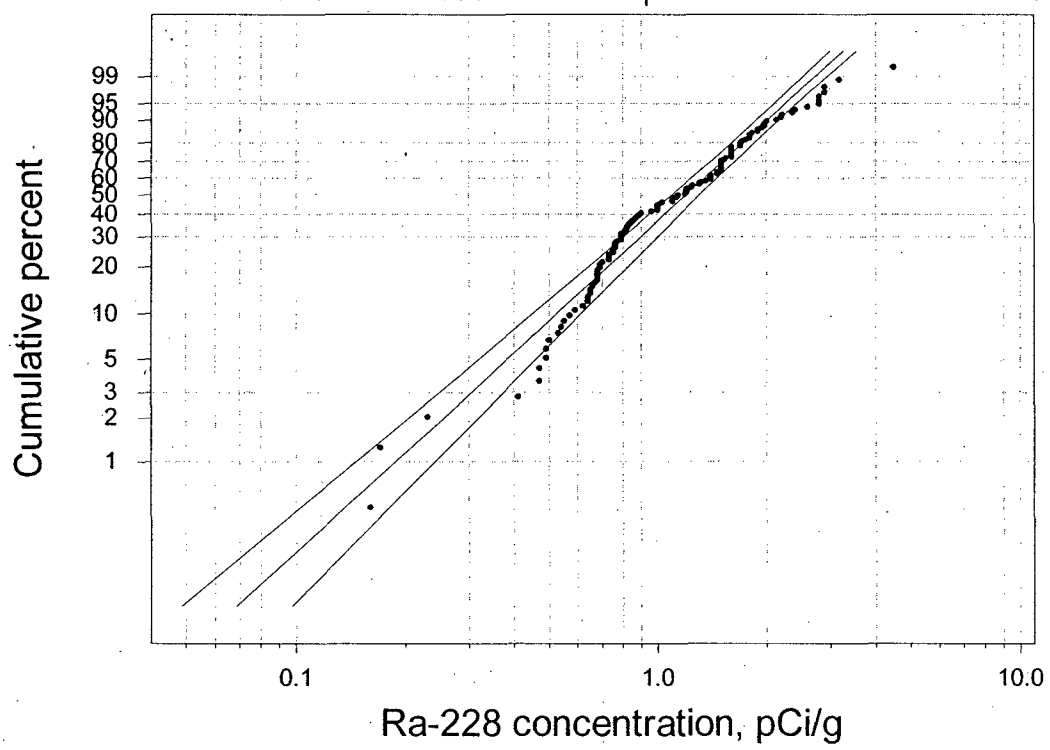
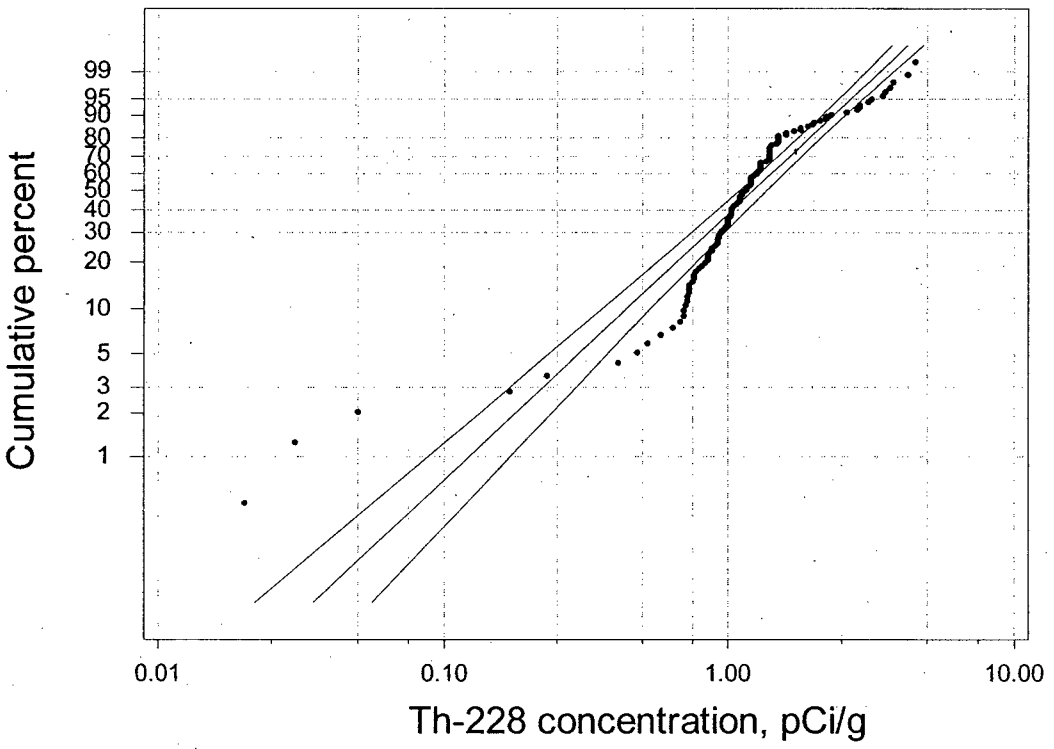


Figure B-14

Distribution Analysis: Th-228 background concentration for cinder/fill

Weibull Distribution - Least Squares X on Y Estimates - 95% CI



APPENDIX C

CALCULATION OF SUM-OF-FRACTIONS OF THE DCGL FOR C-T CHARACTERIZATION SOIL SAMPLES

Mallinckrodt, Inc.

C-T Phase II Decommissioning Plan
May 15, 2003

NRC Docket: 40-06563
NRC License: STB-401

Appendix C

Calculation of Sum-of-fractions of the DCGL for C-T Characterization Soil Samples

A large number of subsurface soil (cinder/fill) samples were collected in the Mallinckrodt Columbium-Tantalum (C-T) Plant 5 area. They were analyzed for various combinations of the radionuclides in the natural uranium series and natural thorium series. Not all sample analyses generated a result for each of the key radionuclides described in Section 4 of this decommissioning plan. In some cases, the concentration of a key radionuclide in one or both series must be estimated in order to fully delineate soils contaminated in excess of the $DCGL_W$ in order to estimate the volume of soil subject to excavation.

C.1 PROBLEM

The Nuclear Regulatory Commission (NRC) provides a radiological dose criterion for release of a licensed facility for unrestricted use. A radionuclide-specific activity concentration may be derived for soil corresponding to the release criterion; *i.e.*, a derived concentration guideline level (DCGL). The DCGL is derived for each long-lived radionuclide considered a contaminant. In the case of a mixture of radionuclides, the release criterion is then evaluated against the unity rule. This is accomplished by determining the fraction of the concentration of each radionuclide in the mixture relative to its DCGL. The unity rule is that the sum of the fractions must be less than or equal to one to satisfy the release criterion.

Some subsurface soils in the C-T Plant 5 area are contaminated with uranium-series and thorium-series radionuclides. Three long-lived radionuclides from each series are being used to delineate the extent of contamination in the Plant 5 area; from the uranium-series: U-238, Th-230, and Ra-226; from the thorium-series: Th-232, Ra-228, and Th-228. Section 5 of this decommissioning plan describes a DCGL for each of these six key radionuclides. Then the extent of contamination in the Plant 5 subsurface soils is determined by application of the sum-of-fractions, *i.e.*, dividing each key radionuclide concentration by its respective $DCGL_W$ and summing the resulting fractions. The sum-of-fractions is an index in which unity represents a condition in which the concentration of a mixture of radionuclides equals the $DCGL_W$.

Some characterization samples of the Plant 5 subsurface soils do not include an analytical result for each of the six key radionuclides. In order to compute a sum-of-fractions and apply the unity rule to these characterization samples, a concentration must be estimated for one or more of the key radionuclides.

C.2 OBJECTIVE

The objective of this appendix is to explain development of a means to estimate the concentration of one or more key radionuclides in a characterization sample given the concentration of other key radionuclides in the sample. The scope of this objective is limited to

the three key radionuclides from each series. The three from the uranium series are U-238, Th-230, and Ra-226; the three from the thorium series are Th-232, Ra-228, and Th-228.

C.3 SOLUTION

The relationship between key radionuclides may be examined to determine a function that would allow the concentration of one key radionuclide to provide for an estimate of the concentration of another key radionuclide. Specifically, the ratios of particular key radionuclide pairs were determined for the set of characterization samples of Plant 5. The resulting ratios were used to estimate the concentration of a key radionuclide in a sample. Once a concentration is available for each key radionuclide of a characterization sample, a calculation can be made of the sum-of-fractions, relative to the release criterion, for that characterization sample.

C.3.1 Description

The data set of characterization samples includes the following characteristics:

a) 221= number of samples for which no estimate of any key radionuclide is needed,
b) 18 = number of samples for which U-238 may be estimated from Th-230,
c) 68 = number of samples for which Th-230 must be estimated from U-238,
d) 4 = number of samples for which Ra-226 must be estimated from U-238,
e) 16 = number of samples for which Th-232 must be estimated: 15 from Ra-228 and 1 from Th-228,
f) 142 = number of samples for which Ra-228 must be estimated: 141from Th-232 and 1 from Th-228, and
g) 261 = number of samples for which Th-228 must be estimated: 245 from Th-232 and 16 from Ra-228.

For each of these characteristics, the key radionuclide concentration pairs, for which both were measured, were gathered and a calculation was made of the respective ratios individually. In each case, the concentration pairs were limited to those pairs for which each key radionuclide concentration was greater than or equal to the upper bound background concentration (see Appendix B). As an example, the characterization sample data set included 46 samples with a U-238 concentration and a Th-230 concentration, each greater than or equal to 10 pCi/g. The data set of characterization samples includes the following characteristics:

h) 46 = number of samples for which U-238 and Th-230 are greater than or equal to 10 pCi/g (see items b and c, above),
i) 22 = number of samples for which U-238 and Ra-226 are greater than or equal to 10 pCi/g (see item d, above),
j) 15 = number of samples for which Th-232 and Ra-228 are greater than or equal to 5 pCi/g (see items e and f, above),
k) 19 = number of samples for which Th-232 and Th-228 are greater than or equal to 5 pCi/g (see item g, above), and

l) 13 = number of samples for which Ra-228 and Th-228 are greater than or equal to 5 pCi/g (see item h, above).

The selection of radionuclide concentration pairs was based solely on which radionuclide concentration was available as a surrogate for every case of another radionuclide concentration not available. For example, regarding item c), for each of the 68 samples missing a Th-230 concentration, a U-238 concentration was available. Then all 68 missing Th-230 concentrations were estimated from the U-238 concentration of the respective sample. In no case was an estimated concentration used to estimate another concentration.

The radionuclide concentration pairs described in items i) through m) are shown in tables C-1 through C-5, respectively. The ratio of the individual pairs is also shown in the respective table.

In order to estimate the central tendency of the ratios among key radionuclides to represent them, a graphical analysis of the frequency of occurrence of the ratios for each of items i) through m) was done. Figures C-1 through C-5 show the probability plots for ratios developed in Tables C-1 through C-5 to be lognormally distributed. Tables C-1 through C-5 also include some statistical properties of the concentration ratios.

C.3.2 Results

The geometric mean of each distribution shown in figures C-1 through C-5 is presented as the best estimate of the ratio of the respective key radionuclides. The mean ratios are summarized as:

- Th-230/U-238 = 1.1 (apply to items b and c, above),
- Ra-226/U-238 = 2.8 (apply to item d, above),
- Ra-228/Th-232 = 1.6 (apply to items e and f, above),
- Th-228/Th-232 = 1.3 (apply to items g, above), and
- Th-228/Ra-228 = 0.8 (apply to items h, above).

Fifteen years since cessation of C-T processing is enough to allow thorium series nuclides to grow or decay within about 0.20 of radioactive equilibrium. Considering uncertainty in alpha spectrometry of separate radioelements at low concentration, the thorium series might rationally be assumed to be in radioactive equilibrium in Plant 5 soil samples.

C.4 CONCLUSION

In samples in which the concentration of a key radionuclide is not available, it was estimated as the product of a concentration of another key radionuclide in that sample and the relevant mean ratio. For example, in the case of a sample without an analytical result for Th-230, the Th-230 concentration will be estimated by multiplying the U-238 concentration in that sample by 1.1. Also, in the case of a sample without an analytical result for U-238, the U-238 concentration will be estimated by multiplying the Th-230 concentration by 1/1.1 (*i.e.*, 0.91). This will allow a best estimate of the sum-of-fractions value to be calculated for each characterization sample.

The results of this appendix were applied to interpretation of characterization data for the purpose of estimating the volume of subsurface soil with radionuclide concentrations that exceed the $DCGL_w$ and may be subject to excavation.

Table C-1. Distribution Analysis: Th-230 / U-238 Concentration Ratio of Subsurface Soil

Count 46

Estimation Method: Least Squares (X on Y)
Distribution: Lognormal base e

Parameter Estimates

Parameter	Estimate	Standard Error	95.00% Lower	Normal CL Upper
Location	0.0613	0.1203	-0.1745	0.2972
Scale	0.8162	0.0861	0.6638	1.0035

Goodness-of-Fit
Correlation Coefficient = 0.9768 (Pearson correlation coefficient, r)

Characteristics of Distribution

	Estimate	Standard Error	95.00% Lower	Normal CL Upper
Mean	1.4835	0.2067	1.1290	1.9493
Standard Deviation	1.4434	0.3552	0.8911	2.3381
Median	1.0633	0.1279	0.8399	1.3461
First Quartile	0.6131	0.0819	0.4719	0.7967
Third Quartile	1.8438	0.2463	1.4190	2.3957
Interquartile Range	1.2307	0.2056	0.8870	1.7074

	Sample Depth (ft)		Radionuclide Concentration		
Location ID	Top	Bottom	U-238 (pCi/g)	Th-230 (pCi/g)	Th-230 / U-238
BH-010	0	2.5	21.5	262	12.1860
BH-010	0	4.5	20	18	0.9000
BH-011	0	9.5	30.4	24.8	0.8158
BH-012	0	5.5	10.4	24.3	2.3365
BH-012	0	9.5	10	16.3	1.6300
BH-014	0	4.5	28.7	20.2	0.7038
BH-015	0	5.5	16.3	98.8	6.0613
BH-015	0	9.5	71.7	261.9	3.6527
BH-021	0	2.5	16.6	10.4	0.6265
BH-022	0	5.5	34.8	54.3	1.5603
BH-022	0	9.5	13	17.3	1.3308
BH-026	0	4.5	17.8	24.9	1.3989
BH-029	0	2.5	53.4	16.9	0.3165

(continued next page)

Table C-1 (continued)

	Sample Depth (ft)		Radionuclide Concentration		
Location ID	Top	Bottom	U-238 (pCi/g)	Th-230 (pCi/g)	Th-230 / U-238
BH-038	0	1	56.9	138.6	2.4359
BH-038	0	6.5	10.3	22.4	2.1748
BH-039	0	1.5	29.7	23.3	0.7845
BH-041	0	3.5	17.5	61.5	3.5143
BH-042	0	1	11.1	32	2.8829
BH-052	0	4	28.5	29.4	1.0316
BH-054	0	1.5	30.8	25.2	0.8182
BH-066	0	1.5	66.01	77.9	1.1801
BH-083	0.5	1.5	23.9	24.4	1.0209
BH-087	1	1.5	31.6	13.3	0.4209
BH-088	3	4.5	18.8	11.7	0.6223
BH-091	12	13.5	36.5	28	0.7671
BH-092	12	13.5	18	10.8	0.6000
BH-112	0	2	26.54	11.5	0.4333
BH-114	0	2	19.17	10.03	0.5232
BH-114	2	4	36.74	30.43	0.8283
BH-Z-22	0	3	11.48	11.14	0.9704
JA-01	0	5	216.06	43.72	0.2024
JA-02	0	1	89.96	60.72	0.6750
JA-03	0	1	28.39	41.14	1.4491
JA-04	0	1	33.46	79.74	2.3831
JA-05	0	1	26.87	50.32	1.8727
JA-06	0	1	36.27	53.73	1.4814
JA-07	0	1	51.91	60.64	1.1682
JA-08	0	1	33.08	32.39	0.9791
JA-09	0	1	69.76	50.47	0.7235
JA-10	0	1	70.7	81.27	1.1495
JA-11	0	1	172.48	123.1	0.7137
JA-12	0	1	166.5	19.3	0.1159
JA-17A	0	3	14.5	19.6	1.3517

Table C-2. Distribution Analysis: Ra-226 / U-238 Concentration Ratio of Subsurface Soil

Count 22

Estimation Method: Least Squares (X on Y)
Distribution: Lognormal base e

Parameter Estimates

Parameter	Estimate	Standard Error	95.00% Lower	Normal CL Upper
Location	1.0135	0.3429	0.3414	1.6855
Scale	1.6082	0.2620	1.1687	2.2131

Goodness-of-Fit
Correlation Coefficient = 0.9922 (Pearson correlation coefficient, r)

Characteristics of Distribution

	Estimate	Standard Error	95.00% Lower	Normal CL Upper
Mean	10.0405	5.4538	3.4626	29.1145
Standard Deviation	35.1865	33.1290	5.5584	222.7429
Median	2.7551	0.9446	1.4070	5.3950
First Quartile	0.9312	0.3592	0.4372	1.9832
Third Quartile	8.1513	3.1441	3.8274	17.3601
Interquartile Range	7.2201	2.9502	3.2414	16.0825

	Sample Depth (ft)		Radionuclide Concentration		
Location ID	Top	Bottom	U-238 (pCi/g)	Ra-226 (pCi/g)	Ra-226 / U-238
BH-010	0	2.5	21.5	239.3	11.1302
BH-010	0	4.5	20	31.8	1.5900
BH-011	0	9.5	30.4	40.4	1.3289
BH-012	0	5.5	10.4	250.2	24.0577
BH-012	0	9.5	10	208.7	20.8700
BH-014	0	4.5	28.7	16.4	0.5714
BH-015	0	5.5	16.3	327.4	20.0859
BH-015	0	9.5	71.7	744.6	10.3849
BH-015	0	11.5	210	667	3.1762
BH-026	0	4.5	17.8	21.9	1.2303
BH-038	0	1	56.9	16.7	0.2935
BH-039	0	1.5	29.7	21.1	0.7104
BH-043	0	2.5	10.2	24.8	2.4314
BH-052	0	4	28.5	1511	53.0175
BH-054	0	1.5	30.8	192	6.2338
BH-055	0	15	18.7	60.7	3.2460
BH-090	12	13.5	18	11.1	0.6167
BH-091	12	13.5	36.5	24.3	0.6658
JA-02	0	1	89.96	13.44	0.1494
JA-03	0	1	28.39	28.08	0.9891
JA-04	0	1	33.46	132.8	3.9689
JA-06	0	1	36.27	242.7	6.6915

Table C-3. Distribution Analysis: Ra-228 / Th-232 Concentration Ratio of Subsurface Soil

Count 15

Estimation Method: Least Squares (X on Y)
Distribution: Lognormal base e

Parameter Estimates

Parameter	Estimate	Standard Error	95.00% Lower	Normal CL Upper
Location	0.5006	0.1732	0.1612	0.8400
Scale	0.6707	0.1348	0.4523	0.9946

Goodness-of-Fit
Correlation Coefficient = 0.9817 (Pearson correlation coefficient, r)

Characteristics of Distribution

	Estimate	Standard Error	95.00% Lower	Normal CL Upper
Mean	2.0658	0.4036	1.4087	3.0296
Standard Deviation	1.5570	0.5941	0.7370	3.2893
Median	1.6498	0.2857	1.1749	2.3164
First Quartile	1.0494	0.2053	0.7153	1.5397
Third Quartile	2.5935	0.5073	1.7676	3.8051
Interquartile Range	1.5440	0.4257	0.8994	2.6506

	Sample Depth (ft)		Radionuclide Concentration		
Location ID	Top	Bottom	Th-232 (pCi/g)	Ra-228 (pCi/g)	Ra-228 / Th-232
BH-009	0	2.5	5.5	6.3	1.1455
BH-010	0	2.5	51.1	81.5	1.5949
BH-010A	0	6.5	10.8	28.2	2.6111
BH-011	0	3.5	25.9	47.4	1.8301
BH-011	0	9.5	15.3	33.3	2.1765
BH-012	0	5.5	33.8	40.3	1.1923
BH-012	0	9.5	8.3	23	2.7711
BH-012	0	11.5	5.95	5.99	1.0067
BH-014	0	4.5	11.9	8.5	0.7143
BH-015	0	5.5	11.1	78	7.0270
BH-015	0	9.5	48.2	193.3	4.0104
BH-020	0	9.5	9.4	11.3	1.2021
BH-031	0	9	6.86	6.97	1.0160
BH-052	0	4	7	13.3	1.9000
BH-086	6	7.5	27.5	17	0.6182

Table C-4. Distribution Analysis: Th-228 / Th-232 Concentration Ratio of Subsurface Soil

Count 19

Estimation Method: Least Squares (X on Y)
Distribution: Lognormal base e

Parameter Estimates

Parameter	Estimate	Standard Error	95.00% Lower	Normal CL Upper
Location	0.22483	0.07084	0.08599	0.36367
Scale	0.30878	0.04775	0.22805	0.41809

Goodness-of-Fit
Correlation Coefficient = 0.9065 (Pearson correlation coefficient, r)

Characteristics of Distribution

	Estimate	Standard Error	95.00% Lower	Normal CL Upper
Mean	1.3132	0.0950	1.1396	1.5133
Standard Deviation	0.4154	0.0791	0.2859	0.6034
Median	1.2521	0.0887	1.0898	1.4386
First Quartile	1.0167	0.0791	0.8729	1.1842
Third Quartile	1.5420	0.1200	1.3239	1.7961
Interquartile Range	0.5253	0.0904	0.3749	0.7361

	Sample Depth (ft)		Radionuclide Concentration		
Location ID	Top	Bottom	Th-232 (pCi/g)	Th-228 (pCi/g)	Th-228 / Th-232
BH-009	0	2.5	5.5	6.4	1.1636
BH-010	0	2.5	51.1	64.6	1.2642
BH-010A	0	6.5	10.8	14.2	1.3148
BH-011	0	3.5	25.9	28.1	1.0849
BH-011	0	9.5	15.3	19.3	1.2614
BH-012	0	5.5	33.8	38.3	1.1331
BH-012	0	9.5	8.3	12.5	1.5060
BH-014	0	4.5	11.9	16.9	1.4202
BH-015	0	5.5	11.1	32	2.8829
BH-015	0	9.5	48.2	60.9	1.2635
BH-020	0	9.5	9.4	8.3	0.8830
BH-052	0	4	7	19	2.7143
BH-086	3	4.5	8.6	7.9	0.9186
BH-086	6	7.5	27.5	29.2	1.0618
BH-088	6	7.5	7.4	6.7	0.9054
BH-091	12	13.5	7.7	7.3	0.9481
BH-099	0	3	6.49	7.06	1.0878
BH-100	3	6	6.12	9.04	1.4771
BH-101	0	3	8.15	7.75	0.9509

Table C-5. Distribution Analysis: Th-228 / Ra-228 Concentration Ratio of Subsurface Soil

Count 13

Estimation Method: Least Squares (X on Y)
Distribution: Lognormal base e

Parameter Estimates

Parameter	Estimate	Standard Error	95.00% Lower	Normal CL Upper
Location	-0.2616	0.1601	-0.5754	0.0521
Scale	0.5772	0.1282	0.3735	0.8920

Goodness-of-Fit
Correlation Coefficient = 0.9883 (Pearson correlation coefficient, r)

Characteristics of Distribution

	Estimate	Standard Error	95.00% Lower	Normal CL Upper
Mean	0.9093	0.1604	0.6436	1.2848
Standard Deviation	0.5718	0.2123	0.2761	1.1840
Median	0.7698	0.1232	0.5625	1.0535
First Quartile	0.5215	0.0949	0.3651	0.7450
Third Quartile	1.1362	0.2067	0.7954	1.6230
Interquartile Range	0.6146	0.1738	0.3531	1.0700

	Sample Depth (ft)		Radionuclide Concentration		
Location ID	Top	Bottom	Ra-228 (pCi/g)	Th-228 (pCi/g)	Th-228 / Ra-228
BH-009	0	2.5	6.3	6.4	1.0159
BH-010	0	2.5	81.5	64.6	0.7926
BH-010A	0	6.5	28.2	14.2	0.5035
BH-011	0	3.5	47.4	28.1	0.5928
BH-011	0	9.5	33.3	19.3	0.5796
BH-012	0	5.5	40.3	38.3	0.9504
BH-012	0	9.5	23	12.5	0.5435
BH-014	0	4.5	8.5	16.9	1.9882
BH-015	0	5.5	78	32	0.4103
BH-015	0	9.5	193.3	60.9	0.3151
BH-020	0	9.5	11.3	8.3	0.7345
BH-052	0	4	13.3	19	1.4286
BH-086	6	7.5	17	29.2	1.7176

Figure C-1

Distribution Analysis: Th-230 / U-238 concentration ratio of cinder/fill

Lognormal base e Distribution - Least Squares X on Y Estimates - 95.0% CI

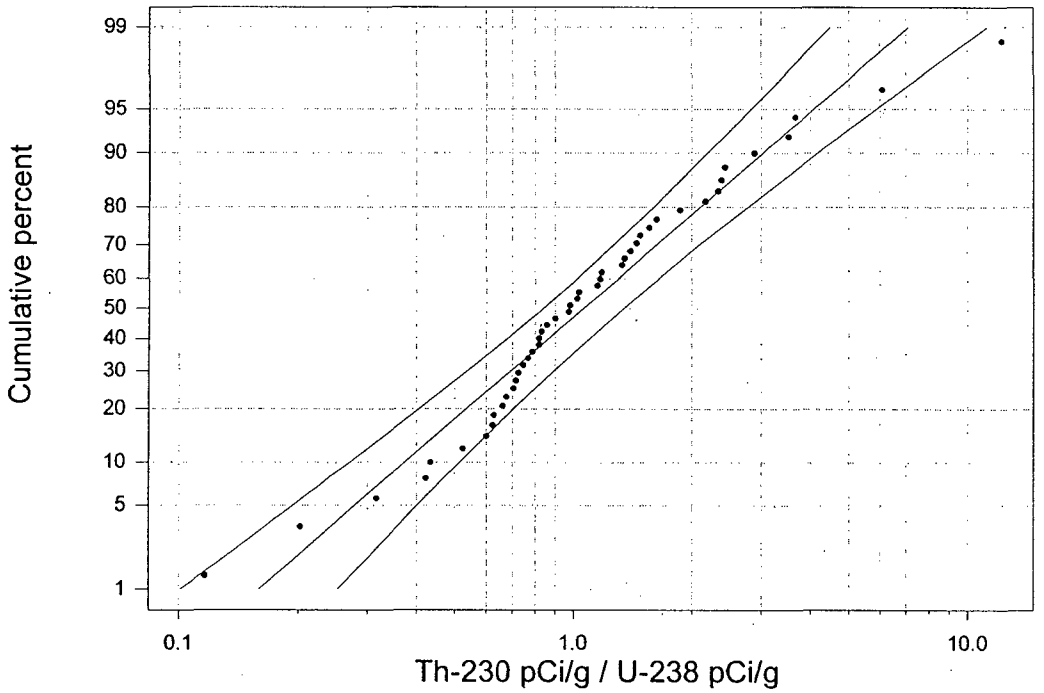


Figure C-2

Distribution Analysis: Ra-226 / U-238 concentration ratio of cinder/fill

Lognormal base e Distribution - Least Squares X on Y Estimates - 95.0% CI

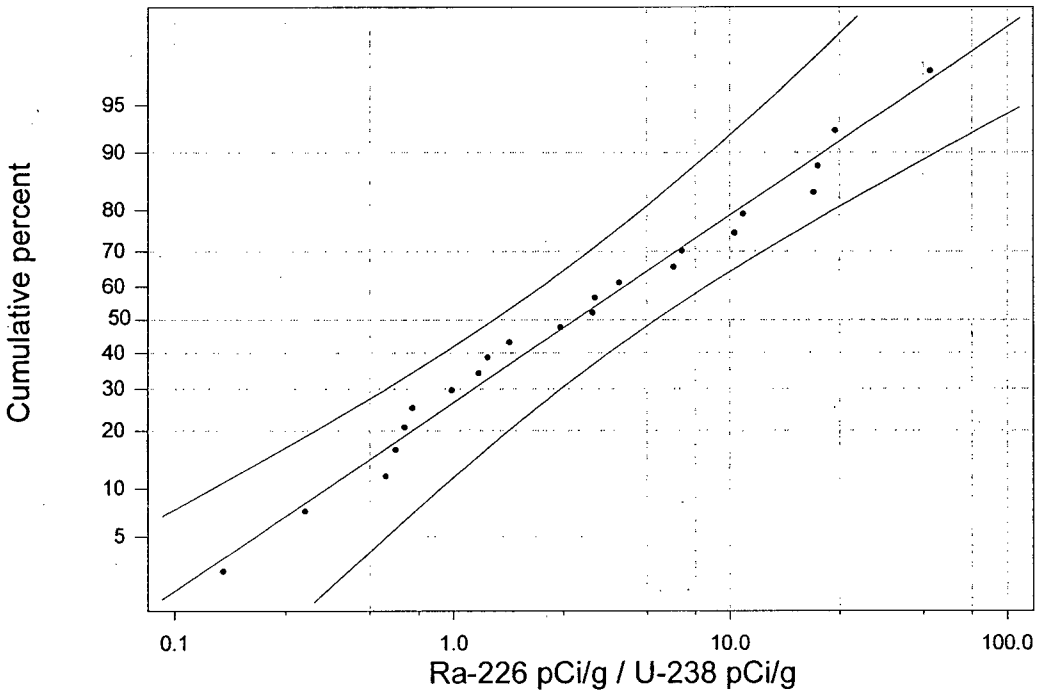


Figure C-3

Distribution Analysis: Ra-228 / Th-232 concentration ratio of cinder/fill

Lognormal base e Distribution - Least Squares X on Y Estimates - 95.0% CI

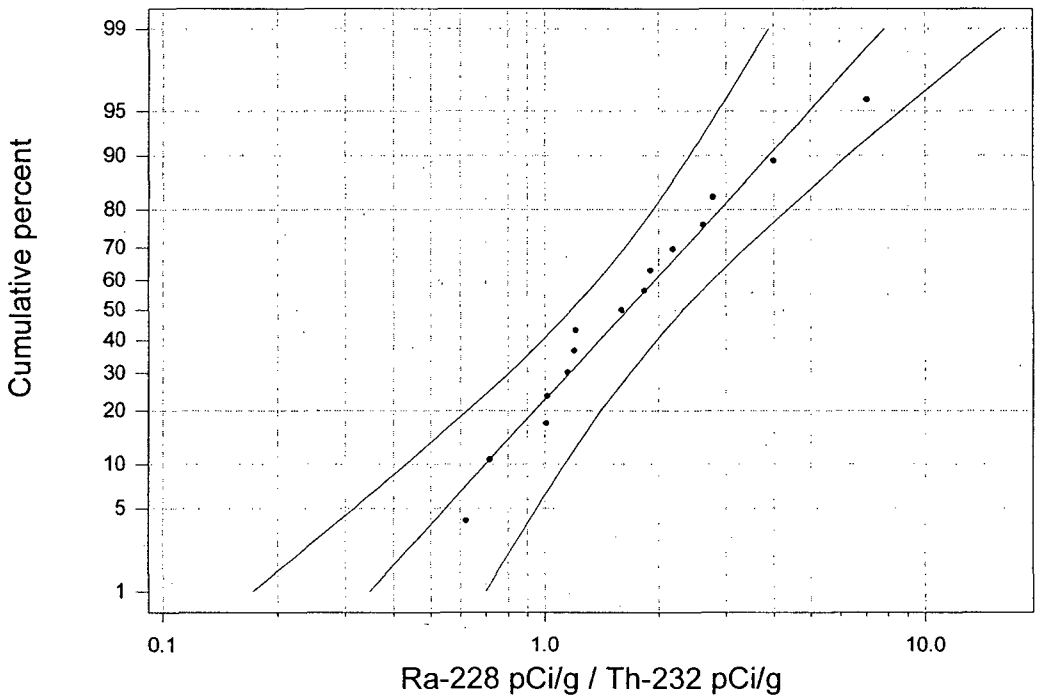


Figure C-4

Distribution Analysis: Th-228 / Th-232 concentration ratio of cinder/fill

Lognormal base e Distribution - Least Squares X on Y Estimates - 95.0% CI

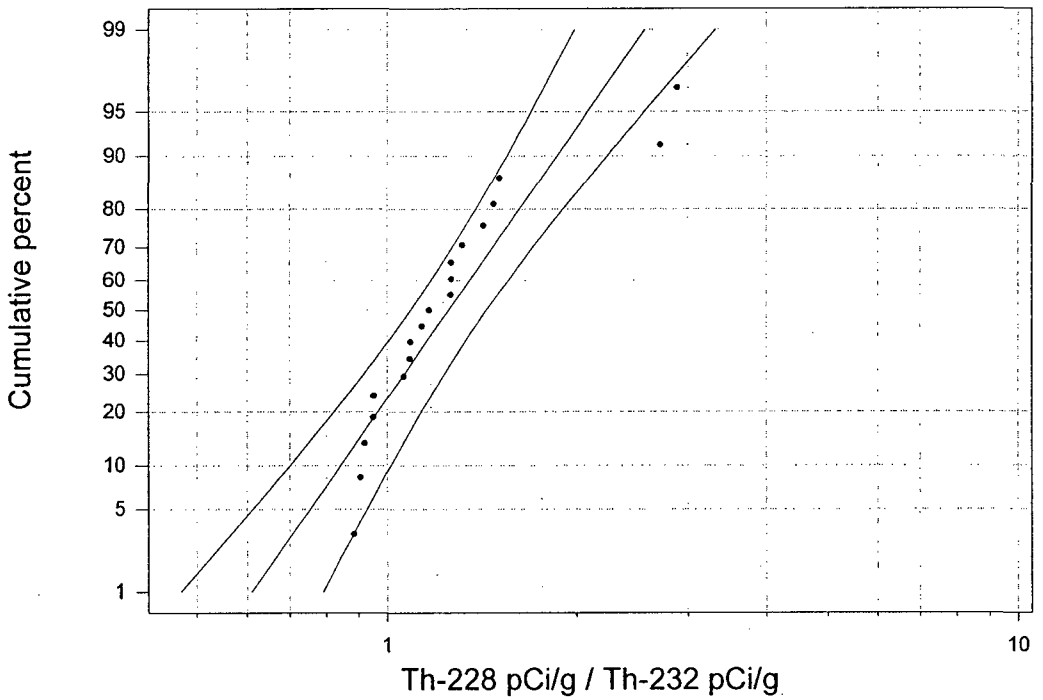
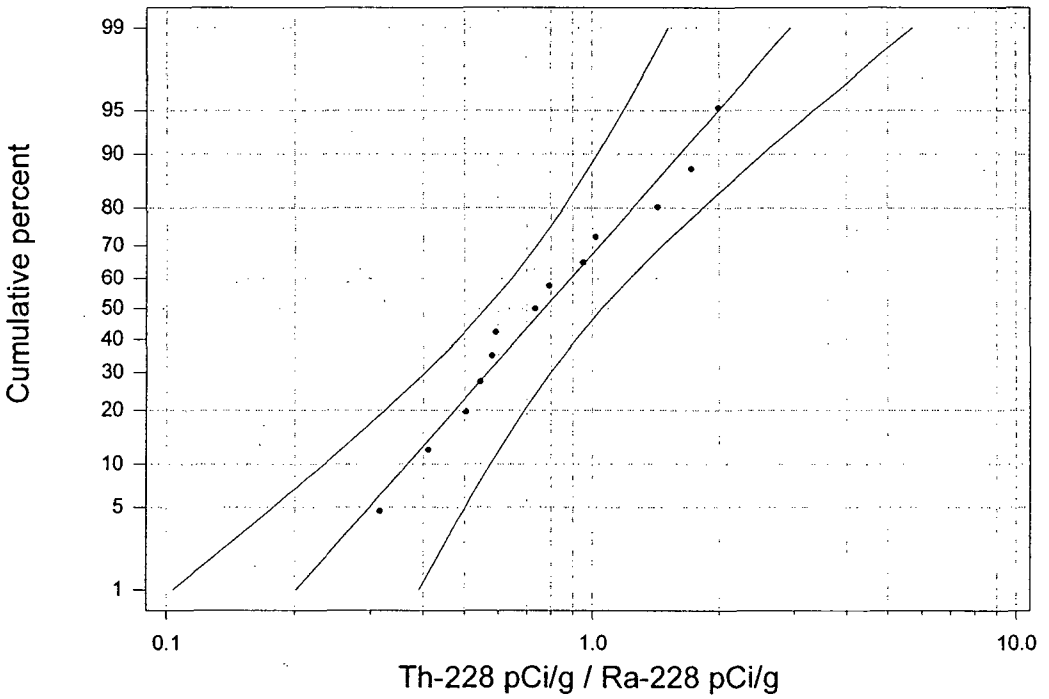


Figure C-5

Distribution Analysis: Th-228 / Ra-228 concentration ratio of cinder/fill

Lognormal base e Distribution - Least Squares X on Y Estimates - 95.0% CI



APPENDIX D

PROBABILISTIC DERIVATION OF RADIOLOGICAL DOSE FACTORS AND $DCGL_W$ APPLICABLE IN C-T SOIL

Mallinckrodt, Inc.

C-T Phase II Decommissioning Plan
August 8, 2008

NRC Docket: 40-06563
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APPENDIX D

PROBABILISTIC DERIVATION OF RADIOLOGICAL DOSE FACTORS AND DCGLw APPLICABLE IN C-T SOIL

1. INTRODUCTION

In its proposed C-T Phase II Decommissioning Plan, Mallinckrodt included a chapter 5, Dose Modeling, describing derivation of radiological dose factors and Derived Concentration Guideline Levels (DCGL). They were derived with the aid of the RESRAD computer code. Commenting on Mallinckrodt's derivation of proposed radiological dose factors and DCGLw applicable to soil, Boby Eid suggested that Mallinckrodt derive them by probabilistic modeling. This report describes such a derivation of dose factors[1] and DCGLw with probabilistic treatment of parameters described in written response to comments by NRC staff.[2]

Derivation of DCGL and assessment of compliance requires integral planning including radionuclides to be measured and tested for compliance. Measurement of key radionuclides by a single method, gamma spectrometry, would be desirable. Otherwise, measurement of Th^{230} would have to be done separately, would be slower than by gamma spectrometry, would introduce additional uncertainty, and would slow remediation prominently. It would be worthwhile to determine conditions and establish specifications under which assessment of compliance can be assured without need to measure Th^{230} routinely during remediation and final status survey. This will involve evaluation of the effect of Th^{230} on radiological dose relative to an associated radionuclide that is measured. Corresponding dose factors from which DCGL are derived are the convenient parameter for analysis.

Another objective will be to explain the methodology of DCGLw derivation and implementation clearly.

2. RADIONUCLIDE SOURCE DISTRIBUTION

Historical assessment and characterization surveys have described the radionuclides of interest and their relative concentrations.[3] Radionuclides include the uranium series, the actinium series in naturally-occurring proportion to the uranium series, and the thorium series. More than 500 soil samples were analyzed for key, long-lived, uranium and thorium series radionuclides during soil characterization survey in Plant 5 . Results are tabulated in CT 2 DP, §4 Radiological Status of Facility.

The ratio of uranium in the U series -to- thorium in the Th series has been observed to be commonly in the range of 2 to 3 in the C-T residual source in Plant 5.

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1 Dose factor = annual radiological dose (mrem/yr) per unit source per gram of soil (pCi/g)
2 Mallinckrodt response items 41 thru 44 to NRC RAI set 1, EPAD Queries.
3 Mallinckrodt C-T Phase II Decommissioning Plan. §4 Radiological Status of Facility.

Relative proportions, or concentrations, of key radionuclides in the U series and in the Th series[4] have been estimated from characterization survey data that are above background.[5] The geometric mean ratios of each distribution of key radionuclides in those data are:

Th-230/U-238 = 1.1
Ra-226/U-238 = 2.8
Ra-228/Th-232 = 1.6
Th-228/Th-232 = 1.3
Th-228/Ra-228 = 0.8
Th-230/Ra226 = 0.66

Uranium Series. As expected, U^{238} and U^{234}, representing the uranium series are measured in approximately equal radioactivity concentration. The actinium series, *i.e.*, U^{235} series, is measured in approximately naturally-occurring proportion to the uranium series. It would be logical to assume U^{238} through U^{234} radionuclides are in radioactive equilibrium and that the actinium series exists in the naturally-occurring ratio to uranium in the uranium series.

Thorium Series. Now, more than fifteen years after cessation of C-T processing, thorium series nuclides are expected to have grown or decayed within about 0.20 of radioactive equilibrium. Considering that C-T feed was ore and that alpha spectrometry of separate radioelements poses some uncertainty at low concentration, the thorium series might rationally be assumed to be in radioactive equilibrium in Plant 5 soil samples. Characterization survey data also suggest an assumption of equilibrium is reasonable. The thorium series will be assumed to be in radioactive equilibrium.

Uranium-to-Thorium. The characterization survey data suggest that a reasonably representative range of source terms would be U -to- Th ratio of approximately 3, with U isotopes in radioactive equilibrium, with Th series in radioactive equilibrium, and with a range of excess Ra^{226}.

Th^{230} -to- Ra^{226}. Among about 600 soil characterization samples collected in Plant 5, more than 500 pairs of Th^{230} and Ra^{226} measurements exist. Among those pairs were 41 pairs containing Th^{230} and Ra^{226} more than 1 standard deviation above mean background concentration. The geometric mean Th^{230} -to- Ra^{226} ratio among those 41 samples is 0.66. Among the 500 pairs, only 3 samples, or 0.006 of samples, exhibit $Th^{230}/Ra^{226} > 6$. Thus, occurrence of Th^{230} -to- Ra^{226} >6 in future sampling would be highly unlikely.

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4 Key radionuclides are those radionuclides, each of whose radioactive half-life is greater than 180 days and whose progeny down to the next radionuclide in the series whose radioactive half-life is also greater than 180 days are assumed in secular equilibrium with their parent key radionuclide.

5 Mallinckrodt. CT II DP. apx C.

3. DOSE MODELING

3.1. METHOD

At the suggestion of NRC staff, Boby Eid, probabilistic modeling to derive radiological dose factors and DCGL has been done.

NRC guidance also interprets, "For probabilistic analyses, the peak of the plot of mean dose over time should be compared with the regulatory standard to determine compliance." ... "Essentially a mean dose is determined at each discrete time in the analysis. A plot is then made of these means over time. The mean dose provides the "best estimate" of dose at each discrete time. The overall peak of these best estimates is then used to determine compliance with the rule." [6] With the aid of RESRAD, probabilistic modeling has been done to derive dose factors and DCGL at the *peak of the mean* dose as the guidance suggests.[7]

RESRAD is able to compute and tabulate the time of peak mean dose rate and the peak mean dose rate (mrem/yr). With that information in the probabilistic total dose summary, one can read the contribution by each long-lived radionuclide entered in the source term column corresponding to the time of peak mean dose. The *average (avg)* dose of each source radionuclide at the time of peak mean dose, summed over all of the source radionuclides, equals the peak of the mean dose. Having identified the contribution of each source radionuclide to the peak of the mean total dose, one may derive an appropriate probabilistic dose factor (mrem/yr per pCi/g) as the quotient of the average dose of each source radionuclide at the time of peak mean total dose and the concentration of that radionuclide entered into the source term in RESRAD.

One may derive a composite dose factor for a related series of radionuclides by summing the average dose of each source radionuclide in the series at the time of the peak of the mean dose. Then derive the dose factor as the quotient of that sum and the concentration of the radionuclides to which it is referenced. For example, the composite dose factor of the thorium series would be the sum of doses of the principal radionuclides, including their short-lived progeny, at the time of the peak of the mean dose divided by the initial concentration of the reference, or parent Th^{232}.

Within the range of relative radionuclide concentrations, or spectrum, reasonably expected to be encountered and in question of remediation, the time of peak mean dose was determined by RESRAD probabilistic simulations.

In order to derive the appropriate dose factors, probabilistic simulations were computed across a range of radionuclide source terms encompassing a reasonably representative spectrum of radionuclides expected in Plant 5. Parameters mentioned in §4 herein were described probabilistically.

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[6] NRC. *NMSS Decommissioning Standard Review Plan.* NUREG-1727. apx C, §8.3.2.2, p. C116.
[7] NUREG-1757, 2, §5.

3.2. PARAMETERS TREATED PROBABILISTICALLY

In an NRC Request for Additional Information (RAI) concerning C-T Phase II DP, set 1, "EPAD Queries," included suggestion that certain variables could be better represented as a variable with a distribution:

- Thickness of the contaminated zone,
- Mass loading for inhalation factor,
- Indoor gamma shielding factor, and
- Occupancy time.

At the same time, EPAD commentary about occupancy time did find Mallinckrodt's proposed allocation of occupancy time to be acceptable.

Mallinckrodt's examination and development of probabilistic distribution of these parameters appears in Mallinckrodt's responses to the NRC RAI set 1. Therein, Mallinckrodt proposed:

- To assume a one-meter-thick contaminated zone,
- A probabilistic distribution of the mass loading for inhalation factor,
- A probabilistic distribution of the indoor gamma shielding factor, and
- 0.2 of 2000 hr/yr out-of-doors onsite and 0.8 of 2000 hr/yr indoors onsite, which EPAD comments found acceptable.

Probability distributions of these variables are discussed in Attachment A herein..

NRC staff suggested that the probable distribution of indoor concrete thickness include some fraction of thin and of zero thickness concrete. The original distribution has been revised to include some thin and zero thickness concrete, such that now an industrial worker is assumed to be exposed to bare ground 0.24 of exposure time overall and through a 3-inch, thin concrete floor another 0.056 of the time. This is reflected in the probability distribution of indoor gamma shielding factor discussed in Attachment A and illustrated in Figure A3.

A relevant association is that, in plant areas subject to the FUSRAP, with remediation performed by the USACE, radioactivity concentration limit in soil, and radiological dose modeling are being done on the premise that the land will be covered with at least six inches of pavement, gravel, or imported soil, thereby attenuating some of the gamma radiation emanating from soil.

4. COMPLIANCE MODEL

In the uranium series, U^{238} through U^{234} will be assumed to be in radioactive equilibrium and will be represented by measurement of uranium isotope(s) or surrogate progeny. The actinium (U^{235}) series will be assumed to exist in its naturally-occurring proportion to the uranium series.

Radium-226 and its progeny, including Pb^{210}, will be assumed to be in radioactive equilibrium and will be referenced to measured Ra^{226} concentration. Th^{230} will be associated with Ra^{226} and Pb^{210} because the Ra^{226}, to which it decays, presents the dominant dose factor.

Thorium series radionuclides will be assumed to be in radioactive equilibrium and will be represented by measurement of a surrogate radionuclide, Ac^{228}, in the series.

Radiological **dose factors** of individual radionuclides in each subseries may then be composited and stated simply as

$$DF_U = [D(U^{238}) + D(U^{234}) + D(U^{235} + Ac^{227} + Pa^{231})] \div C(U^{238})$$

$$DF_{Ra226\ \&\ Th230} = [D(Ra^{226}) + D(Pb^{210}) + D(Th^{230}{=}6 \cdot Ra^{226})] \div C(Ra^{226})$$

$$DF_{Th\ series} = [D(Th^{232}) + D(Ra^{228}) + D(Th^{228})] \div C(Th^{232})$$

where D_i = annual dose rate of principal radionuclide *ii* and its short-lived progeny at the time of the peak of the mean dose rate posed by the related group of radionuclides (mrem/yr)

C_i = concentration of reference radionuclide *i* in soil (pCi/g soil)

DF = radiological dose factor (mrem/yr)/(pCi/g soil)

Dose factors include long-lived radionuclides mentioned and their short-lived progeny.

The **derived concentration guideline level** may then be stated as

$$DCGL_{W\ U} = \frac{25}{DF_U}$$

$$DCGL_{W\ Ra226} = \frac{25}{DF_{Ra226+Th230}}$$

$$DCGL_{W\ Th\ series} = \frac{25}{DF_{Th\ series}}$$

where 25 = maximum acceptable annual radiological dose (mrem/yr)

$DCGL_W$ = derived concentration guideline level (pCi/g soil)

This permits a simplified statement of the **sum-of-fractions** of the radionuclides encountered in C-T decommissioning to be:

$$SOF = \frac{C_{U238}}{DCGL_{W\ U}} + \frac{C_{Ra226}}{DCGL_{W\ Ra226}} + \frac{C_{Th232}}{DCGL_{W\ Th\ series}}$$

where: SOF = sum-of-fractions of $DCGL_W$

C_{U238} = concentration of U^{238} in soil (pCi/g)

C_{Ra226} = concentration of Ra^{226} in soil (pCi/g)

C_{Th232} = concentration of Th^{232} in soil (pCi/g)

$DCGL_{W\ U}$ = $DCGL_W$ of U^{238} + U^{234} + actinium (U^{235}) series in its naturally-occurring ratio to the uranium series (pCi/g)

$DCGL_{W\ Ra226}$ = $DCGL_W$ of 6 Th^{230} + Ra^{226} and its progeny, including Pb^{210}, in radioactive equilibrium (pCi/g)

$DCGL_{W\ Th\ series}$ = $DCGL_W$ of Th^{232} and its progeny, including Ra^{228} and Th^{228}, in radioactive equilibrium (pCi/g)

The index, or SOF, determined for each soil sample or location measured, will be the basis of testing compliance with population statistics and elevated measurements criteria.

5. DERIVATION OF THORIUM SERIES DOSE FACTOR AND DCGLw

Thorium series nuclides associated with C-T processing have grown or decayed within about 0.20 of radioactive equilibrium. Considering that C-T feed was ore and that alpha spectrometry of separate radioelements poses some uncertainty at low concentration, the thorium series might rationally be assumed to be in radioactive equilibrium in Plant 5 soil samples. Especially for future estimation, the shorter radioactive half-lives of Ra^{228}, 6.7 yr, and of Th^{228}, 1.9 yr, imply that Th^{232} parent concentration is controlling. Characterization survey data also indicate the thorium series occurs at about a 1/3 of the uranium series concentration in soil.

Assuming the thorium series to be in radioactive equilibrium, a composite dose factor representing the series was derived probabilistically with RESRAD (ref. case 408guti in Attachment C herein). Equal concentrations of principal radionuclides, Th^{232}, Ra^{228}, and Th^{228}, entered into RESRAD, produce peak of the mean annual dose at year zero and corresponding peak of the mean composite dose factor, DF = 1.05 (mrem/yr)/(pCi Th^{232}/g soil). The corresponding DCGLw = 23.8 pCi Th^{232}/g soil.

Table 5.1. Thorium Series Dose Factor

Radionuclide	Concentration (pCi/g soil)	Annual Dose Rate (mrem/yr)	Dose Factor (mrem/yr)/(pCi/g)
Ra^{228}	6.248	2.86	
Th^{228}	6.248	3.33	
Th^{232}	6.248	0.348	
	total	6.54	
		composite	1.05

$$DF_{Th\ series} = [D(Th^{232}) + D(Ra^{228}) + D(Th^{228})] \div C(Th^{232})$$
$$= 6.54\ (mrem/yr) \div 6.248\ pCi\ Th^{232}/g\ soil$$
$$= 1.05\ (mrem/yr)/(pCi/g)$$
$$DCGL_{W\ Th\ series} = 25\ mrem/yr \div DF_{Th\ series}$$
$$= 25 \div 1.05 = 23.8\ pCi\ Th^{232}/g\ soil$$

6. DERIVATION OF URANIUM DOSE FACTOR AND DCGLw

Since C-T residue includes natural uranium, it would be logical to consider U^{238} through U^{234} and include the actinium, or U^{235}, series in its naturally-occurring proportion to the uranium series. The principal, or longer-lived radionuclides in the group are

Radionuclide	Proportion
U^{238}	1
U^{234}	1
U^{235}	0.0455
Pa^{231}	0.0455
Ac^{227}	0.0455

When these radionuclides are the source in a RESRAD probabilistic simulation of an industrial land use scenario, the peak of the mean annual dose occurs in the first year of exposure (ref. case 407guti in Attachment C). The composite dose factor,[8] corresponding to the peak of the mean annual dose rate = 0.0347 mrem/yr per pCi U^{238}/g soil. The corresponding $DCGL_W$ = 721 pCi U^{238}/g soil.

Table 6.1. Natural Uranium Dose Factor

Radionuclide	Concentration (pCi/g soil)	Annual Dose Rate (mrem/yr)	Dose Factor (mrem/yr)/(pCi/g)
U^{238}	6.248	7.66×10^{-2}	
U^{234}	6.248	1.79×10^{-2}	
U^{235}	0.2843	1.47×10^{-2}	
Pa^{231}	0.2843	2.97×10^{-2}	
Ac^{227}	0.2843	7.76×10^{-2}	
	total	2.17×10^{-1}	
		composite	3.47×10^{-2}

$$DF_{Th\ series} = [D(U^{238}) + D(U^{234}) + D(U^{235}) + D(Pa^{231} + D(Ac^{227})] \div C(U^{238})$$
$$= 0.217\ (\text{mrem/yr}) \div 6.248\ \text{pCi}\ U^{238}/\text{g soil}$$
$$= 3.47 \times 10^{-2}\ (\text{mrem/yr})/(\text{pCi}\ U^{238}/\text{g})$$
$$DCGL_{W\ Th\ series} = 25\ \text{mrem/yr} \div DF_U$$
$$= 25 \div 3.47 \times 10^{-2} = 721\ \text{pCi}\ U^{238}/\text{g soil}$$

A range of sources, including Th^{230}, Ra^{226}, and the thorium series were also entered into RESRAD along with uranium, and the time of the peak of the mean annual dose including each entire source term was determined. The composite dose factor and $DCGL_W$ representing the uranium nuclide group at the time of the peak of the mean dose caused by the entire source was derived. Results, tabulated in Table 8.2 , demonstrate that the peak of the mean annual dose of a representative range of expected sources predominantly occurs during the first year of exposure. Whenever it occurs during a future year, the derived composite dose factor for uranium is diminished relative to that applicable during the first year of exposure.

Thus, the most conservative composite dose factor and $DCGL_W$ representing uranium at the peak of the mean dose rate it poses are DF = 0.0347 mrem/yr per pCi U^{238}/g soil and $DCGL_W$ = 721 pCi U^{238}/g soil.

[8] including all the principal radionuclides and their short-lived progeny

7. DERIVATION OF THE DOSE FACTOR AND DCGLw OF TH^{230} AND RA^{226}

7.1. BASIS

Since Th^{230} transmutes into Ra^{226}, is observed together with Ra^{226} in soil samples, and since the dose factor of Ra^{226} and its progeny, including Pb^{210}, exceed other radionuclides in the uranium series, it is logical to associate Th^{230} and Ra^{226} in dose estimation. Measurement of Th^{230} requires analysis that is slow, expensive, and separate from other key radionuclides. To the extent its presence in excess of uranium or Ra^{226} does not increase potential annual dose substantially and specific measurement is unnecessary, remediation can be done without undue delay.

It would be desirable to adopt a conventional association that does not underestimate potential radiological dose and that allows measured Ra^{226} to represent the subseries. For this reason, it would be logical and useful to link Th^{230} with Ra^{226} in lieu of further measurement of Th^{230} itself.

A subseries beginning with Th^{230} and including Ra^{226}, Pb^{210}, and their short-lived progeny is a logical grouping. In soil, it would be reasonable to assume Ra^{226}, Pb^{210}, and their short-lived progeny are in radioactive equilibrium; although exhalation of Rn^{222} could even leave progeny below equilibrium. The relatively short half-life of Pb^{210}, 21 years, and its lower dose factor than of Ra^{226} justifies compositing the contributions of Ra^{226}, Pb^{210}, and their short-lived progeny to radiological dose.

The sensitivity of Th^{230} contribution to radiological dose and dose factor, particularly within the spectral range of U series and Th series radionuclides present in soil in Plant 5 has been investigated. One goal is to determine the effect of Th^{230} relative to Ra^{226} on influencing radiological dose. What Th^{230} -to- Ra^{226} ratio yields a composite dose factor that does not underestimate the dose from soil samples of C-T residue, and thus DCGLw that assures compliance with the 25 mrem/yr dose criterion? Or, within the range of Th^{230} relative to Ra^{226}, what would be the maximum composite dose factor to represent C-T residue, including Th^{230}, Ra^{226}, Pb^{210}, and their short-lived progeny as a function of increasing Th^{230} -to- Ra^{226}?

7.2. OBSERVED SOURCE

Among about 600 soil characterization samples collected in Plant 5, more than 500 pairs of Th^{230} and Ra^{226} measurements exist. Among those pairs were 41 pairs containing Th^{230} and Ra^{226} more than 1 standard deviation above mean background concentration. The Th^{230}-to-Ra^{226} ratio in these 41 soil samples has a geometric mean value of 0.66. Among those, only 3 samples, or 0.006 of 500 samples, exhibit $Th^{230}/Ra^{226} > 6$. The extensive characterization survey thus indicates that occurrence of Th^{230} -to- $Ra^{226} > 6$ in future soil sampling would be highly unlikely, especially after remediation and that derivation of DF and DCGLw at Th^{230} -to- $Ra^{226} \leq 6$ will assure that the DF is highly unlikely to be underestimated.

7.3. SENSITIVITY ANALYSIS

A series of probabilistic dose modeling was computed with RESRAD in which principal radionuclides, Th^{230}, Ra^{226}, and Pb^{210} were the source. Th^{230} concentration was incremented in excess of Ra^{226} and Pb^{210}. Results are summarized in Table 7.1. Base case 329guti represents Th^{230}, Ra^{226}, Pb^{210}, and their progeny, in radioactive equilibrium, *i.e.*, with Th^{230}/Ra^{226} ratio = 1.

Table 7.1. Dose Factor and DCGLw as a Function of Th^{230}-to-Ra^{226} Ratio

RESRAD Case I.D.	Relative Quantity of Each Radionuclide			Time of Peak of Mean Dose (yr)	$Th^{230} + Ra^{226} + Pb^{210}$	
	Th^{230}	Ra^{226}	Pb^{210}		Dose Factor (mrem/yr)/(pCi/g)	DCGLw (pCi/g)
329guti	1	1	1	0	0.766	32.65
333guti	2	1	1	0	0.772	32.4
335guti	3	1	1	0	0.778	32.1
338guti	4	1	1	0	0.784	31.9
403guti	5	1	1	123	0.811	30.8
399guti	6	1	1	161	0.852	29.4
400guti	8	1	1	239	0.962	26.0
401guti	10	1	1	293	1.08	23.05

Within a population of more than 500 soil characterization samples and among the 41 pairs in which Ra^{226} and Th^{230} are above background mean by more than 1 standard deviation, only 3 samples, or 0.6 %, exhibit Th^{230} -to- $U^{238} > 6$. The peak of the mean dose as a function of increasing Th^{230} -to- the peak of the mean dose when Th^{230} concentration equals Ra^{226} concentration only exceeds 1.1, or increases by as much as 11 percent only when the Th^{230} -to- U^{238} ratio exceeds 6. Adopting the composite dose factor representing Th^{230}, Ra^{226}, Pb^{210}, and their progeny, with Th^{230}/Ra^{226} ratio = 6, would be expected to encompass more than 99% of soil samples. [ref. RESRAD case 399guti]

7.4. RATIO OF PEAK OF MEAN DOSE RATE AT ACTUAL TH^{230} VS $TH^{230} = 6\ RA^{226}$

RESRAD computations were performed to derive radiological dose factors and DCGLw associated with characterization survey samples exhibiting the most excessive Th^{230} and or Ra^{226} concentrations.

Soil characterization survey samples were sorted to select ones in which the ratio of Th^{230}-to-$U_{avg} > 2$ and or Th^{230}-to-$Ra^{226} > 5$, which is > 1 standard deviation above background mean.[9, 10] The most excessive of these sample concentration data, identified in

[9] Mallinckrodt. CT II DP. §4, Table 4-7.

Table 7.2, were entered into RESRAD to compute the probabilistic peak of the mean annual dose rate. A second computation was done for each sample, assuming the Th^{230} concentration equals 6 times the Ra^{226} concentration. Then the ratio of the peak of the mean dose rate at actual Th^{230} concentration -to- the peak of the mean dose rate when Th^{230} concentration is assumed equal to 6 times the Ra^{226} concentration, was derived and is tabulated in Table 7.2.

An objective is to draw conclusion about the significance and boundary condition of assuming Th^{230} to equal 6 times the Ra^{226} concentration when applied to observed radioactivity concentration and extremes of Th^{230} to Ra^{226} concentration. This can be done by deriving the probabilistic peak of mean dose rate at actual Th^{230} concentration and the peak of the mean dose rate when Th^{230} concentration is assumed equal to 6 times the Ra^{226} concentration and comparing the results.

Results of this comparison, in Table 7.2, are that all cases but two demonstrate a peak of the mean dose rate no more than that if Th^{230} were assumed equal to 6 times the Ra^{226} concentration. The exceptions were only 2 and 14 percent greater than when Th^{230} was assumed equal to 6 times the Ra^{226} concentration.

These ratios of peak mean dose rate at actual Th^{230} concentration -to- those when Th^{230} is assumed equal to 6 times the Ra^{226} concentration averages 0.99. In only one anomalous sample was the ratio notably above one. Even in soil samples containing the most excessive concentrations of Th^{230} and Ra^{226}, an assumption that Th^{230} concentration is 6 times the Ra^{226} concentration can be expected to yield a dose factor that will not underestimate radiological dose when applied to practically all soil samples.

Thus, it is reasonable to apply a composite dose factor = 0.852 (mrem/yr)/(pCi Ra^{226}/g soil) and a $DCGL_W$ = 29.4 pCi Ra^{226}/g soil to represent the subseries including Th^{230}, Ra^{226}, and Pb^{210}.

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[10] Mallinckrodt. CT II DP, apx. C, Table C-1.

Table 7.2. Dose Estimation for Soil Characterization Samples Containing Excess Th^{230} and or Ra^{226}

RESRAD Case I.D.	Sample Identification Location	Sample Identification Depth at Bottom (ft)	Th^{230} to U_{avg} ratio	Th^{230} to Ra^{226} ratio	Ra^{226} to U_{avg} ratio	Time to Peak of Mean (yr)	Peak of Mean Dose Rate (mrem/yr)	Ratio of Peak of Mean Dose Rate at actual Th^{230} vs $Th^{230} = 6\ Ra^{226}$
348bh11	BH-011	3.5	101.	2.07	48.9	0	124.7	0.978
409guti	BH-011	3.5	293.	6	48.9	0	127.5	
349bh22	BH-022	5.5	1.53	5.84	0.26	0	10.14	0.999
410bh22	BH-022	5.5	1.57	6.0	0.26	0	10.15	
353bh09	BH-009	2.5	7.6	1.7	4.5	0	19.04	0.976
411bh09	BH-009	2.5	26.8	6.0	4.5	0	19.47	
355bh10	BH-010	2.5	12.7	0.91	11.6	0	252.1	0.972
412bh10	BH-010	2.5	69.6	6.0	11.6	0	259.3	
357bh12	BH-012	5.5	2.39	0.097	24.6	0	229.2	0.949
413bh12	BH-012	5.5	148.	6.0	24.6	125	241.6	
359bh15	BH-015	5.5	6.33	0.302	21.0	0	291.5	0.944
414bh15	BH-015	5.5	126.	6.0	21.0	125	308.9	
361bh15a	BH-015A	9.5	3.7	0.352	10.6	0	673.9	0.947
415bh15a	BH-015A	9.5	63.4	6.0	10.6	125	711.4	
363bh38	BH-038	1.0	2.46	8.30	0.30	125	21.31	1.02
416bh38	BH-038	1.0	1.77	6.0	0.30	0	20.93	
365bh38	BH-038	6.5	2.22	5.90	0.38	0	4.701	1.00
417bh38	BH-038	6.5	2.26	6.0	0.38	0	4.703	
367bh41	BH-041	3.5	3.69	10.4	0.35	244	7.841	1.136
418bh41	BH-041	3.5	2.13	6.0	0.35	0	6.901	
369bh42	BH-042	1.0	3.01	6.40	0.47	0	6.119	1.00
419bh42	BH-042	1.0	2.83	6.0	0.47	0	6.107	
371ja04	JA-04	1.0	2.38	0.60	3.97	0	111.1	0.932
420ja04	JA-04	1.0	1.0	6.0	3.97	159	119.2	

8. DERIVATION OF DOSE FACTORS AND DCGLw IN A RANGE OF SOURCE TERMS

Radiological dose factors may be demonstrated applicable over a wide range of source distribution encompassing C-T residue in soil. Source terms including: a) 2 U series -to- 1 Th series and 3 U series -to- 1 Th series, most representative in C-T samples, b) a range of excess Ra^{226} and Pb^{210}, and c) a range of excess Th^{230} were subject to simulation with RESRAD. From these separate cases and source terms, identified in Table 8.1, composite dose factors and DCGLw were derived.

Table 8.1. Composite Dose Factor and DCGLw Derived Separately

Radionuclide Group	Composite Dose Factor[11] (mrem/yr)/(pCi/g)	DCGLw[20] (pCi/g)	RESRAD case
Th series	1.05	23.9	408guti
Natural Uranium	0.0347	721.	407guti
6 Th^{230} + Ra^{226} + Pb^{210}	0.852	29.4	399guti

Evident in these simulations are that:

- Dose factors and DCGLw derived separately for natural uranium and for the thorium series (ref. Tables 5.1, 6.1, 7.1, and 8.1) agree closely with the dose factors and DCGLw in Table 8.2.
- When the Th^{230} -to- Ra^{226} ratio is ≤ 6, dose factors are lower and DCGLw are higher than when derived separately for 6 Th^{230} + Ra^{226} + Pb^{210}.

Thus, over a wide range, encompassing the C-T source distribution in soil, the derived dose factor and DCGLw proposed for natural uranium and the thorium series are representative, and for Th^{230} + Ra^{226} + Pb^{210}, overestimates the dose. Only if the Th^{230} -to- Ra^{226} ratio were > 6 could the Ra^{226} dose be underestimated; yet the occurrence of that was very low, < 0.01, in characterization survey measurements.

[11] DF and DCGLw are referenced to Th^{232}, U^{238}, and Ra^{226} respectively.

Table 8.2. Composite Dose Factor and DCGLw Derived in a Range of Source Distribution

RESRAD case	Relative Concentration of Key Radionuclide in Soil				Time of Peak of Mean Dose (yr)	Natural Uranium: U238, U234, + U235 series		Th^{230} + Ra^{226} + Pb^{210}		Thorium series	
	U series	Th series	Excess Ra226	Excess Th230		Dose Factor (mrem/yr)/(pCi/g	DCGLw (pCi/g)	Dose Factor (mrem/yr)/(pCi/g	DCGLw (pCi/g)	Dose Factor (mrem/yr)/(pCi/g	DCGLw (pCi/g)
301guti	3	1	0	1	0	3.47E-02	7.21E+02	7.73E-01	3.23E+01	1.05E+00	2.39E+01
302guti	3	1	0	2	0	3.47E-02	7.21E+02	7.75E-01	3.23E+01	1.05E+00	2.39E+01
303guti	3	1	0	3	0	3.47E-02	7.21E+02	7.77E-01	3.22E+01	1.05E+00	2.39E+01
304guti	3	1	0	4	0	3.47E-02	7.21E+02	7.79E-01	3.21E+01	1.05E+00	2.39E+01
305guti	3	1	0	6	0	3.47E-02	7.21E+02	7.83E-01	3.19E+01	1.05E+00	2.39E+01
384guti	3	1	0	8	0	3.47E-02	7.21E+02	7.87E-01	3.18E+01	1.05E+00	2.39E+01
385guti	3	1	0	10	0	3.47E-02	7.21E+02	7.91E-01	3.16E+01	1.05E+00	2.39E+01
388guti	3	1	0	27	234	1.51E-02	1.66E+03	1.08E+00	2.31E+01	7.30E-01	3.43E+01
307guti	3	1	1	1	0	3.47E-02	7.21E+02	7.70E-01	3.25E+01	1.05E+00	2.39E+01
308guti	3	1	2	2	0	3.47E-02	7.21E+02	7.69E-01	3.25E+01	1.05E+00	2.39E+01
309guti	3	1	4	4	0	3.47E-02	7.21E+02	7.68E-01	3.25E+01	1.05E+00	2.39E+01
310guti	3	1	6	6	0	3.47E-02	7.21E+02	7.70E-01	3.25E+01	1.05E+00	2.39E+01
311guti	3	1	2	1	0	3.47E-02	7.21E+02	7.68E-01	3.26E+01	1.05E+00	2.39E+01
312guti	3	1	4	1	0	3.47E-02	7.21E+02	7.66E-01	3.27E+01	1.05E+00	2.39E+01
313guti	3	1	6	1	0	3.47E-02	7.21E+02	7.66E-01	3.26E+01	1.05E+00	2.39E+01
314guti	3	1	1	2	0	3.47E-02	7.21E+02	7.72E-01	3.24E+01	1.05E+00	2.39E+01
315guti	3	1	4	2	0	3.47E-02	7.21E+02	7.66E-01	3.26E+01	1.05E+00	2.39E+01
316guti	3	1	6	2	0	3.47E-02	7.21E+02	7.67E-01	3.26E+01	1.05E+00	2.39E+01
317guti	3	1	3	1	0	3.47E-02	7.21E+02	7.73E-01	3.23E+01	1.05E+00	2.39E+01
318guti	3	1	2	3	0	3.47E-02	7.21E+02	7.70E-01	3.24E+01	1.05E+00	2.39E+01
319guti	3	1	3	3	0	3.47E-02	7.21E+02	7.69E-01	3.25E+01	1.05E+00	2.39E+01
320guti	3	1	4	3	0	3.47E-02	7.21E+02	7.67E-01	3.26E+01	1.05E+00	2.39E+01
321guti	3	1	6	3	0	3.47E-02	7.21E+02	7.68E-01	3.26E+01	1.05E+00	2.39E+01
322guti	3	1	1	4	0	3.47E-02	7.21E+02	7.75E-01	3.23E+01	1.05E+00	2.39E+01
323guti	3	1	2	4	0	3.47E-02	7.21E+02	7.72E-01	3.24E+01	1.05E+00	2.39E+01
324guti	3	1	6	4	0	3.47E-02	7.21E+02	7.68E-01	3.25E+01	1.05E+00	2.39E+01
325guti	3	1	1	6	0	3.47E-02	7.21E+02	7.78E-01	3.21E+01	1.05E+00	2.39E+01
326guti	3	1	2	6	0	3.47E-02	7.21E+02	7.74E-01	3.23E+01	1.05E+00	2.39E+01
327guti	3	1	3	6	0	3.47E-02	7.21E+02	7.72E-01	3.24E+01	1.05E+00	2.39E+01

RESRAD case	Relative Concentration				Time of Peak of Mean Dose (yr)	Natural Uranium		Th^{230} + Ra^{226} + Pb^{210}		Thorium series	
	U series	Th series	Excess Ra^{226}	Excess Th^{230}		Dose Factor (mrem/yr)/(pCi/g	$DCGL_W$ (pCi/g)	Dose Factor (mrem/yr)/(pCi/g	$DCGL_W$ (pCi/g)	Dose Factor (mrem/yr)/(pCi/g	$DCGL_W$ (pCi/g)
328guti	3	1	4	6	0	3.47E-02	7.21E+02	7.70E-01	3.25E+01	1.05E+00	2.39E+01
340guti	3	1	0	0	0	3.46E-02	7.23E+02	7.66E-01	3.27E+01	1.04E+00	2.40E+01
341guti	2	1	0	1	0	3.46E-02	7.22E+02	7.69E-01	3.25E+01	1.04E+00	2.40E+01
342guti	2	1	0	2	0	3.46E-02	7.22E+02	7.72E-01	3.24E+01	1.04E+00	2.40E+01
343guti	2	1	0	4	0	3.46E-02	7.22E+02	7.78E-01	3.21E+01	1.04E+00	2.40E+01
344guti	2	1	0	6	0	3.46E-02	7.22E+02	7.84E-01	3.19E+01	1.04E+00	2.40E+01
386guti	2	1	0	10	0	3.46E-02	7.22E+02	7.97E-01	3.14E+01	1.04E+00	2.40E+01
387guti	2	1	0	18	186	1.72E-02	5.42E+03	1.05E+00	2.38E+01	7.71E-01	3.24E+01
345guti	2	1	1	1	0	3.46E-02	7.22E+02	7.66E-01	3.26E+01	1.04E+00	2.40E+01
346guti	2	1	1	2	0	3.46E-02	7.22E+02	7.68E-01	3.26E+01	1.04E+00	2.40E+01
375guti	1	0	0	0	0	3.46E-02	7.23E+02	7.71E-01	3.24E+01	-	-
402guti	1 U238 + 1 U234 + 0.0455 U235 + 0.0455 Ac227 + 0.0455 Pa231)				0	3.47E-02	7.21E+02	-	-	-	-

Natural uranium dose factor and DCGLw referenced per pCi parent U238/g soil
Th230 + Ra226 + Pb210 dose factor and DCGLw referenced per pCi Ra226/g soil
Th series dose factor and DCGLw referenced per pCi Th232/g soil

9. APPLICATION OF DERIVED DOSE FACTORS

Whether the proposed compositing of dose factors to enable practical measurement of radionuclides during remediation and final status survey is reasonable was tested by calculating in two ways the potential radiological dose associated with soil samples containing Th^{230} and Ra^{226} above background and maximal Th^{230}-to-Ra^{226} ratio. Soil characterization survey samples were sorted to select ones in which Th^{230} and Ra^{226} are above background mean by more than one standard deviation. Results are in Attachment B herein. In only 3 samples was the ratio of Th^{230}-to-Ra^{226} > 6 and was > 5 in only two more.

Results of dose estimates by RESRAD and by the composite dose factors are tabulated.

Table 9.1. Estimates of Radiological Dose by RESRAD and by Composite Dose Factors

Soil Sample		Radionuclide Concentration[A]			Th^{230}/Ra^{226}	Radiological Dose	
Location	Depth to bottom (ft)	U^{238} (pCi/g)	Ra^{226} (pCi/g)	Th^{232} (pCi/g)	ratio	by RESRAD (mrem/yr)	by Composite Dose Factors (mrem/yr)
BH-022	5.5	35.5	9.3	1.6	5.8	10.2	10.8
BH-038	1	56.4	16.7	5.3	8.3	21.3	21.8
BH-041	3.5	16.65	5.9	1.47	10.4	7.8	7.2
BH-042	1	10.6	5.0	1.7	6.4	6.1	6.4
BH-114	4	34.8	5.6	1.11	5.4	6.7	7.1

A U^{238} represents average of U^{238} and U^{234} analyses
Ra^{226} represents Ra^{226}.
Th^{232} represents average of Th^{232}, Ra^{228}, and Th^{228} analyses.

The composite radiological dose factors for this table include dose from concentrations in soil of

- U^{238}, U^{234}, and U^{235} series in natural proportion per pCi U^{238}/g soil;
- Th^{230}, Ra^{226}, and Pb^{210} where Th^{230} = 6 times Ra^{226} and Pb^{210} = Ra^{226}, referenced per pCi Ra^{226}/g and
- Thorium series in radioactive equilibrium, referenced per pCi Th^{232} per g.

Radiological dose rate employing the composite dose factors was estimated with the equation:

$$\text{Dose Rate} = (C \times DF)_{U^{238}\ \text{thru}\ U^{234}} + (C \times DF)_{Th^{230} + Ra^{226}} + (C \times DF)_{\text{Th series}}$$

where: C_i = radioactivity concentration of U^{238}, representing average of U^{238} and U^{234} (pCi/g); of Ra^{226}, representing Ra^{226}, and of Th^{232}, representing the average of Th^{232}, Ra^{228}, and Th^{228} (pCi/g)

DF_i = composite radiological dose factor (mrem/yr)/(pCi/g)

In these instances of maximum observed Th^{230} -to- Ra^{226} ratio, dose estimates by RESRAD and by the composite dose factors are nearly the same. DCGLw derived with these same composite dose factors would, likewise, be appropriate to ensure compliance when U^{238}, Ra^{226}, and Th^{232} are measured.

Even if the Th^{230} -to- Ra^{226} ratio were somewhat higher than 6 in one or two instances after remediation to remove substantially contaminated soil, the peak of the mean dose would remain below the elevated measurement criterion and would be tolerable even if underestimated on the basis of a DCGL derived when Th^{230} concentration is assumed equal to the U^{238} concentration.

10. MEASUREMENT

Properties of the residual radioactive source observed during characterization surveys have enabled the radioactive properties and range of the source term expected to remain after remediation to be estimated.

The thorium series will be assumed to be in radioactive equilibrium. One or more surrogate radionuclides such as Ac^{228} and or Tl^{208} may be measured as surrogate(s) to represent the concentration of key radionuclides and thus the thorium series.

Either uranium isotope(s) may be measured during final status survey or surrogate progeny may be measured to represent the parent uranium. Considering characterization survey data, the U^{238} and U^{234} will be assumed to be in radioactive equilibrium, *i.e.,* equal radioactivity concentration, together with the actinium (U^{235}) series in its naturally-occurring ratio.

Radium-226 may be measured, either directly and or by surrogate progeny to represent Ra^{226}.

Characterization survey measurements (ref. CT 2 DP, Tables 4-7 thru 4-16), and Attachment B, herein, indicate that Th^{230} is unlikely to be more than 6 times the Ra^{226} concentration above background. Probabilistic dose calculations have determined that, within the reasonably expected distribution, i.e., spectra, of key radionuclides in soil, Th^{230} may be grouped with its progeny, Ra^{226}. Thus, the subseries of Th^{230}, Ra^{226}, and Pb^{210}, and their short-lived progeny will be represented by measuring Ra^{226} and or surrogate progeny to represent it.

The radiological dose is very unlikely to be underestimated when combined dose factors include 1) U^{234} and U^{238} in equal concentration, 2) U^{235} series in radioactive equilibrium existing in naturally-occurring proportion to U^{238}, 3) Th230 assumed to exist in 6 times the concentration of Ra^{226}, and 4) the thorium series is assumed in radioactive equilibrium.

ATTACHMENT A

DOSE MODELING PARAMETERS SIMULATED PROBABILISTICALLY

THICKNESS OF THE CONTAMINATED ZONE

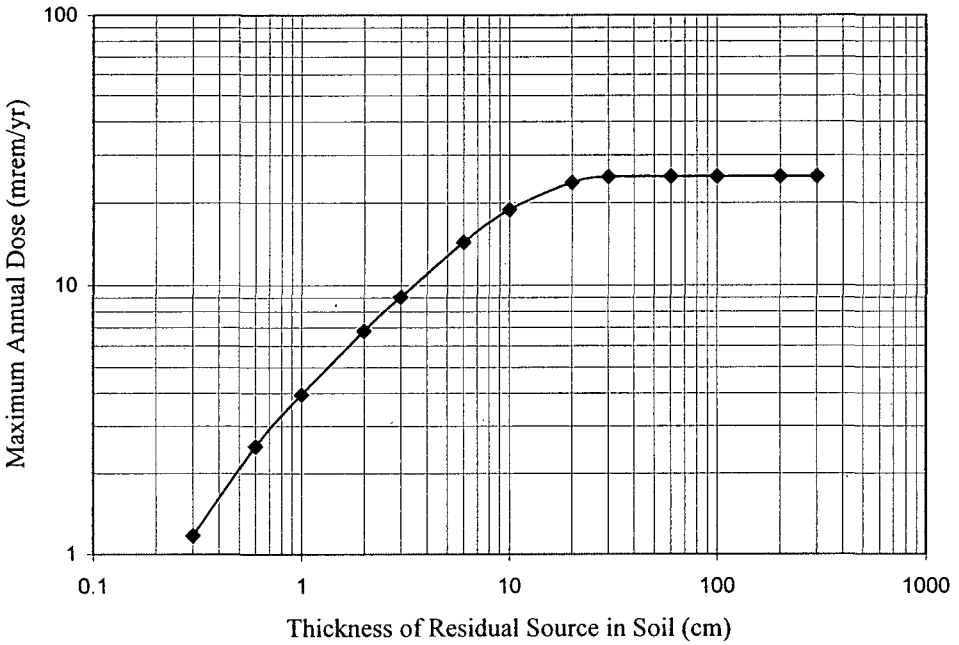
In response to the RAI set 1 EPAD comment about thickness of the contaminated zone, it was demonstrated that assuming greater than a one-meter-thick contamination depth in soil would not cause additional dose, increase the dose factor, nor diminish the DCGL. The thickness of the contaminated zone is the depth distance between the uppermost and lowermost soil samples that have radionuclide concentration above background. Whereas, in deterministic modeling, a one-meter-thick depth of contaminated soil was modeled, in probabilistic modeling, Mallinckrodt proposes a uniform distribution ranging from 0 to 1 meter.

Probabilistic. An analysis of the effect of contaminated zone thickness on radiological dose during industrial land use was done to interpret the depth beyond which additional contribution from a representative source in soil to irradiation dose to a person would become negligible. Essential features of modeling to perform this analysis were:

- a reasonably representative source ratio of 3 U series, 0.0455 x 3 actinide (U^{235}) series, and 1 Th series together.
- bare land in which residual source contamination extends from land surface downward into the soil;
- indoor time fraction = 0.0 in order to simulate effect of irradiation on bare land;
- the same industrial land use scenario modeled to derive $DCGL_W$ originally, except absent ingestion of soil and inhalation of dust; (for the origin of inadvertently ingested dust and of dust suspended into air is surficial topsoil); and
- deterministic simulation using RESRAD to derive the effect of increasing contamination depth in soil on exposure to direct irradiation. [ref. RESRAD cases 203gutir2000 through 215 gutir0003]

The result of this analysis is summarized graphically in Figure A1. It determined that, in representative simulation, maximum dose rate by direct irradiation is reached asymptotically when the depth of the contaminated zone in topsoil reaches about 30 cm. Additional source thickness would not produce significantly greater dose rate.

Figure A1. Maximum Annual Radiological Dose Versus Source Depth in Soil
(infinitely-thick source ratio 3 U series + 1 Th series produces 25 mrem/yr)



As a result of this analysis, the thickness of contaminated zone parameter will be represented as a variable in probabilistic dose modeling. It is being represented as a uniform distribution ranging from 0 to 1 meter thick since characterization survey soil sampling intervals are insufficient to resolve a well-defined gradient within this range. A maximum depth of 1 meter is more than sufficient to be a conservative representation insofar as direct irradiation is concerned.

MASS LOADING FOR INHALATION

Estimation of intake by inhalation depends on the airborne concentration of contaminated airborne particulate matter, *i.e.*, soil, that is respirable. Respirable particles are those less than 10 μm in diameter. About 0.28 to 0.33 of airborne particles have been found to be respirable.[12, 13, 14, 15] The mass loading of respirable particulate in air may be

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[12] USEPA. *Proposed Guidance on Dose Limits for Persons Exposed to Transuranium Elements in the General Environment.* EPA 520/4-77-016. pp. 31-32. Sept. 1977.

[13] Chepil, W.S., "Sedimentary Characteristics of Dust Storms: III Composition of Suspended Dust." Am. J. Sci., 225, p. 206, 1957. in EPA 520/4-77-016, p. 57

[14] Sehmel, G.A., *Radioactive Particle Resuspension Research Experiments on the Hanford Reservation*, BNWL-2081, 1977.

[15] Willeke, K. *et.al.*, "Size Distribution of Denver Aerosols - A Comparison of Two Sites," Atm. Env., 8, p. 609, 1974.

estimated as the product of the total mass loading of airborne dust and the respirable fraction.

Deterministic. The total mass loading of airborne dust in an urban area has been estimated to range from 60 to 220 μg/m³ by USHEW[16] and 33 to 254 by Gilbert, *et.al.*[17] A best geometric estimate is about 115 μg/m³. Thus, a reasonable estimate of respirable mass loading for inhalation in an urban, industrial area is 0.3 x 115 μg/m³ = 35 μg/m³. (This is about the upper 90th percentile recommended for use in RESRAD in a residential environment.[18] Long-term measurements of mass loading in ambient air are 23 μg/m³ at the 50th percentile.)

Probabilistic. The model of radionuclides in outdoor air subject to inhalation is the product of the radionuclide concentration in surface soil and the airborne density of particulates of respirable size in ambient air. Biwer, *et.al.*,[19] summarized the distribution of respirable particulate in ambient air reported by the EPA[20] for about 1790 air monitoring stations in a range of environments. At cumulative probability = 0.50, the most frequent respirable particulate density in the EPA distribution occurs at about 23 μg/m³ air.[21]

Three other sources of data were examined to get more comprehensive information about airborne particulate density in urban air. The total mass loading of airborne dust in an urban area has been estimated to range from 60 to 220 μg/m³ by USHEW[22] and 33 to 254 by Gilbert, *et.al.*[23] Their respective geometric means are approximately 115 and 92 μg/m³. Airborne particulates measured in 14494 urban and 3114 non-urban air samples in the National Air Sampling Network exhibited a geometric mean of 98 μg/m³.[24] A best geometric estimate of those is about 102 μg/m³.

Estimation of intake by inhalation depends on the airborne concentration of contaminated airborne particulate matter, *i.e.*, soil, that is respirable. About 0.28 to 0.33 of airborne particles have been found to be respirable, *i.e.*, less than 10 μm in diameter.[25, 26, 27,

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16 USHEW. *Air Quality Criteria for Particulate Matter.* 1969. in NUREG/CR-5512, 1, p. 6.11.

17 Gilbert, T.L., *et.al., Pathways Analysis and Radiation Dose Estimates for Radioactive Residues at Formerly Utilized MED/AEC Sites.* ORO-832 rev. Jan 1984. in Yu, C. *et.al., Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil.* ANL/EAIS-8. pp. 110-111, Apr. 1983.

18 Biwer, *et.al.* atch C, p. c4-16 in NUREG/CR-6697.

19 Biwer, *et.al.* "Parameter Distributions for Use in RESRAD and RESRAD-BUILD Computer Codes." atch C, pp. C4-15 & C4-16 in NUREG/CR-6697. Dec. 2000.

20 USEPA. Aerometric Information Retrieval System. internet site http://www.epa.gov/airs/airs.html. 1999.

21 Biwer, *et.al.*, Table 4.6-1 and Fig. 4.6-1 in NUREG/CR-6697.

22 USHEW. *Air Quality Criteria for Particulate Matter.* 1969. in NUREG/CR-5512, 1, p. 6.11.

23 Gilbert, T.L., *et.al., Pathways Analysis and Radiation Dose Estimates for Radioactive Residues at Formerly Utilized MED/AEC Sites.* ORO-832 rev. Jan 1984. in Yu, C. *et.al., Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil.* ANL/EAIS-8. pp. 110-111, Apr. 1983.

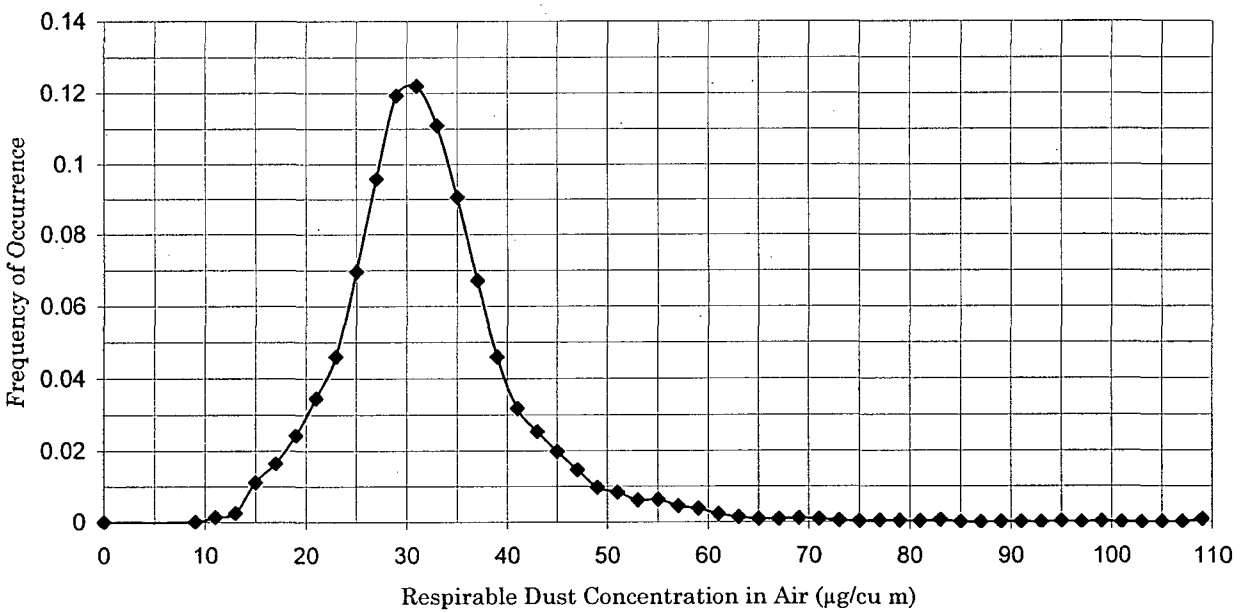
24 Stern, A.C., ed. *Air Pollution.* 2nd ed. Academic Press. NY. 1968.

25 USEPA. *Proposed Guidance on Dose Limits for Persons Exposed to Transuranium Elements in the General Environment.* EPA 520/4-77-016. pp. 31-32. Sept. 1977.

[28] The mass loading of respirable particulate in air may be estimated as the product of the total mass loading of airborne dust and the respirable fraction. Thus, a reasonable estimate of the geometric mean of respirable mass loading for inhalation in an urban, industrial area is about 0.3 x 102 $\mu g/m^3$ = 31 $\mu g/m^3$.

A distribution representing airborne particulate loading in urban air may be estimated by the shape of the distribution in NUREG/CR-6697, Table 4.6-1 and shifted upward by an increment representing the increase in dust in urban air relative to all ambient air. The result, in Figure A2, becomes the probabilistic distribution to replace the default distribution in RESRAD v. 6.22. This distribution represents careful, reasonable appraisal of values of airborne mass loading in an urban environment.

Figure A2. Frequency Distribution of Respirable Dust in Urban Air
(EPA AIRS PM-10 data normalized to urban environment)



It is represented in RESRAD as a continuous linear distribution with entries in Table A1.

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[26] Chepil, W.S., "Sedimentary Characteristics of Dust Storms: III Composition of Suspended Dust." Am. J. Sci., 225, p. 206, 1957. in EPA 520/4-77-016, p. 57

[27] Sehmel, G.A., *Radioactive Particle Resuspension Research Experiments on the Hanford Reservation*, BNWL-2081, 1977.

[28] Willeke, K. *et.al.*, "Size Distribution of Denver Aerosols - A Comparison of Two Sites," Atm. Env., 8, p. 609, 1974.

Table A1. Respirable Particulate in Urban Air

Respirable Particulate Concentration ($\mu g/m^3$)	Frequency
0.	0.0
15.	0.0151
23.	0.1365
37.	0.8119
47.	0.9495
67.	0.9937
83.	0.9983
107.	0.9992

GAMMA SHIELDING FACTOR

The gamma shielding factor indoors has been revised to treat it probabilistically and to assume a fractional occurrence on bare ground and a thin floor. Table A2 describes the discrete cumulative probability distribution simulating the external gamma shielding factor applicable indoors.

Table A2. Gamma Shielding Factor Distribution

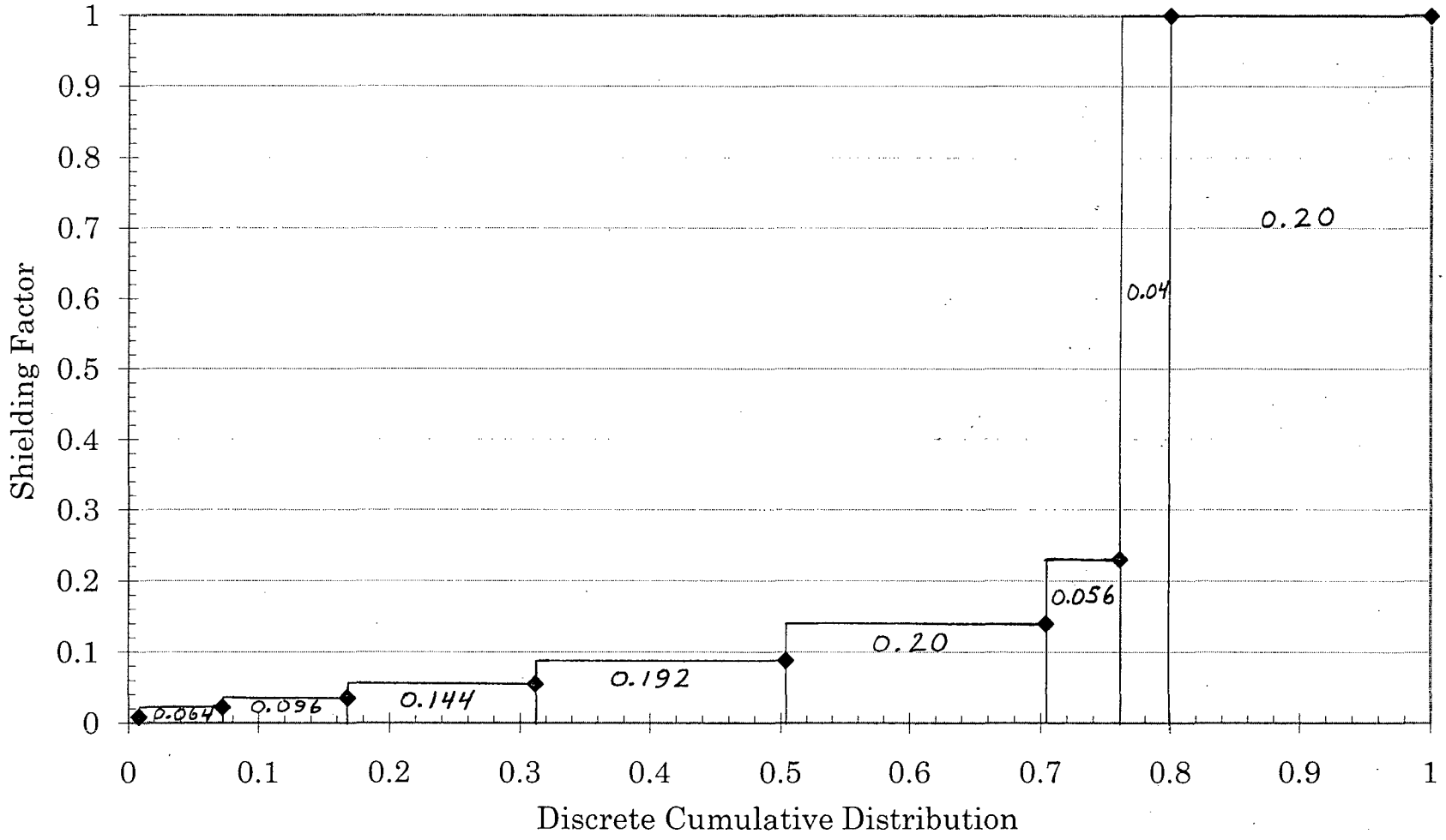
Location	Shielding Thickness (in)	Shielding Factor ("value")	Fractional Occurrence	Cumulative Distribution Indoor Only (cdf)
indoor	10	0.0084	0.01	0.01
indoor	8	0.022	0.08	0.09
indoor	7	0.035	0.12	0.21
indoor	6	0.055	0.18	0.39
indoor	5	0.088	0.24	0.63
indoor	4	0.14	0.25	0.88
indoor	3	0.23	0.07	0.95
indoor	0	1.0	0.05	1.0
outdoor	0	1.0	0.20	

Occupancy 20% of the time on bare ground, with gamma shielding factor = 1.0, is, in addition, assumed to apply deterministically while out-of-doors, even though most of Plant 5 is paved. Overall, then, dose modeling has been adjusted to simulate a person on bare ground about 24% of their time while on-site and thin shielding an additional 5.6% of the

time. This is illustrated diagrammatically in Figure A3.

A relevant association is that, on the area of the site that is subject to the FUSRAP, the USACE remediation and dose modeling are based on a premise that the land will be covered by at least six inches of pavement, gravel, or unaffected fill.

Figure A3. Cumulative Distribution of Indoor and Outdoor Shielding Fraction



ATTACHMENT B

THORIUM-230 -TO- RADIUM-226 RATIO IN SOIL CHARACTERIZATION SAMPLES

Soil characterization survey samples were sorted to select ones in which Th^{230} and Ra^{226} are above background mean by more than one standard deviation. Among more than 500 samples were 41 qualifying samples. Among these 41 samples, the Th^{230}-to-Ra^{226} ratio exceeded 6 in only 3 samples and exceeded 5 in only 2 more.

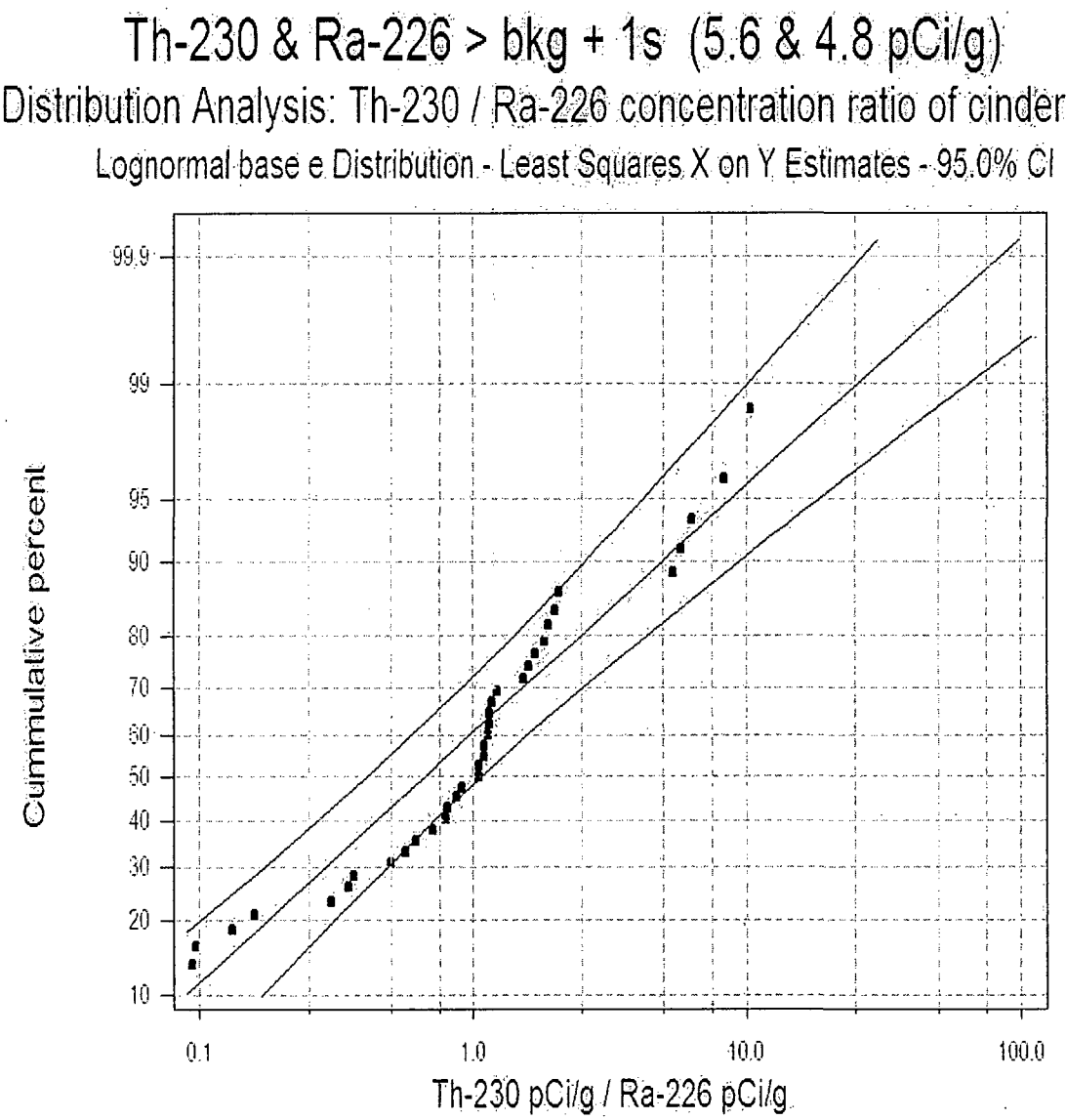


Figure B1. Th^{230} -to- Ra^{226} Ratio in Soil Characterization Samples

Table B1. C-T Soil Characterization Survey Data in which Ra-226 and Th-230 Concentrations are More than One Standard Deviation above Natural Background Mean

Location ID	Sample Depth (ft)		Radionuclide Concentration		Ratio
	Top	Bottom	Th-230 (pCi/g)	Ra-226 (pCi/g)	Th-230 / Ra-226
BH-009		2.5	27.6	16.3	1.7
BH-010		2.5	262	239.3	1.1
BH-010		4.5	18	31.8	0.6
BH-010A		6.5	11.2	22.5	0.5
BH-011		3.5	238	115.2	2.1
BH-011		9.5	24.8	40.4	0.6
BH-012		5.5	24.3	250.2	0.1
BH-012		9.5	16.3	208.7	0.1
BH-014		4.5	20.2	16.4	1.2
BH-015		5.5	98.8	327.4	0.3
BH-015A		9.5	261.9	744.6	0.4
BH-015A		11.5	6.1	667	0.0
BH-015A		14.5	14	462	0.0
BH-016		7.5	6.3	7.8	0.8
BH-017		3.5	11.5	122.5	0.1
BH-021		2.5	10.4	9	1.2
BH-022		5.5	54.3	9.3	5.8
BH-026		4.5	24.9	21.9	1.1
BH-026		12.5	6.8	8.5	0.8
BH-031		10.5	9.7	26.5	0.4
BH-032		2	6.6	6.3	1.0
BH-034		3.5	6.3	6.9	0.9
BH-038		1	138.6	16.7	8.3
BH-039		1.5	23.3	21.1	1.1
BH-039		8.5	7.7	5	1.5
BH-041		3.5	61.5	5.9	10.4
BH-042		1	32	5	6.4
BH-042		11	9.7	5.3	1.8
BH-051		13.5	8.3	7.9	1.1
BH-052		4	29.4	1511	0.0
BH-053		2	7	9.8	0.7
BH-054		1.5	25.2	192	0.1
BH-055		15	9.6	60.7	0.2
BH-069	0.5	1	5.91	5.05	1.2
BH-086	6	7.5	11.4	7.1	1.6
BH-090	12	13.5	9.7	11.1	0.9
BH-091	12	13.5	28	24.3	1.2
BH-092	12	13.5	10.8	5.36	2.0
BH-112	0	2	11.5	6.06	1.9
BH-114	2	4	30.43	5.6	5.4
BH-121	0	1	6.73	82.51	0.1

ATTACHMENT C

Record of RESRAD Computations for Derivation of DCGL in C-T Soil

Pertinent RESRAD cases that are the bases of this report were provided in electronic form as RESRAD input and output files. RESRAD cases 408guti, 407guti, and 399guti, which are bases of C-T Phase II Decommissioning Plan, §5 Dose Modeling, Table 5-3 Composite Dose Factors and DCGLw in soil, are included herein.

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Dose Conversion Factor (and Related) Parameter Summary
Dose Library: FGR 11

Menu	Parameter	Current Value#	Base Case*	Parameter Name
A-1	DCF's for external ground radiation, (mrem/yr)/(pCi/g)			
A-1	Ac-228 (Source: FGR 12)	5.978E+00	5.978E+00	DCF1(1)
A-1	Bi-212 (Source: FGR 12)	1.171E+00	1.171E+00	DCF1(2)
A-1	Pb-212 (Source: FGR 12)	7.043E-01	7.043E-01	DCF1(3)
A-1	Po-212 (Source: FGR 12)	0.000E+00	0.000E+00	DCF1(4)
A-1	Po-216 (Source: FGR 12)	1.042E-04	1.042E-04	DCF1(5)
A-1	Ra-224 (Source: FGR 12)	5.119E-02	5.119E-02	DCF1(6)
A-1	Ra-228 (Source: FGR 12)	0.000E+00	0.000E+00	DCF1(7)
A-1	Rn-220 (Source: FGR 12)	2.298E-03	2.298E-03	DCF1(8)
A-1	Th-228 (Source: FGR 12)	7.940E-03	7.940E-03	DCF1(9)
A-1	Th-232 (Source: FGR 12)	5.212E-04	5.212E-04	DCF1(10)
A-1	Tl-208 (Source: FGR 12)	2.298E+01	2.298E+01	DCF1(11)
B-1	Dose conversion factors for inhalation, mrem/pCi:			
B-1	Ra-228+D	5.078E-03	4.770E-03	DCF2(1)
B-1	Th-228+D	3.454E-01	3.420E-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	1.442E-03	1.440E-03	DCF3(1)
D-1	Th-228+D	8.086E-04	3.960E-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)

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

Site-Specific Parameter Summary

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)	1.000E+00	2.000E+00	---	THICK0
R011	Length parallel to aquifer flow (m)	not used	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	2.500E+01	3.000E+01	---	BRDL
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	3.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	3.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	3.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(9)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): Ra-228	6.248E+00	0.000E+00	---	S1(1)
R012	Initial principal radionuclide (pCi/g): Th-228	6.248E+00	0.000E+00	---	S1(2)
R012	Initial principal radionuclide (pCi/g): Th-232	6.248E+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)	1.500E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	1.000E-03	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	4.000E-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)	4.000E+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)	0.000E+00	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)	not used	1.000E+06	---	WAREA
R013	Accuracy for water/soil computations	not used	1.000E-03	---	EPS
R014	Density of saturated zone (g/cm**3)	not used	1.500E+00	---	DENSAQ
R014	Saturated zone total porosity	not used	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	not used	2.000E-01	---	EPSZ
R014	Saturated zone field capacity	not used	2.000E-01	---	FCSZ
R014	Saturated zone hydraulic conductivity (m/yr)	not used	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	not used	2.000E-02	---	HGWT
R014	Saturated zone b parameter	not used	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	not used	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	not used	1.000E+01	---	DWIBWT

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	not used	ND	---	MODEL
R014	Well pumping rate (m**3/yr)	not used	2.500E+02	---	UW
R015	Number of unsaturated zone strata	not used	1	---	NS
R015	Unsat. zone 1, thickness (m)	not used	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	not used	1.500E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	not used	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	not used	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, field capacity	not used	2.000E-01	---	FCUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	not used	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	not used	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)	not used	7.000E+01	---	DCNUCU(1,1)
R016	Saturated zone (cm**3/g)	not used	7.000E+01	---	DCNUCS(1)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	3.798E-03	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)	not used	6.000E+04	---	DCNUCU(2,1)
R016	Saturated zone (cm**3/g)	not used	6.000E+04	---	DCNUCS(2)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	4.444E-06	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)	not used	6.000E+04	---	DCNUCU(3,1)
R016	Saturated zone (cm**3/g)	not used	6.000E+04	---	DCNUCS(3)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	4.444E-06	ALEACH(3)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(3)
R017	Inhalation rate (m**3/yr)	1.227E+04	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	3.500E-05	1.000E-04	---	MLINH
R017	Exposure duration	3.000E+01	3.000E+01	---	ED
R017	Shielding factor, inhalation	6.000E-01	4.000E-01	---	SHF3
R017	Shielding factor, external gamma	1.700E-01	7.000E-01	---	SHF1
R017	Fraction of time spent indoors	1.825E-01	5.000E-01	---	FIND
R017	Fraction of time spent outdoors (on site)	4.563E-02	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)
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)	not used	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	not used	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	not used	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	not used	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	not used	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	not used	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	3.650E+01	3.650E+01	---	SOIL
R018	Drinking water intake (L/yr)	not used	5.100E+02	---	DWI
R018	Contamination fraction of drinking water	not used	1.000E+00	---	FDW
R018	Contamination fraction of household water	not used	1.000E+00	---	FHHW
R018	Contamination fraction of livestock water	not used	1.000E+00	---	FLW
R018	Contamination fraction of irrigation water	not used	1.000E+00	---	FIRW
R018	Contamination fraction of aquatic food	not used	5.000E-01	---	FR9
R018	Contamination fraction of plant food	not used	-1	---	FPLANT
R018	Contamination fraction of meat	not used	-1	---	FMEAT
R018	Contamination fraction of milk	not used	-1	---	FMILK
R019	Livestock fodder intake for meat (kg/day)	not used	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	not used	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	not used	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	not used	1.600E+02	---	LWI6
R019	Livestock soil intake (kg/day)	not used	5.000E-01	---	LSI

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R019	Mass loading for foliar deposition (g/m**3)	not used	1.000E-04	---	MLFD
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	not used	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	not used	1.000E+00	---	FGWDW
R019	Household water fraction from ground water	not used	1.000E+00	---	FGWHH
R019	Livestock water fraction from ground water	not used	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	not used	1.000E+00	---	FGWIR
R19B	Wet weight crop yield for Non-Leafy (kg/m**2)	not used	7.000E-01	---	YV(1)
R19B	Wet weight crop yield for Leafy (kg/m**2)	not used	1.500E+00	---	YV(2)
R19B	Wet weight crop yield for Fodder (kg/m**2)	not used	1.100E+00	---	YV(3)
R19B	Growing Season for Non-Leafy (years)	not used	1.700E-01	---	TE(1)
R19B	Growing Season for Leafy (years)	not used	2.500E-01	---	TE(2)
R19B	Growing Season for Fodder (years)	not used	8.000E-02	---	TE(3)
R19B	Translocation Factor for Non-Leafy	not used	1.000E-01	---	TIV(1)
R19B	Translocation Factor for Leafy	not used	1.000E+00	---	TIV(2)
R19B	Translocation Factor for Fodder	not used	1.000E+00	---	TIV(3)
R19B	Dry Foliar Interception Fraction for Non-Leafy	not used	2.500E-01	---	RDRY(1)
R19B	Dry Foliar Interception Fraction for Leafy	not used	2.500E-01	---	RDRY(2)
R19B	Dry Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RDRY(3)
R19B	Wet Foliar Interception Fraction for Non-Leafy	not used	2.500E-01	---	RWET(1)
R19B	Wet Foliar Interception Fraction for Leafy	not used	2.500E-01	---	RWET(2)
R19B	Wet Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RWET(3)
R19B	Weathering Removal Constant for Vegetation	not used	2.000E+01	---	WLAM
C14	C-12 concentration in water (g/cm**3)	not used	2.000E-05	---	C12WTR
C14	C-12 concentration in contaminated soil (g/g)	not used	3.000E-02	---	C12CZ
C14	Fraction of vegetation carbon from soil	not used	2.000E-02	---	CSOIL
C14	Fraction of vegetation carbon from air	not used	9.800E-01	---	CAIR
C14	C-14 evasion layer thickness in soil (m)	not used	3.000E-01	---	DMC
C14	C-14 evasion flux rate from soil (1/sec)	not used	7.000E-07	---	EVSN
C14	C-12 evasion flux rate from soil (1/sec)	not used	1.000E-10	---	REVSN
C14	Fraction of grain in beef cattle feed	not used	8.000E-01	---	AVFG4
C14	Fraction of grain in milk cow feed	not used	2.000E-01	---	AVFG5
STOR	Storage times of contaminated foodstuffs (days):				
STOR	Fruits, non-leafy vegetables, and grain	1.400E+01	1.400E+01	---	STOR_T(1)
STOR	Leafy vegetables	1.000E+00	1.000E+00	---	STOR_T(2)
STOR	Milk	1.000E+00	1.000E+00	---	STOR_T(3)
STOR	Meat and poultry	2.000E+01	2.000E+01	---	STOR_T(4)
STOR	Fish	7.000E+00	7.000E+00	---	STOR_T(5)
STOR	Crustacea and mollusks	7.000E+00	7.000E+00	---	STOR_T(6)
STOR	Well water	1.000E+00	1.000E+00	---	STOR_T(7)
STOR	Surface water	1.000E+00	1.000E+00	---	STOR_T(8)
STOR	Livestock fodder	4.500E+01	4.500E+01	---	STOR_T(9)
R021	Thickness of building foundation (m)	not used	1.500E-01	---	FLOOR1
R021	Bulk density of building foundation (g/cm**3)	not used	2.400E+00	---	DENSFL
R021	Total porosity of the cover material	not used	4.000E-01	---	TPCV
R021	Total porosity of the building foundation	not used	1.000E-01	---	TPFL

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
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
TITL	Maximum number of integration points for risk	1	---	---	KYMAX

Summary of Pathway Selections

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

Contaminated Zone Dimensions		Initial Soil Concentrations, pCi/g	
Area:	10000.00 square meters	Ra-228	6.248E+00
Thickness:	1.00 meters	Th-228	6.248E+00
Cover Depth:	0.00 meters	Th-232	6.248E+00

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

t (years):	0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
TDOSE(t):	7.627E+00	7.613E+00	7.581E+00	7.486E+00	7.413E+00	7.403E+00	7.392E+00	0.000E+00
M(t):	3.051E-01	3.045E-01	3.032E-01	2.995E-01	2.965E-01	2.961E-01	2.957E-01	0.000E+00

Maximum TDOSE(t): 7.627E+00 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	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	3.246E+00	0.4256	2.223E-03	0.0003	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.705E-02	0.0101
Th-228	3.860E+00	0.5061	1.108E-02	0.0015	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.529E-02	0.0046
Th-232	1.859E-01	0.0244	6.283E-02	0.0082	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.466E-01	0.0192
Total	7.292E+00	0.9561	7.613E-02	0.0100	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.590E-01	0.0340

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.
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	3.325E+00	0.4360
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	3.907E+00	0.5122
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	3.954E-01	0.0518
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.627E+00	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)	Thread Fraction	DSR(j,t) At Time in Years (mrem/yr)/(pCi/g) 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Ra-228+D	Ra-228+D	1.000E+00	4.171E-01	3.683E-01	2.872E-01	1.203E-01	1.000E-02	1.659E-06	2.627E-17	0.000E+00
Ra-228+D	Th-228+D	1.000E+00	1.151E-01	2.797E-01	4.138E-01	2.823E-01	2.558E-02	4.245E-06	6.715E-17	0.000E+00
Ra-228+D	∑DSR(j)		5.322E-01	6.480E-01	7.010E-01	4.026E-01	3.558E-02	5.905E-06	9.342E-17	0.000E+00
Th-228+D	Th-228+D	1.000E+00	6.253E-01	4.352E-01	2.109E-01	1.669E-02	1.190E-05	1.150E-16	0.000E+00	0.000E+00
Th-232	Th-232	1.000E+00	3.281E-02	3.281E-02	3.281E-02	3.281E-02	3.281E-02	3.280E-02	3.277E-02	0.000E+00
Th-232	Ra-228+D	1.000E+00	2.566E-02	7.294E-02	1.516E-01	3.134E-01	4.203E-01	4.298E-01	4.294E-01	0.000E+00
Th-232	Th-228+D	1.000E+00	4.815E-03	2.951E-02	1.170E-01	4.327E-01	6.977E-01	7.223E-01	7.210E-01	0.000E+00
Th-232	∑DSR(j)		6.329E-02	1.353E-01	3.014E-01	7.789E-01	1.151E+00	1.185E+00	1.183E+00	0.000E+00

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

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 2.500E+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	4.697E+01	3.858E+01	3.566E+01	6.209E+01	7.027E+02	4.234E+06	*2.726E+14	*2.726E+14
Th-228	3.998E+01	5.744E+01	1.186E+02	1.498E+03	2.101E+06	*8.195E+14	*8.195E+14	*8.195E+14
Th-232	3.950E+02	1.848E+02	8.295E+01	3.210E+01	2.172E+01	2.110E+01	2.113E+01	*1.097E+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	6.248E+00	2.628 ± 0.005	7.031E-01	3.556E+01	5.322E-01	4.697E+01
Th-228	6.248E+00	0.000E+00	6.253E-01	3.998E+01	6.253E-01	3.998E+01
Th-232	6.248E+00	83.0 ± 0.2	1.185E+00	2.110E+01	6.329E-02	3.950E+02

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

Nuclide (j)	Parent (i)	THF(i)	DOSE(j,t), mrem/yr t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Ra-228	Ra-228	1.000E+00	2.606E+00	2.301E+00	1.795E+00	7.515E-01	6.250E-02	1.037E-05	1.641E-16	0.000E+00
Ra-228	Th-232	1.000E+00	1.603E-01	4.557E-01	9.469E-01	1.958E+00	2.626E+00	2.685E+00	2.683E+00	0.000E+00
Ra-228	∑DOSE(j)		2.766E+00	2.757E+00	2.741E+00	2.709E+00	2.688E+00	2.685E+00	2.683E+00	0.000E+00
Th-228	Ra-228	1.000E+00	7.194E-01	1.748E+00	2.586E+00	1.764E+00	1.598E-01	2.653E-05	4.196E-16	0.000E+00
Th-228	Th-228	1.000E+00	3.907E+00	2.719E+00	1.318E+00	1.043E-01	7.434E-05	7.185E-16	0.000E+00	0.000E+00
Th-228	Th-232	1.000E+00	3.008E-02	1.844E-01	7.311E-01	2.704E+00	4.359E+00	4.513E+00	4.505E+00	0.000E+00
Th-228	∑DOSE(j)		4.656E+00	4.651E+00	4.634E+00	4.572E+00	4.519E+00	4.513E+00	4.505E+00	0.000E+00
Th-232	Th-232	1.000E+00	2.050E-01	2.050E-01	2.050E-01	2.050E-01	2.050E-01	2.049E-01	2.047E-01	0.000E+00

THF(i) is the thread fraction of the parent nuclide.

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	THF(i)	S(j,t), pCi/g t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Ra-228	Ra-228	1.000E+00	6.248E+00	5.517E+00	4.303E+00	1.802E+00	1.499E-01	2.486E-05	3.935E-16	0.000E+00
Ra-228	Th-232	1.000E+00	0.000E+00	7.082E-01	1.886E+00	4.310E+00	5.911E+00	6.055E+00	6.049E+00	6.031E+00
Ra-228	∑S(j):		6.248E+00	6.226E+00	6.189E+00	6.112E+00	6.061E+00	6.055E+00	6.049E+00	6.031E+00
Th-228	Ra-228	1.000E+00	0.000E+00	1.779E+00	3.343E+00	2.489E+00	2.280E-01	3.785E-05	5.991E-16	0.000E+00
Th-228	Th-228	1.000E+00	6.248E+00	4.349E+00	2.107E+00	1.668E-01	1.189E-04	1.149E-15	0.000E+00	0.000E+00
Th-228	Th-232	1.000E+00	0.000E+00	1.163E-01	7.738E-01	3.482E+00	5.835E+00	6.055E+00	6.049E+00	6.031E+00
Th-228	∑S(j):		6.248E+00	6.244E+00	6.224E+00	6.138E+00	6.064E+00	6.055E+00	6.049E+00	6.031E+00
Th-232	Th-232	1.000E+00	6.248E+00	6.248E+00	6.248E+00	6.248E+00	6.247E+00	6.245E+00	6.240E+00	6.220E+00

THF(i) is the thread fraction of the parent nuclide.

RESCALC.EXE execution time = 93.68 seconds

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Probabilistic Input

Number of Sample Runs: 1200

Number	Name	Distribution	Parameters							
1	THICK0	UNIFORM	0	1						
2	MLINH	CONTINUOUS LINEAR	8	0	0	.000015	.0151	.000023	.1365	.0000
3	SHF1	DISCRETE CUMULATIVE	8	.0084	.01	.022	.09	.035	.21	.055

Probabilistic Total Dose Summary

Nuclide (j)	Peak Time	Peak Dose	DOSE(j,t), mrem/yr t= 0.00E+00	1.00E+00	3.00E+00	1.00E+01	3.00E+01	1.00E+02	3.00E+02	1.00E+03
Ra-228										
Min	0.00E+00	6.13E-05	6.13E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Max	2.64E+00	1.29E+01	9.74E+00	1.19E+01	1.29E+01	7.40E+00	6.52E-01	1.07E-04	1.66E-15	0.00E+00
Avg	2.38E+00	3.70E+00	2.87E+00	3.45E+00	3.67E+00	2.01E+00	1.58E-01	1.99E-05	1.96E-16	0.00E+00
Std	4.71E-01	2.15E+00	1.63E+00	1.99E+00	2.15E+00	1.24E+00	1.07E-01	1.66E-05	2.27E-16	0.00E+00
Th-228										
Min	0.00E+00	9.00E-05	9.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Max	0.00E+00	1.15E+01	1.15E+01	8.03E+00	3.89E+00	3.08E-01	2.19E-04	2.12E-15	0.00E+00	0.00E+00
Avg	0.00E+00	3.33E+00	3.33E+00	2.32E+00	1.12E+00	8.80E-02	6.13E-05	5.47E-16	0.00E+00	0.00E+00
Std	0.00E+00	1.92E+00	1.92E+00	1.34E+00	6.50E-01	5.18E-02	3.77E-05	3.81E-16	0.00E+00	0.00E+00
Th-232										
Min	0.00E+00	1.69E-06	1.69E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Max	1.77E+02	2.13E+01	8.19E-01	2.13E+00	5.15E+00	1.39E+01	2.07E+01	2.13E+01	2.13E+01	0.00E+00
Avg	6.20E+01	5.90E+00	3.48E-01	7.33E-01	1.61E+00	4.04E+00	5.74E+00	5.50E+00	4.22E+00	0.00E+00
Std	3.23E+01	3.55E+00	1.16E-01	3.32E-01	8.42E-01	2.32E+00	3.50E+00	3.77E+00	4.00E+00	0.00E+00
∑ALL										
Min	0.00E+00	1.53E-04	1.53E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Max	0.00E+00	2.21E+01	2.21E+01	2.20E+01	2.19E+01	2.16E+01	2.14E+01	2.13E+01	2.13E+01	0.00E+00
Avg	0.00E+00	6.54E+00	6.54E+00	6.50E+00	6.40E+00	6.14E+00	5.90E+00	5.50E+00	4.22E+00	0.00E+00
Std	0.00E+00	3.66E+00	3.66E+00	3.65E+00	3.64E+00	3.61E+00	3.61E+00	3.77E+00	4.00E+00	0.00E+00

∑ALL is total dose summed for all nuclides.

Cumulative Probability Summary for: Total Dose Over Pathways

Cumulative Probability	Dose(t), mrem/yr t= 0.00E+00	1.00E+00	3.00E+00	1.00E+01	3.00E+01	1.00E+02	3.00E+02	1.00E+03
0.025	1.93E+00	1.72E+00	1.36E+00	7.46E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.050	2.89E+00	2.78E+00	2.55E+00	1.78E+00	1.03E+00	0.00E+00	0.00E+00	0.00E+00
0.075	3.79E+00	3.69E+00	3.44E+00	2.69E+00	1.96E+00	0.00E+00	0.00E+00	0.00E+00
0.100	4.43E+00	4.35E+00	4.13E+00	3.58E+00	2.91E+00	0.00E+00	0.00E+00	0.00E+00
0.125	4.79E+00	4.73E+00	4.57E+00	4.08E+00	3.56E+00	1.56E+00	0.00E+00	0.00E+00
0.150	4.92E+00	4.87E+00	4.75E+00	4.41E+00	3.98E+00	2.34E+00	0.00E+00	0.00E+00
0.175	5.03E+00	5.00E+00	4.90E+00	4.67E+00	4.37E+00	3.31E+00	0.00E+00	0.00E+00
0.200	5.04E+00	5.03E+00	4.98E+00	4.81E+00	4.59E+00	3.93E+00	0.00E+00	0.00E+00
0.225	5.12E+00	5.07E+00	5.02E+00	4.90E+00	4.73E+00	4.26E+00	0.00E+00	0.00E+00
0.250	5.24E+00	5.22E+00	5.16E+00	4.94E+00	4.82E+00	4.58E+00	0.00E+00	0.00E+00
0.275	5.26E+00	5.24E+00	5.20E+00	5.01E+00	4.88E+00	4.72E+00	0.00E+00	0.00E+00
0.300	5.28E+00	5.26E+00	5.22E+00	5.08E+00	4.94E+00	4.82E+00	0.00E+00	0.00E+00
0.325	5.36E+00	5.31E+00	5.25E+00	5.13E+00	5.01E+00	4.88E+00	1.91E+00	0.00E+00
0.350	5.55E+00	5.51E+00	5.38E+00	5.17E+00	5.07E+00	4.96E+00	2.72E+00	0.00E+00
0.375	5.59E+00	5.57E+00	5.51E+00	5.28E+00	5.11E+00	5.03E+00	3.54E+00	0.00E+00
0.400	5.61E+00	5.59E+00	5.54E+00	5.38E+00	5.23E+00	5.08E+00	4.19E+00	0.00E+00
0.425	5.62E+00	5.60E+00	5.56E+00	5.43E+00	5.30E+00	5.14E+00	4.52E+00	0.00E+00
0.450	5.63E+00	5.61E+00	5.58E+00	5.47E+00	5.36E+00	5.28E+00	4.73E+00	0.00E+00
0.475	5.72E+00	5.64E+00	5.59E+00	5.50E+00	5.41E+00	5.34E+00	4.84E+00	0.00E+00
0.500	6.04E+00	5.98E+00	5.86E+00	5.53E+00	5.45E+00	5.38E+00	4.90E+00	0.00E+00
0.525	6.15E+00	6.12E+00	6.05E+00	5.79E+00	5.54E+00	5.43E+00	5.02E+00	0.00E+00
0.550	6.16E+00	6.14E+00	6.09E+00	5.91E+00	5.73E+00	5.47E+00	5.08E+00	0.00E+00
0.575	6.17E+00	6.15E+00	6.11E+00	5.96E+00	5.83E+00	5.70E+00	5.24E+00	0.00E+00
0.600	6.18E+00	6.17E+00	6.13E+00	6.01E+00	5.89E+00	5.83E+00	5.34E+00	0.00E+00
0.625	6.19E+00	6.18E+00	6.14E+00	6.04E+00	5.94E+00	5.88E+00	5.39E+00	0.00E+00
0.650	6.20E+00	6.19E+00	6.15E+00	6.06E+00	5.97E+00	5.94E+00	5.44E+00	0.00E+00
0.675	6.23E+00	6.21E+00	6.18E+00	6.07E+00	6.00E+00	5.97E+00	5.66E+00	0.00E+00
0.700	6.72E+00	6.66E+00	6.53E+00	6.13E+00	6.02E+00	6.00E+00	5.88E+00	0.00E+00
0.725	7.00E+00	6.95E+00	6.85E+00	6.56E+00	6.33E+00	6.03E+00	5.93E+00	0.00E+00
0.750	7.05E+00	7.03E+00	6.96E+00	6.75E+00	6.57E+00	6.42E+00	5.95E+00	0.00E+00
0.775	7.07E+00	7.05E+00	6.98E+00	6.81E+00	6.68E+00	6.65E+00	5.99E+00	0.00E+00
0.800	7.08E+00	7.05E+00	7.01E+00	6.87E+00	6.75E+00	6.72E+00	6.06E+00	0.00E+00
0.825	7.09E+00	7.07E+00	7.03E+00	6.90E+00	6.81E+00	6.79E+00	6.62E+00	0.00E+00
0.850	7.10E+00	7.08E+00	7.04E+00	6.93E+00	6.85E+00	6.82E+00	6.76E+00	0.00E+00
0.875	7.12E+00	7.10E+00	7.07E+00	6.97E+00	6.88E+00	6.87E+00	6.80E+00	0.00E+00
0.900	8.34E+00	8.27E+00	8.12E+00	7.71E+00	7.33E+00	6.94E+00	6.85E+00	0.00E+00
0.925	8.63E+00	8.60E+00	8.52E+00	8.31E+00	8.15E+00	8.12E+00	6.89E+00	0.00E+00
0.950	8.68E+00	8.66E+00	8.62E+00	8.49E+00	8.40E+00	8.39E+00	8.28E+00	0.00E+00
0.975	2.20E+01	2.19E+01	2.17E+01	2.11E+01	2.07E+01	2.07E+01	1.97E+01	0.00E+00
1.000	2.21E+01	2.20E+01	2.19E+01	2.16E+01	2.14E+01	2.13E+01	2.13E+01	0.00E+00

Probabilistic results summary : 1Thorium series in soil, industrial, probabilit-
y File: C:\RESRAD_FAMILY\RESRAD\USERFILES\408GUTI.RAD

Peak of the mean dose (averaged over observations) at graphical times

Repetition	Time of peak mean dose	Peak mean dose
	Years	mrem/yr
1	0.000E+00	6.517E+00
2	0.000E+00	6.571E+00
3	0.000E+00	6.563E+00
4	0.000E+00	6.522E+00

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Dose Conversion Factor (and Related) Parameter Summary
Dose Library: FGR 11

Menu	Parameter	Current Value#	Base Case*	Parameter Name
A-1	DCF's for external ground radiation, (mrem/yr)/(pCi/g)			
A-1	Ac-227 (Source: FGR 12)	4.951E-04	4.951E-04	DCF1(1)
A-1	At-218 (Source: FGR 12)	5.847E-03	5.847E-03	DCF1(2)
A-1	Bi-210 (Source: FGR 12)	3.606E-03	3.606E-03	DCF1(3)
A-1	Bi-211 (Source: FGR 12)	2.559E-01	2.559E-01	DCF1(4)
A-1	Bi-214 (Source: FGR 12)	9.808E+00	9.808E+00	DCF1(5)
A-1	Fr-223 (Source: FGR 12)	1.980E-01	1.980E-01	DCF1(6)
A-1	Pa-231 (Source: FGR 12)	1.906E-01	1.906E-01	DCF1(7)
A-1	Pa-234 (Source: FGR 12)	1.155E+01	1.155E+01	DCF1(8)
A-1	Pa-234m (Source: FGR 12)	8.967E-02	8.967E-02	DCF1(9)
A-1	Pb-210 (Source: FGR 12)	2.447E-03	2.447E-03	DCF1(10)
A-1	Pb-211 (Source: FGR 12)	3.064E-01	3.064E-01	DCF1(11)
A-1	Pb-214 (Source: FGR 12)	1.341E+00	1.341E+00	DCF1(12)
A-1	Po-210 (Source: FGR 12)	5.231E-05	5.231E-05	DCF1(13)
A-1	Po-211 (Source: FGR 12)	4.764E-02	4.764E-02	DCF1(14)
A-1	Po-214 (Source: FGR 12)	5.138E-04	5.138E-04	DCF1(15)
A-1	Po-215 (Source: FGR 12)	1.016E-03	1.016E-03	DCF1(16)
A-1	Po-218 (Source: FGR 12)	5.642E-05	5.642E-05	DCF1(17)
A-1	Ra-223 (Source: FGR 12)	6.034E-01	6.034E-01	DCF1(18)
A-1	Ra-226 (Source: FGR 12)	3.176E-02	3.176E-02	DCF1(19)
A-1	Rn-219 (Source: FGR 12)	3.083E-01	3.083E-01	DCF1(20)
A-1	Rn-222 (Source: FGR 12)	2.354E-03	2.354E-03	DCF1(21)
A-1	Th-227 (Source: FGR 12)	5.212E-01	5.212E-01	DCF1(22)
A-1	Th-230 (Source: FGR 12)	1.209E-03	1.209E-03	DCF1(23)
A-1	Th-231 (Source: FGR 12)	3.643E-02	3.643E-02	DCF1(24)
A-1	Th-234 (Source: FGR 12)	2.410E-02	2.410E-02	DCF1(25)
A-1	Tl-207 (Source: FGR 12)	1.980E-02	1.980E-02	DCF1(26)
A-1	Tl-210 (Source: no data)	0.000E+00	-2.000E+00	DCF1(27)
A-1	U-234 (Source: FGR 12)	4.017E-04	4.017E-04	DCF1(28)
A-1	U-235 (Source: FGR 12)	7.211E-01	7.211E-01	DCF1(29)
A-1	U-238 (Source: FGR 12)	1.031E-04	1.031E-04	DCF1(30)
B-1	Dose conversion factors for inhalation, mrem/pCi:			
B-1	Ac-227+D	6.724E+00	6.700E+00	DCF2(1)
B-1	Pa-231	1.280E+00	1.280E+00	DCF2(2)
B-1	Pb-210+D	2.320E-02	1.360E-02	DCF2(3)
B-1	Ra-226+D	8.594E-03	8.580E-03	DCF2(4)
B-1	Th-230	3.260E-01	3.260E-01	DCF2(5)
B-1	U-234	1.320E-01	1.320E-01	DCF2(6)
B-1	U-235+D	1.230E-01	1.230E-01	DCF2(7)
B-1	U-238	1.180E-01	1.180E-01	DCF2(8)
B-1	U-238+D	1.180E-01	1.180E-01	DCF2(9)
D-1	Dose conversion factors for ingestion, mrem/pCi:			
D-1	Ac-227+D	1.480E-02	1.410E-02	DCF3(1)
D-1	Pa-231	1.060E-02	1.060E-02	DCF3(2)
D-1	Pb-210+D	7.276E-03	5.370E-03	DCF3(3)
D-1	Ra-226+D	1.321E-03	1.320E-03	DCF3(4)
D-1	Th-230	5.480E-04	5.480E-04	DCF3(5)
D-1	U-234	2.830E-04	2.830E-04	DCF3(6)

Dose Conversion Factor (and Related) Parameter Summary (continued)
Dose Library: FGR 11

Menu	Parameter	Current Value#	Base Case*	Parameter Name
D-1	U-235+D	2.673E-04	2.660E-04	DCF3(7)
D-1	U-238	2.550E-04	2.550E-04	DCF3(8)
D-1	U-238+D	2.687E-04	2.550E-04	DCF3(9)
D-34	Food transfer factors:			
D-34	Ac-227+D , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(1,1)
D-34	Ac-227+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	2.000E-05	2.000E-05	RTF(1,2)
D-34	Ac-227+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	2.000E-05	2.000E-05	RTF(1,3)
D-34				
D-34	Pa-231 , plant/soil concentration ratio, dimensionless	1.000E-02	1.000E-02	RTF(2,1)
D-34	Pa-231 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	5.000E-03	5.000E-03	RTF(2,2)
D-34	Pa-231 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(2,3)
D-34				
D-34	Pb-210+D , plant/soil concentration ratio, dimensionless	1.000E-02	1.000E-02	RTF(3,1)
D-34	Pb-210+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	8.000E-04	8.000E-04	RTF(3,2)
D-34	Pb-210+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	3.000E-04	3.000E-04	RTF(3,3)
D-34				
D-34	Ra-226+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(4,1)
D-34	Ra-226+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(4,2)
D-34	Ra-226+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(4,3)
D-34				
D-34	Th-230 , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(5,1)
D-34	Th-230 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(5,2)
D-34	Th-230 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(5,3)
D-34				
D-34	U-234 , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(6,1)
D-34	U-234 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(6,2)
D-34	U-234 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(6,3)
D-34				
D-34	U-235+D , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(7,1)
D-34	U-235+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(7,2)
D-34	U-235+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(7,3)
D-34				
D-34	U-238 , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(8,1)
D-34	U-238 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(8,2)
D-34	U-238 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(8,3)
D-34				
D-34	U-238+D , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(9,1)
D-34	U-238+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(9,2)
D-34	U-238+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(9,3)
D-5	Bioaccumulation factors, fresh water, L/kg:			
D-5	Ac-227+D , fish	1.500E+01	1.500E+01	BIOFAC(1,1)
D-5	Ac-227+D , crustacea and mollusks	1.000E+03	1.000E+03	BIOFAC(1,2)
D-5				
D-5	Pa-231 , fish	1.000E+01	1.000E+01	BIOFAC(2,1)
D-5	Pa-231 , crustacea and mollusks	1.100E+02	1.100E+02	BIOFAC(2,2)
D-5				
D-5	Pb-210+D , fish	3.000E+02	3.000E+02	BIOFAC(3,1)
D-5	Pb-210+D , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC(3,2)

Dose Conversion Factor (and Related) Parameter Summary (continued)
Dose Library: FGR 11

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

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

Site-Specific Parameter Summary

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)	1.000E+00	2.000E+00	---	THICK0
R011	Length parallel to aquifer flow (m)	not used	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	2.500E+01	3.000E+01	---	BRDL
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	1.000E+01	3.000E+00	---	T(3)
R011	Times for calculations (yr)	3.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	1.000E+02	3.000E+01	---	T(5)
R011	Times for calculations (yr)	3.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	6.000E+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): Ac-227	2.843E-01	0.000E+00	---	S1(1)
R012	Initial principal radionuclide (pCi/g): Pa-231	2.843E-01	0.000E+00	---	S1(2)
R012	Initial principal radionuclide (pCi/g): U-234	6.248E+00	0.000E+00	---	S1(6)
R012	Initial principal radionuclide (pCi/g): U-235	2.843E-01	0.000E+00	---	S1(7)
R012	Initial principal radionuclide (pCi/g): U-238	6.248E+00	0.000E+00	---	S1(8)
R012	Concentration in groundwater (pCi/L): Ac-227	not used	0.000E+00	---	W1(1)
R012	Concentration in groundwater (pCi/L): Pa-231	not used	0.000E+00	---	W1(2)
R012	Concentration in groundwater (pCi/L): U-234	not used	0.000E+00	---	W1(6)
R012	Concentration in groundwater (pCi/L): U-235	not used	0.000E+00	---	W1(7)
R012	Concentration in groundwater (pCi/L): U-238	not used	0.000E+00	---	W1(8)
R013	Cover depth (m)	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)	1.500E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	1.000E-03	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	4.000E-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)	4.000E+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)	0.000E+00	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)	not used	1.000E+06	---	WAREA
R013	Accuracy for water/soil computations	not used	1.000E-03	---	EPS
R014	Density of saturated zone (g/cm**3)	not used	1.500E+00	---	DENSAQ
R014	Saturated zone total porosity	not used	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	not used	2.000E-01	---	EPSZ
R014	Saturated zone field capacity	not used	2.000E-01	---	FCSZ
R014	Saturated zone hydraulic conductivity (m/yr)	not used	1.000E+02	---	HCSZ

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R014	Saturated zone hydraulic gradient	not used	2.000E-02	---	HGWT
R014	Saturated zone b parameter	not used	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	not used	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	not used	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	not used	ND	---	MODEL
R014	Well pumping rate (m**3/yr)	not used	2.500E+02	---	UW
R015	Number of unsaturated zone strata	not used	1	---	NS
R015	Unsat. zone 1, thickness (m)	not used	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	not used	1.500E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	not used	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	not used	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, field capacity	not used	2.000E-01	---	FCUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	not used	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	not used	1.000E+01	---	HCUZ(1)
R016	Distribution coefficients for Ac-227				
R016	Contaminated zone (cm**3/g)	8.250E+02	2.000E+01	---	DCNUCC(1)
R016	Unsaturated zone 1 (cm**3/g)	not used	2.000E+01	---	DCNUCU(1,1)
R016	Saturated zone (cm**3/g)	not used	2.000E+01	---	DCNUCS(1)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	3.231E-04	ALEACH(1)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(1)
R016	Distribution coefficients for Pa-231				
R016	Contaminated zone (cm**3/g)	3.800E+02	5.000E+01	---	DCNUCC(2)
R016	Unsaturated zone 1 (cm**3/g)	not used	5.000E+01	---	DCNUCU(2,1)
R016	Saturated zone (cm**3/g)	not used	5.000E+01	---	DCNUCS(2)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	7.014E-04	ALEACH(2)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(2)
R016	Distribution coefficients for U-234				
R016	Contaminated zone (cm**3/g)	1.260E+02	5.000E+01	---	DCNUCC(6)
R016	Unsaturated zone 1 (cm**3/g)	not used	5.000E+01	---	DCNUCU(6,1)
R016	Saturated zone (cm**3/g)	not used	5.000E+01	---	DCNUCS(6)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.113E-03	ALEACH(6)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(6)
R016	Distribution coefficients for U-235				
R016	Contaminated zone (cm**3/g)	1.260E+02	5.000E+01	---	DCNUCC(7)
R016	Unsaturated zone 1 (cm**3/g)	not used	5.000E+01	---	DCNUCU(7,1)
R016	Saturated zone (cm**3/g)	not used	5.000E+01	---	DCNUCS(7)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.113E-03	ALEACH(7)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(7)
R016	Distribution coefficients for U-238				
R016	Contaminated zone (cm**3/g)	1.260E+02	5.000E+01	---	DCNUCC(8)
R016	Unsaturated zone 1 (cm**3/g)	not used	5.000E+01	---	DCNUCU(8,1)
R016	Saturated zone (cm**3/g)	not used	5.000E+01	---	DCNUCS(8)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.113E-03	ALEACH(8)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(8)

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for daughter Pb-210				
R016	Contaminated zone (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCC(3)
R016	Unsaturated zone 1 (cm**3/g)	not used	1.000E+02	---	DCNUCU(3,1)
R016	Saturated zone (cm**3/g)	not used	1.000E+02	---	DCNUCS(3)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.661E-03	ALEACH(3)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(3)
R016	Distribution coefficients for daughter Ra-226				
R016	Contaminated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCC(4)
R016	Unsaturated zone 1 (cm**3/g)	not used	7.000E+01	---	DCNUCU(4,1)
R016	Saturated zone (cm**3/g)	not used	7.000E+01	---	DCNUCS(4)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	3.798E-03	ALEACH(4)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(4)
R016	Distribution coefficients for daughter Th-230				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(5)
R016	Unsaturated zone 1 (cm**3/g)	not used	6.000E+04	---	DCNUCU(5,1)
R016	Saturated zone (cm**3/g)	not used	6.000E+04	---	DCNUCS(5)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	4.444E-06	ALEACH(5)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(5)
R017	Inhalation rate (m**3/yr)	1.227E+04	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	3.500E-05	1.000E-04	---	MLINH
R017	Exposure duration	3.000E+01	3.000E+01	---	ED
R017	Shielding factor, inhalation	6.000E-01	4.000E-01	---	SHF3
R017	Shielding factor, external gamma	1.700E-01	7.000E-01	---	SHF1
R017	Fraction of time spent indoors	1.825E-01	5.000E-01	---	FIND
R017	Fraction of time spent outdoors (on site)	4.563E-02	2.500E-01	---	FOTD
R017	Shape factor flag, external gamma	1.000E+00	1.000E+00	>0 shows circular AREA.	FS
R017	Radii of shape factor array (used if FS = -1):				
R017	Outer annular radius (m), ring 1:	not used	5.000E+01	---	RAD_SHAPE(1)
R017	Outer annular radius (m), ring 2:	not used	7.071E+01	---	RAD_SHAPE(2)
R017	Outer annular radius (m), ring 3:	not used	0.000E+00	---	RAD_SHAPE(3)
R017	Outer annular radius (m), ring 4:	not used	0.000E+00	---	RAD_SHAPE(4)
R017	Outer annular radius (m), ring 5:	not used	0.000E+00	---	RAD_SHAPE(5)
R017	Outer annular radius (m), ring 6:	not used	0.000E+00	---	RAD_SHAPE(6)
R017	Outer annular radius (m), ring 7:	not used	0.000E+00	---	RAD_SHAPE(7)
R017	Outer annular radius (m), ring 8:	not used	0.000E+00	---	RAD_SHAPE(8)
R017	Outer annular radius (m), ring 9:	not used	0.000E+00	---	RAD_SHAPE(9)
R017	Outer annular radius (m), ring 10:	not used	0.000E+00	---	RAD_SHAPE(10)
R017	Outer annular radius (m), ring 11:	not used	0.000E+00	---	RAD_SHAPE(11)
R017	Outer annular radius (m), ring 12:	not used	0.000E+00	---	RAD_SHAPE(12)

Site-Specific Parameter Summary (continued)

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

Site-Specific Parameter Summary (continued)

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

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
TITL	Maximum number of integration points for dose	17	---	---	LYMAX
TITL	Maximum number of integration points for risk	1	---	---	KYMAX

Summary of Pathway Selections

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

Contaminated Zone Dimensions	
Area:	10000.00 square meters
Thickness:	1.00 meters
Cover Depth:	0.00 meters

Initial Soil Concentrations, pCi/g	
Ac-227	2.843E-01
Pa-231	2.843E-01
U-234	6.248E+00
U-235	2.843E-01
U-238	6.248E+00

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

t (years):	0.000E+00	1.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	6.000E+02	1.000E+03
TDOSE(t):	2.429E-01	2.426E-01	2.398E-01	2.335E-01	2.124E-01	1.637E-01	1.153E-01	0.000E+00
M(t):	9.717E-03	9.705E-03	9.592E-03	9.340E-03	8.495E-03	6.546E-03	4.613E-03	0.000E+00

Maximum TDOSE(t): 2.429E-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	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ac-227	4.088E-02	0.1683	1.152E-02	0.0474	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.447E-02	0.1419
Pa-231	4.580E-03	0.0189	2.411E-03	0.0099	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.564E-02	0.1055
U-234	1.853E-04	0.0008	5.044E-03	0.0208	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.471E-02	0.0605
U-235	1.571E-02	0.0647	2.139E-04	0.0009	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.325E-04	0.0026
U-238	6.847E-02	0.2819	4.510E-03	0.0186	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.396E-02	0.0575
Total	1.298E-01	0.5344	2.370E-02	0.0975	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.941E-02	0.3681

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.
Ac-227	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.687E-02	0.35[illegible]
Pa-231	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.263E-02	0.1343
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.994E-02	0.0821
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.655E-02	0.0681
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.694E-02	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	2.429E-01	1.0000

*Sum of all water independent and dependent pathways.

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Probabilistic Input

Number of Sample Runs: 900

Number	Name	Distribution	Parameters							
1	THICK0	UNIFORM	0	1						
2	MLINH	CONTINUOUS LINEAR	8	0	0	.000015	.0151	.000023	.1365	.0000
3	SHF1	DISCRETE CUMULATIVE	8	.0084	.01	.022	.09	.035	.21	.055

Probabilistic Total Dose Summary

Nuclide (j)	Peak Time	Peak Dose	DOSE(j,t), mrem/yr t= 0.00E+00	1.00E+00	1.00E+01	3.00E+01	1.00E+02	3.00E+02	6.00E+02	1.00E+03
Ac-227										
Min	0.00E+00	1.55E-06	1.55E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Max	0.00E+00	1.74E-01	1.74E-01	1.69E-01	1.26E-01	6.62E-02	6.89E-03	1.08E-05	6.96E-10	0.00E+00
Avg	0.00E+00	7.77E-02	7.77E-02	7.51E-02	5.54E-02	2.82E-02	2.69E-03	3.22E-06	1.11E-10	0.00E+00
Std	0.00E+00	2.52E-02	2.52E-02	2.45E-02	1.91E-02	1.08E-02	1.32E-03	2.53E-06	1.55E-10	0.00E+00
Pa-231										
Min	0.00E+00	3.45E-07	3.45E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Max	1.13E+02	1.92E-01	4.31E-02	4.85E-02	8.98E-02	1.47E-01	1.92E-01	1.68E-01	1.34E-01	0.00E+00
Avg	7.88E+01	8.70E-02	2.97E-02	3.21E-02	4.95E-02	7.15E-02	8.13E-02	5.28E-02	2.29E-02	0.00E+00
Std	3.09E+01	3.24E-02	6.98E-03	7.74E-03	1.43E-02	2.51E-02	3.89E-02	4.13E-02	3.19E-02	0.00E+00
U-234										
Min	0.00E+00	2.15E-07	2.15E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Max	0.00E+00	2.84E-02	2.84E-02	2.83E-02	2.74E-02	2.56E-02	2.15E-02	1.43E-02	8.63E-03	0.00E+00
Avg	0.00E+00	1.79E-02	1.79E-02	1.78E-02	1.67E-02	1.48E-02	1.05E-02	4.92E-03	1.72E-03	0.00E+00
Std	0.00E+00	4.37E-03	4.37E-03	4.44E-03	4.87E-03	5.31E-03	5.46E-03	4.13E-03	2.46E-03	0.00E+00
U-235										
Min	0.00E+00	5.04E-07	5.04E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Max	0.00E+00	4.80E-02	4.80E-02	4.77E-02	4.65E-02	4.46E-02	3.85E-02	2.56E-02	1.41E-02	0.00E+00
Avg	0.00E+00	1.47E-02	1.47E-02	1.46E-02	1.37E-02	1.21E-02	8.60E-03	4.01E-03	1.34E-03	0.00E+00
Std	0.00E+00	7.94E-03	7.94E-03	7.93E-03	7.81E-03	7.45E-03	6.32E-03	4.06E-03	2.10E-03	0.00E+00
U-238										
Min	0.00E+00	2.18E-06	2.18E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Max	0.00E+00	2.25E-01	2.25E-01	2.24E-01	2.18E-01	2.08E-01	1.78E-01	1.15E-01	6.05E-02	0.00E+00
Avg	0.00E+00	7.66E-02	7.66E-02	7.60E-02	7.12E-02	6.30E-02	4.44E-02	1.97E-02	5.93E-03	0.00E+00
Std	0.00E+00	3.57E-02	3.57E-02	3.58E-02	3.57E-02	3.47E-02	3.01E-02	1.93E-02	9.24E-03	0.00E+00
∑ALL										
Min	0.00E+00	4.79E-06	4.79E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Max	0.00E+00	5.13E-01	5.13E-01	5.12E-01	5.03E-01	4.82E-01	4.28E-01	3.18E-01	2.17E-01	0.00E+00
Avg	0.00E+00	2.17E-01	2.17E-01	2.16E-01	2.06E-01	1.90E-01	1.48E-01	8.15E-02	3.19E-02	0.00E+00
Std	0.00E+00	7.59E-02	7.59E-02	7.62E-02	7.84E-02	8.02E-02	7.96E-02	6.74E-02	4.53E-02	0.00E+00

∑ALL is total dose summed for all nuclides.

Cumulative Probability Summary for: Total Dose Over Pathways

Cumulative	Dose(t), mrem/yr							
Probability	t= 0.00E+00	1.00E+00	1.00E+01	3.00E+01	1.00E+02	3.00E+02	6.00E+02	1.00E+03
0.025	5.92E-02	5.37E-02	2.42E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.050	1.01E-01	9.64E-02	6.65E-02	2.50E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.075	1.34E-01	1.30E-01	1.01E-01	5.47E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.100	1.66E-01	1.63E-01	1.38E-01	9.27E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.125	1.84E-01	1.82E-01	1.64E-01	1.20E-01	2.20E-02	0.00E+00	0.00E+00	0.00E+00
0.150	1.90E-01	1.90E-01	1.78E-01	1.41E-01	4.44E-02	0.00E+00	0.00E+00	0.00E+00
0.175	1.93E-01	1.92E-01	1.85E-01	1.65E-01	6.69E-02	0.00E+00	0.00E+00	0.00E+00
0.200	1.94E-01	1.94E-01	1.88E-01	1.72E-01	9.62E-02	0.00E+00	0.00E+00	0.00E+00
0.225	1.96E-01	1.95E-01	1.89E-01	1.75E-01	1.12E-01	0.00E+00	0.00E+00	0.00E+00
0.250	1.97E-01	1.96E-01	1.91E-01	1.79E-01	1.25E-01	0.00E+00	0.00E+00	0.00E+00
0.275	1.98E-01	1.98E-01	1.92E-01	1.81E-01	1.35E-01	0.00E+00	0.00E+00	0.00E+00
0.300	2.00E-01	1.99E-01	1.93E-01	1.82E-01	1.40E-01	0.00E+00	0.00E+00	0.00E+00
0.325	2.01E-01	2.00E-01	1.95E-01	1.84E-01	1.45E-01	2.22E-02	0.00E+00	0.00E+00
0.350	2.02E-01	2.02E-01	1.97E-01	1.85E-01	1.50E-01	3.84E-02	0.00E+00	0.00E+00
0.375	2.04E-01	2.04E-01	1.98E-01	1.87E-01	1.53E-01	5.11E-02	0.00E+00	0.00E+00
0.400	2.06E-01	2.05E-01	2.00E-01	1.88E-01	1.55E-01	6.60E-02	0.00E+00	0.00E+00
0.425	2.07E-01	2.06E-01	2.01E-01	1.90E-01	1.58E-01	7.95E-02	0.00E+00	0.00E+00
0.450	2.08E-01	2.08E-01	2.03E-01	1.91E-01	1.60E-01	9.34E-02	0.00E+00	0.00E+00
0.475	2.10E-01	2.09E-01	2.04E-01	1.93E-01	1.62E-01	9.88E-02	0.00E+00	0.00E+00
0.500	2.11E-01	2.10E-01	2.05E-01	1.95E-01	1.65E-01	1.04E-01	0.00E+00	0.00E+00
0.525	2.13E-01	2.12E-01	2.06E-01	1.96E-01	1.66E-01	1.07E-01	0.00E+00	0.00E+00
0.550	2.14E-01	2.13E-01	2.08E-01	1.97E-01	1.68E-01	1.11E-01	0.00E+00	0.00E+00
0.575	2.15E-01	2.15E-01	2.10E-01	1.98E-01	1.70E-01	1.13E-01	0.00E+00	0.00E+00
0.600	2.17E-01	2.16E-01	2.11E-01	2.00E-01	1.72E-01	1.16E-01	0.00E+00	0.00E+00
0.625	2.19E-01	2.18E-01	2.13E-01	2.02E-01	1.74E-01	1.18E-01	2.00E-02	0.00E+00
0.650	2.21E-01	2.21E-01	2.15E-01	2.03E-01	1.75E-01	1.21E-01	3.37E-02	0.00E+00
0.675	2.24E-01	2.23E-01	2.17E-01	2.05E-01	1.77E-01	1.23E-01	4.76E-02	0.00E+00
0.700	2.26E-01	2.25E-01	2.19E-01	2.07E-01	1.78E-01	1.25E-01	5.96E-02	0.00E+00
0.725	2.27E-01	2.26E-01	2.21E-01	2.09E-01	1.80E-01	1.27E-01	6.96E-02	0.00E+00
0.750	2.29E-01	2.28E-01	2.22E-01	2.12E-01	1.82E-01	1.29E-01	7.75E-02	0.00E+00
0.775	2.30E-01	2.30E-01	2.24E-01	2.13E-01	1.84E-01	1.31E-01	8.27E-02	0.00E+00
0.800	2.32E-01	2.31E-01	2.25E-01	2.15E-01	1.87E-01	1.33E-01	8.66E-02	0.00E+00
0.825	2.34E-01	2.33E-01	2.27E-01	2.17E-01	1.89E-01	1.36E-01	8.90E-02	0.00E+00
0.850	2.35E-01	2.35E-01	2.29E-01	2.20E-01	1.91E-01	1.38E-01	9.12E-02	0.00E+00
0.875	2.41E-01	2.41E-01	2.34E-01	2.24E-01	1.95E-01	1.42E-01	9.52E-02	0.00E+00
0.900	2.54E-01	2.53E-01	2.47E-01	2.31E-01	1.99E-01	1.46E-01	9.73E-02	0.00E+00
0.925	2.60E-01	2.59E-01	2.54E-01	2.41E-01	2.06E-01	1.51E-01	1.01E-01	0.00E+00
0.950	2.77E-01	2.75E-01	2.68E-01	2.55E-01	2.23E-01	1.58E-01	1.06E-01	0.00E+00
0.975	4.96E-01	4.94E-01	4.82E-01	4.56E-01	3.77E-01	2.28E-01	1.17E-01	0.00E+00
1.000	5.13E-01	5.12E-01	5.03E-01	4.82E-01	4.28E-01	3.18E-01	2.17E-01	0.00E+00

Peak of the mean dose (averaged over observations) at graphical times

Repetition	Time of peak mean dose	Peak mean dose
	Years	mrem/yr
1	0.000E+00	2.162E-01
2	0.000E+00	2.170E-01
3	0.000E+00	2.169E-01

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Dose Conversion Factor (and Related) Parameter Summary
Dose Library: FGR 11

Menu	Parameter	Current Value#	Base Case*	Parameter Name
A-1	DCF's for external ground radiation, (mrem/yr)/(pCi/g)			
A-1	At-218 (Source: FGR 12)	5.847E-03	5.847E-03	DCF1(1)
A-1	Bi-210 (Source: FGR 12)	3.606E-03	3.606E-03	DCF1(2)
A-1	Bi-214 (Source: FGR 12)	9.808E+00	9.808E+00	DCF1(3)
A-1	Pb-210 (Source: FGR 12)	2.447E-03	2.447E-03	DCF1(4)
A-1	Pb-214 (Source: FGR 12)	1.341E+00	1.341E+00	DCF1(5)
A-1	Po-210 (Source: FGR 12)	5.231E-05	5.231E-05	DCF1(6)
A-1	Po-214 (Source: FGR 12)	5.138E-04	5.138E-04	DCF1(7)
A-1	Po-218 (Source: FGR 12)	5.642E-05	5.642E-05	DCF1(8)
A-1	Ra-226 (Source: FGR 12)	3.176E-02	3.176E-02	DCF1(9)
A-1	Rn-222 (Source: FGR 12)	2.354E-03	2.354E-03	DCF1(10)
A-1	Th-230 (Source: FGR 12)	1.209E-03	1.209E-03	DCF1(11)
A-1	Tl-210 (Source: no data)	0.000E+00	-2.000E+00	DCF1(12)
B-1	Dose conversion factors for inhalation, mrem/pCi:			
B-1	Pb-210+D	2.320E-02	1.360E-02	DCF2(1)
B-1	Ra-226+D	8.594E-03	8.580E-03	DCF2(2)
B-1	Th-230	3.260E-01	3.260E-01	DCF2(3)
D-1	Dose conversion factors for ingestion, mrem/pCi:			
D-1	Pb-210+D	7.276E-03	5.370E-03	DCF3(1)
D-1	Ra-226+D	1.321E-03	1.320E-03	DCF3(2)
D-1	Th-230	5.480E-04	5.480E-04	DCF3(3)
D-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)
D-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)
D-34	Ra-226+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(2,2)
D-34	Ra-226+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(2,3)
D-34				
D-34	Th-230 , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(3,1)
D-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-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)

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

Site-Specific Parameter Summary

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)	1.000E+00	2.000E+00	---	THICK0
R011	Length parallel to aquifer flow (m)	not used	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	2.500E+01	3.000E+01	---	BRDL
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+01	1.000E+00	---	T(2)
R011	Times for calculations (yr)	1.000E+02	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.500E+02	1.000E+01	---	T(4)
R011	Times for calculations (yr)	2.000E+02	3.000E+01	---	T(5)
R011	Times for calculations (yr)	3.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	6.000E+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	6.250E+00	0.000E+00	---	S1(1)
R012	Initial principal radionuclide (pCi/g): Ra-226	6.250E+00	0.000E+00	---	S1(2)
R012	Initial principal radionuclide (pCi/g): Th-230	3.750E+01	0.000E+00	---	S1(3)
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)
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)	1.500E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	1.000E-03	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	4.000E-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)	4.000E+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)	0.000E+00	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)	not used	1.000E+06	---	WAREA
R013	Accuracy for water/soil computations	not used	1.000E-03	---	EPS
R014	Density of saturated zone (g/cm**3)	not used	1.500E+00	---	DENSAQ
R014	Saturated zone total porosity	not used	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	not used	2.000E-01	---	EPSZ
R014	Saturated zone field capacity	not used	2.000E-01	---	FCSZ
R014	Saturated zone hydraulic conductivity (m/yr)	not used	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	not used	2.000E-02	---	HGWT
R014	Saturated zone b parameter	not used	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	not used	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	not used	1.000E+01	---	DWIBWT

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	not used	ND	---	MODEL
R014	Well pumping rate (m**3/yr)	not used	2.500E+02	---	UW
R015	Number of unsaturated zone strata	not used	1	---	NS
R015	Unsat. zone 1, thickness (m)	not used	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	not used	1.500E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	not used	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	not used	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, field capacity	not used	2.000E-01	---	FCUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	not used	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	not used	1.000E+01	---	HCUZ(1)
R016	Distribution coefficients for Pb-210				
R016	Contaminated zone (cm**3/g)	2.392E+03	1.000E+02	---	DCNUCC(1)
R016	Unsaturated zone 1 (cm**3/g)	not used	1.000E+02	---	DCNUCU(1,1)
R016	Saturated zone (cm**3/g)	not used	1.000E+02	---	DCNUCS(1)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.115E-04	ALEACH(1)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(1)
R016	Distribution coefficients for Ra-226				
R016	Contaminated zone (cm**3/g)	3.533E+03	7.000E+01	---	DCNUCC(2)
R016	Unsaturated zone 1 (cm**3/g)	not used	7.000E+01	---	DCNUCU(2,1)
R016	Saturated zone (cm**3/g)	not used	7.000E+01	---	DCNUCS(2)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	7.547E-05	ALEACH(2)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(2)
R016	Distribution coefficients for Th-230				
R016	Contaminated zone (cm**3/g)	5.884E+03	6.000E+04	---	DCNUCC(3)
R016	Unsaturated zone 1 (cm**3/g)	not used	6.000E+04	---	DCNUCU(3,1)
R016	Saturated zone (cm**3/g)	not used	6.000E+04	---	DCNUCS(3)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	4.532E-05	ALEACH(3)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(3)
R017	Inhalation rate (m**3/yr)	1.227E+04	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	3.500E-05	1.000E-04	---	MLINH
R017	Exposure duration	3.000E+01	3.000E+01	---	ED
R017	Shielding factor, inhalation	6.000E-01	4.000E-01	---	SHF3
R017	Shielding factor, external gamma	1.700E-01	7.000E-01	---	SHF1
R017	Fraction of time spent indoors	1.825E-01	5.000E-01	---	FIND
R017	Fraction of time spent outdoors (on site)	4.563E-02	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)
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)	not used	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	not used	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	not used	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	not used	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	not used	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	not used	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	3.650E+01	3.650E+01	---	SOIL
R018	Drinking water intake (L/yr)	not used	5.100E+02	---	DWI
R018	Contamination fraction of drinking water	not used	1.000E+00	---	FDW
R018	Contamination fraction of household water	not used	1.000E+00	---	FHHW
R018	Contamination fraction of livestock water	not used	1.000E+00	---	FLW
R018	Contamination fraction of irrigation water	not used	1.000E+00	---	FIRW
R018	Contamination fraction of aquatic food	not used	5.000E-01	---	FR9
R018	Contamination fraction of plant food	not used	-1	---	FPLANT
R018	Contamination fraction of meat	not used	-1	---	FMEAT
R018	Contamination fraction of milk	not used	-1	---	FMILK
R019	Livestock fodder intake for meat (kg/day)	not used	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	not used	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	not used	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	not used	1.600E+02	---	LWI6
R019	Livestock soil intake (kg/day)	not used	5.000E-01	---	LSI

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R019	Mass loading for foliar deposition (g/m**3)	not used	1.000E-04	---	MLFD
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	not used	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	not used	1.000E+00	---	FGWDW
R019	Household water fraction from ground water	not used	1.000E+00	---	FGWHH
R019	Livestock water fraction from ground water	not used	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	not used	1.000E+00	---	FGWIR
R19B	Wet weight crop yield for Non-Leafy (kg/m**2)	not used	7.000E-01	---	YV(1)
R19B	Wet weight crop yield for Leafy (kg/m**2)	not used	1.500E+00	---	YV(2)
R19B	Wet weight crop yield for Fodder (kg/m**2)	not used	1.100E+00	---	YV(3)
R19B	Growing Season for Non-Leafy (years)	not used	1.700E-01	---	TE(1)
R19B	Growing Season for Leafy (years)	not used	2.500E-01	---	TE(2)
R19B	Growing Season for Fodder (years)	not used	8.000E-02	---	TE(3)
R19B	Translocation Factor for Non-Leafy	not used	1.000E-01	---	TIV(1)
R19B	Translocation Factor for Leafy	not used	1.000E+00	---	TIV(2)
R19B	Translocation Factor for Fodder	not used	1.000E+00	---	TIV(3)
R19B	Dry Foliar Interception Fraction for Non-Leafy	not used	2.500E-01	---	RDRY(1)
R19B	Dry Foliar Interception Fraction for Leafy	not used	2.500E-01	---	RDRY(2)
R19B	Dry Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RDRY(3)
R19B	Wet Foliar Interception Fraction for Non-Leafy	not used	2.500E-01	---	RWET(1)
R19B	Wet Foliar Interception Fraction for Leafy	not used	2.500E-01	---	RWET(2)
R19B	Wet Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RWET(3)
R19B	Weathering Removal Constant for Vegetation	not used	2.000E+01	---	WLAM
C14	C-12 concentration in water (g/cm**3)	not used	2.000E-05	---	C12WTR
C14	C-12 concentration in contaminated soil (g/g)	not used	3.000E-02	---	C12CZ
C14	Fraction of vegetation carbon from soil	not used	2.000E-02	---	CSOIL
C14	Fraction of vegetation carbon from air	not used	9.800E-01	---	CAIR
C14	C-14 evasion layer thickness in soil (m)	not used	3.000E-01	---	DMC
C14	C-14 evasion flux rate from soil (1/sec)	not used	7.000E-07	---	EVSN
C14	C-12 evasion flux rate from soil (1/sec)	not used	1.000E-10	---	REVSN
C14	Fraction of grain in beef cattle feed	not used	8.000E-01	---	AVFG4
C14	Fraction of grain in milk cow feed	not used	2.000E-01	---	AVFG5
STOR	Storage times of contaminated foodstuffs (days):				
STOR	Fruits, non-leafy vegetables, and grain	1.400E+01	1.400E+01	---	STOR_T(1)
STOR	Leafy vegetables	1.000E+00	1.000E+00	---	STOR_T(2)
STOR	Milk	1.000E+00	1.000E+00	---	STOR_T(3)
STOR	Meat and poultry	2.000E+01	2.000E+01	---	STOR_T(4)
STOR	Fish	7.000E+00	7.000E+00	---	STOR_T(5)
STOR	Crustacea and mollusks	7.000E+00	7.000E+00	---	STOR_T(6)
STOR	Well water	1.000E+00	1.000E+00	---	STOR_T(7)
STOR	Surface water	1.000E+00	1.000E+00	---	STOR_T(8)
STOR	Livestock fodder	4.500E+01	4.500E+01	---	STOR_T(9)
R021	Thickness of building foundation (m)	not used	1.500E-01	---	FLOOR1
R021	Bulk density of building foundation (g/cm**3)	not used	2.400E+00	---	DENSFL
R021	Total porosity of the cover material	not used	4.000E-01	---	TPCV
R021	Total porosity of the building foundation	not used	1.000E-01	---	TPFL

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
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
TITL	Maximum number of integration points for risk	1	---	---	KYMAX

Summary of Pathway Selections

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

Contaminated Zone Dimensions		Initial Soil Concentrations, pCi/g	
Area:	10000.00 square meters	Pb-210	6.250E+00
Thickness:	1.00 meters	Ra-226	6.250E+00
Cover Depth:	0.00 meters	Th-230	3.750E+01

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

t (years):	0.000E+00	1.000E+01	1.000E+02	1.500E+02	2.000E+02	3.000E+02	6.000E+02	1.000E+03
TDOSE(t):	5.746E+00	5.854E+00	6.836E+00	7.368E+00	7.886E+00	8.877E+00	1.155E+01	0.000E+00
M(t):	2.299E-01	2.341E-01	2.734E-01	2.947E-01	3.155E-01	3.551E-01	4.619E-01	0.000E+00

Maximum TDOSE(t): 1.242E+01 mrem/yr at t = 767 ± 2 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 = 7.667E+02 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.
Pb-210	1.146E-13	0.0000	3.589E-14	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.531E-11	0.0000
Ra-226	3.300E+00	0.2657	8.311E-04	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.062E-01	0.0246
Th-230	7.877E+00	0.6341	7.370E-02	0.0059	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.639E-01	0.0695
Total	1.118E+01	0.8998	7.453E-02	0.0060	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.170E+00	0.0942

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 7.667E+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.
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.547E-11	0.0000
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.607E+00	0.2904
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.815E+00	0.7096
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	1.242E+01	1.0000

*Sum of all water independent and dependent pathways.

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Probabilistic Input

Number of Sample Runs: 900

Number	Name	Distribution	Parameters							
1	THICK0	UNIFORM	0	1						
2	MLINH	CONTINUOUS LINEAR	8	0	0	.000015	.0151	.000023	.1365	.0000
3	SHF1	DISCRETE CUMULATIVE	8	.0084	.01	.022	.09	.035	.21	.055

Probabilistic Total Dose Summary

Nuclide (j)	Peak Time	Peak Dose	DOSE(j,t), mrem/yr t= 0.00E+00	1.00E+01	1.00E+02	1.50E+02	2.00E+02	3.00E+02	6.00E+02	1.00E+03
Pb-210										
Min	0.00E+00	3.33E-06	3.33E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Max	0.00E+00	3.82E-01	3.82E-01	2.80E-01	1.69E-02	3.54E-03	7.45E-04	3.29E-05	2.83E-09	0.00E+00
Avg	0.00E+00	3.48E-01	3.48E-01	2.51E-01	1.35E-02	2.66E-03	5.23E-04	1.99E-05	8.96E-10	0.00E+00
Std	0.00E+00	7.95E-02	7.95E-02	6.36E-02	5.73E-03	1.34E-03	3.03E-04	1.46E-05	1.22E-09	0.00E+00
Ra-226										
Min	0.00E+00	1.09E-04	1.09E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Max	6.05E+01	1.51E+01	1.51E+01	1.51E+01	1.47E+01	1.43E+01	1.40E+01	1.33E+01	1.14E+01	0.00E+00
Avg	3.56E+01	4.54E+00	4.42E+00	4.44E+00	4.01E+00	3.67E+00	3.34E+00	2.74E+00	1.23E+00	0.00E+00
Std	2.11E+01	2.52E+00	2.53E+00	2.56E+00	2.66E+00	2.66E+00	2.64E+00	2.55E+00	1.89E+00	0.00E+00
Th-230										
Min	0.00E+00	2.31E-06	2.31E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Max	8.04E+02	2.39E+01	3.81E-01	7.11E-01	4.18E+00	6.03E+00	7.83E+00	1.13E+01	2.06E+01	0.00E+00
Avg	3.69E+02	3.89E+00	2.29E-01	3.41E-01	1.25E+00	1.65E+00	1.98E+00	2.43E+00	2.27E+00	0.00E+00
Std	2.42E+02	3.35E+00	5.64E-02	1.07E-01	7.59E-01	1.13E+00	1.51E+00	2.21E+00	3.46E+00	0.00E+00
∑ALL										
Min	0.00E+00	1.14E-04	1.14E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Max	7.66E+02	3.39E+01	1.58E+01	1.61E+01	1.88E+01	2.03E+01	2.18E+01	2.46E+01	3.20E+01	0.00E+00
Avg	3.21E+02	7.49E+00	5.00E+00	5.03E+00	5.28E+00	5.33E+00	5.32E+00	5.16E+00	3.50E+00	0.00E+00
Std	2.46E+02	4.62E+00	2.59E+00	2.68E+00	3.42E+00	3.79E+00	4.15E+00	4.76E+00	5.35E+00	0.00E+00

∑ALL is total dose summed for all nuclides.

Cumulative Probability Summary for: Total Dose Over Pathways

Cumulative Probability	Dose(t), mrem/yr t= 0.00E+00	1.00E+01	1.00E+02	1.50E+02	2.00E+02	3.00E+02	6.00E+02	1.00E+03
0.025	1.41E+00	9.35E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.050	2.27E+00	2.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.075	2.94E+00	2.71E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.100	3.57E+00	3.39E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.125	3.79E+00	3.77E+00	1.62E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.150	3.92E+00	3.93E+00	2.51E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.175	3.95E+00	4.01E+00	3.48E+00	1.65E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.200	3.96E+00	4.02E+00	4.17E+00	2.93E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.225	4.04E+00	4.05E+00	4.44E+00	3.78E+00	1.92E+00	0.00E+00	0.00E+00	0.00E+00
0.250	4.10E+00	4.16E+00	4.61E+00	4.29E+00	3.11E+00	0.00E+00	0.00E+00	0.00E+00
0.275	4.11E+00	4.18E+00	4.66E+00	4.70E+00	3.98E+00	0.00E+00	0.00E+00	0.00E+00
0.300	4.12E+00	4.19E+00	4.69E+00	4.95E+00	4.50E+00	0.00E+00	0.00E+00	0.00E+00
0.325	4.23E+00	4.23E+00	4.82E+00	5.02E+00	5.10E+00	2.36E+00	0.00E+00	0.00E+00
0.350	4.32E+00	4.37E+00	4.85E+00	5.11E+00	5.33E+00	3.58E+00	0.00E+00	0.00E+00
0.375	4.34E+00	4.41E+00	4.86E+00	5.19E+00	5.38E+00	4.51E+00	0.00E+00	0.00E+00
0.400	4.35E+00	4.42E+00	4.91E+00	5.22E+00	5.48E+00	5.26E+00	0.00E+00	0.00E+00
0.425	4.36E+00	4.43E+00	5.08E+00	5.25E+00	5.56E+00	5.74E+00	0.00E+00	0.00E+00
0.450	4.37E+00	4.44E+00	5.12E+00	5.38E+00	5.58E+00	5.96E+00	0.00E+00	0.00E+00
0.475	4.48E+00	4.49E+00	5.14E+00	5.49E+00	5.64E+00	6.04E+00	0.00E+00	0.00E+00
0.500	4.71E+00	4.77E+00	5.16E+00	5.53E+00	5.80E+00	6.14E+00	0.00E+00	0.00E+00
0.525	4.73E+00	4.81E+00	5.18E+00	5.54E+00	5.89E+00	6.26E+00	0.00E+00	0.00E+00
0.550	4.74E+00	4.82E+00	5.44E+00	5.56E+00	5.92E+00	6.30E+00	0.00E+00	0.00E+00
0.575	4.75E+00	4.83E+00	5.57E+00	5.75E+00	5.94E+00	6.50E+00	0.00E+00	0.00E+00
0.600	4.75E+00	4.84E+00	5.60E+00	5.99E+00	6.03E+00	6.63E+00	0.00E+00	0.00E+00
0.625	4.76E+00	4.84E+00	5.61E+00	6.03E+00	6.35E+00	6.66E+00	2.98E+00	0.00E+00
0.650	4.77E+00	4.86E+00	5.62E+00	6.04E+00	6.44E+00	6.69E+00	4.60E+00	0.00E+00
0.675	4.90E+00	4.90E+00	5.64E+00	6.06E+00	6.46E+00	7.07E+00	6.08E+00	0.00E+00
0.700	5.22E+00	5.26E+00	5.66E+00	6.07E+00	6.48E+00	7.24E+00	6.78E+00	0.00E+00
0.725	5.35E+00	5.43E+00	5.99E+00	6.10E+00	6.50E+00	7.26E+00	7.21E+00	0.00E+00
0.750	5.36E+00	5.45E+00	6.27E+00	6.57E+00	6.54E+00	7.29E+00	7.67E+00	0.00E+00
0.775	5.36E+00	5.46E+00	6.34E+00	6.79E+00	7.06E+00	7.31E+00	7.98E+00	0.00E+00
0.800	5.37E+00	5.47E+00	6.35E+00	6.83E+00	7.25E+00	7.57E+00	8.28E+00	0.00E+00
0.825	5.38E+00	5.47E+00	6.36E+00	6.84E+00	7.31E+00	8.07E+00	8.60E+00	0.00E+00
0.850	5.38E+00	5.48E+00	6.37E+00	6.85E+00	7.32E+00	8.21E+00	8.99E+00	0.00E+00
0.875	5.40E+00	5.50E+00	6.39E+00	6.88E+00	7.35E+00	8.24E+00	9.37E+00	0.00E+00
0.900	6.35E+00	6.42E+00	6.53E+00	6.93E+00	7.38E+00	8.27E+00	9.50E+00	0.00E+00
0.925	6.45E+00	6.57E+00	7.65E+00	8.18E+00	8.61E+00	8.32E+00	1.04E+01	0.00E+00
0.950	6.49E+00	6.60E+00	7.70E+00	8.29E+00	8.86E+00	9.95E+00	1.08E+01	0.00E+00
0.975	1.57E+01	1.60E+01	1.87E+01	2.02E+01	2.15E+01	2.33E+01	1.29E+01	0.00E+00
1.000	1.58E+01	1.61E+01	1.88E+01	2.03E+01	2.18E+01	2.46E+01	3.20E+01	0.00E+00

Probabilistic results summary : 6 Th230 + 1 Ra226 in soil, industrial, probability
File: C:\RESRAD_FAMILY\RESRAD\USERFILES\399GUTI.RAD

Summary of dose at graphical times, reptition 1

Dose statistics at graphical times, mrem/yr

Time Years	Minimum	Maximum	Mean	Median	90%	95%	97.5%	99%
0.00E+00	1.78E-01	1.57E+01	4.98E+00	4.71E+00	6.42E+00	6.48E+00	1.57E+01	1.57E+01
1.00E+01	0.00E+00	1.60E+01	5.00E+00	4.76E+00	6.52E+00	6.60E+00	1.60E+01	1.60E+01
1.19E+01	0.00E+00	1.61E+01	5.01E+00	4.77E+00	6.54E+00	6.62E+00	1.61E+01	1.61E+01
1.43E+01	0.00E+00	1.62E+01	5.02E+00	4.78E+00	6.56E+00	6.65E+00	1.61E+01	1.62E+01
1.70E+01	0.00E+00	1.63E+01	5.02E+00	4.80E+00	6.59E+00	6.68E+00	1.62E+01	1.62E+01
2.03E+01	0.00E+00	1.64E+01	5.03E+00	4.81E+00	6.62E+00	6.72E+00	1.63E+01	1.63E+01
2.42E+01	0.00E+00	1.65E+01	5.04E+00	4.80E+00	6.65E+00	6.77E+00	1.64E+01	1.65E+01
2.89E+01	0.00E+00	1.66E+01	5.06E+00	4.83E+00	6.70E+00	6.83E+00	1.66E+01	1.66E+01
3.46E+01	0.00E+00	1.68E+01	5.08E+00	4.86E+00	6.74E+00	6.90E+00	1.67E+01	1.68E+01
4.12E+01	0.00E+00	1.70E+01	5.10E+00	4.88E+00	6.80E+00	6.98E+00	1.69E+01	1.70E+01
4.92E+01	0.00E+00	1.73E+01	5.12E+00	4.89E+00	6.86E+00	7.08E+00	1.72E+01	1.72E+01
5.88E+01	0.00E+00	1.76E+01	5.15E+00	4.87E+00	6.93E+00	7.20E+00	1.75E+01	1.75E+01
7.02E+01	0.00E+00	1.79E+01	5.17E+00	4.95E+00	7.01E+00	7.34E+00	1.78E+01	1.79E+01
8.38E+01	0.00E+00	1.83E+01	5.20E+00	5.03E+00	7.08E+00	7.50E+00	1.82E+01	1.83E+01
1.00E+02	0.00E+00	1.88E+01	5.23E+00	5.16E+00	7.15E+00	7.70E+00	1.87E+01	1.88E+01
1.00E+02	0.00E+00	1.88E+01	5.23E+00	5.16E+00	7.15E+00	7.70E+00	1.87E+01	1.88E+01
1.19E+02	0.00E+00	1.94E+01	5.26E+00	5.30E+00	6.82E+00	7.92E+00	1.93E+01	1.93E+01
1.43E+02	0.00E+00	2.01E+01	5.26E+00	5.47E+00	6.86E+00	8.20E+00	2.00E+01	2.00E+01
1.50E+02	0.00E+00	2.03E+01	5.26E+00	5.52E+00	6.94E+00	8.29E+00	2.02E+01	2.02E+01
1.70E+02	0.00E+00	2.09E+01	5.26E+00	5.66E+00	7.10E+00	8.52E+00	2.07E+01	2.08E+01
2.00E+02	0.00E+00	2.18E+01	5.24E+00	5.82E+00	7.37E+00	8.86E+00	2.15E+01	2.16E+01
2.03E+02	0.00E+00	2.19E+01	5.23E+00	5.84E+00	7.40E+00	8.89E+00	2.16E+01	2.17E+01
2.42E+02	0.00E+00	2.30E+01	5.20E+00	5.91E+00	7.77E+00	9.31E+00	2.25E+01	2.28E+01
2.89E+02	0.00E+00	2.43E+01	5.11E+00	6.16E+00	8.19E+00	9.82E+00	2.34E+01	2.41E+01
3.00E+02	0.00E+00	2.45E+01	5.09E+00	6.14E+00	8.28E+00	9.93E+00	2.36E+01	2.44E+01
3.46E+02	0.00E+00	2.57E+01	4.98E+00	6.30E+00	8.67E+00	1.04E+01	2.39E+01	2.56E+01
4.12E+02	0.00E+00	2.74E+01	4.71E+00	5.54E+00	9.23E+00	1.10E+01	2.27E+01	2.71E+01
4.92E+02	0.00E+00	2.95E+01	4.29E+00	1.30E+00	9.83E+00	1.16E+01	1.52E+01	2.82E+01
5.88E+02	0.00E+00	3.17E+01	3.58E+00	0.00E+00	1.01E+01	1.07E+01	1.29E+01	2.68E+01
6.00E+02	0.00E+00	3.19E+01	3.48E+00	0.00E+00	1.01E+01	1.08E+01	1.30E+01	2.61E+01
7.02E+02	0.00E+00	3.30E+01	2.50E+00	0.00E+00	9.43E+00	1.09E+01	1.27E+01	1.37E+01
8.38E+02	0.00E+00	2.62E+01	1.16E+00	0.00E+00	6.23E+00	8.35E+00	1.01E+01	1.17E+01
1.00E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Probabilistic results summary : 6 Th230 + 1 Ra226 in soil, industrial, probability File: C:\RESRAD_FAMILY\RESRAD\USERFILES\399GUTI.RAD

Peak of the mean dose (averaged over observations) at graphical times

Repetition	Time of peak mean dose Years	Peak mean dose mrem/yr
1	1.425E+02	5.261E+00
2	1.701E+02	5.382E+00
3	1.701E+02	5.367E+00

Appendix D, Attachment C continued

Basis of Area Factors for Elevated Measurements Criterion in Soil
C-T Phase II Decommissioning Plan Figure 5-3

RESRAD cases for the Thorium series are:	408guti
	421gti3k
	422gti1k
	423gti300
	424gti100
	425gti30
	426gti10
RESRAD cases for the Uranium series and Actinium series are:	407guti
	427gui3k
	428gui1k
	429gui300
	436gui100
	437gui30
	438gui10
RESRAD cases for $6Th^{230} + 1Ra^{226} + 1Pb^{210}$ are:	399guti
	430ghi3k
	431ghi1k
	432ghi300
	433ghi100
	434ghi30
	435ghi10

APPENDIX E

LOWER LIMIT OF DETECTION

Mallinckrodt Inc.

C-T Phase II Decommissioning Plan
May 15, 2003

NRC Docket: 40-06563
NRC License: STB-401

APPENDIX E

LOWER LIMIT OF DETECTION

The terminology adopted to reflect the measurement (detection) capability is the lower limit of detection (LLD) or the minimum detectable radioactivity (MDA); it refers to the intrinsic detection capability of the entire measurement process. The lower limit of detection is normally an *a priori*, *i.e.*, before the fact, estimate of the capability of a measurement system, although it might be estimated from background in conjunction with a measurement. The LLD, or MDA, is the smallest concentration of radioactive material in a sample that will yield a net count, above system blank, that will be detected with at least 95% probability with no greater than a 5% probability of falsely concluding that a blank observation represents a real signal. It is desirable to express the MDA as minimum detectable areal density (MDAD) or minimum detectable concentration (MDC) in units comparable to a regulatory limit with which a measurement may be compared.

E.1.1. STATIC MEASUREMENT

E.1.1.1. General

When a gross count is to be compared with a detection decision criterion, without subtracting background, the MDA equation is:

$$\mathrm{MDA} = \frac{3 + 3.29\, s_B}{K\, t}$$

where:
- s_B = standard deviation of background, or blank, count
- 3.29 = 2 x 1.645 = standard normal variate for decision errors, α =0.05 and β = 0.05
- K = factor converting from counts to units in which MDA is expressed
- t = counting time, assuming equal background, or blank, and sample counting times

The form of the equation for estimating MDA when background and sample count times are equal is

$$\mathrm{MDA} = \frac{3 + 4.65\, s_B}{K\, t}$$

Application of MDA estimation to 3 areal density measurement situations is illustrated hereafter.

E.1.1.2. Gross Counting.

When a gross count is to be compared simply with the detection decision criterion, the equation to estimate MDAD is:

$$\mathrm{MDAD} = \frac{3 + 3.29\sqrt{B}}{E\, t_s \dfrac{A}{100}}$$

where:
- B = background, or blank, count (ct)
- E = detection sensitivity (dis/ct)
- t_s = sample count time (min) where $t_{background}=t_{sample}$

A = detection area[1] (cm^2)

E.1.1.3. Gross Minus Blank Counting.

In the event the radiation of interest is measured as the sample gross count minus the blank, or background, count, and the sample gross count time and the blank count time are equal, the equation to estimate minimum detectable areal density is:

$$MDAD = \frac{3 + 4.65\sqrt{B}}{E\, t_s \frac{A}{100}}$$

where t_s = sample count time (min) where $t_{background} = t_{sample}$

E.1.1.4. Unequal Blank and Sample Count Times.

In the event the radiation of interest is measured as the sample gross count minus the blank count, and the sample count time, t_s, and the blank count time, t_b, are unequal, the equation to estimate MDAD is:

$$MDAD = \frac{3 + 3.29\sqrt{B \frac{t_s}{t_b}\left(\frac{t_s + t_b}{t_b}\right)}}{E\, t_s \frac{A}{100}}$$

where: t_b = background, or blank, count (ct)

E.1.1.5. Ambient Gamma Radiation.

Ambient gamma radiation in a survey unit will be measured by the detector type , an AB-100 or equivalent, that is to be used to perform a final status survey in that unit. Its purpose will be to assess whether ambient gamma radiation might be elevated enough to warrant recalculation of the minimum detectable radioactivity estimate of the measurement capability.

E.1.1.6. *A priori* Lower Limit of Detection.

The lower limits of detection of instruments that may be used to perform final radiation status surveys are estimated in Tables 14-1 and 14-2 where background readings representative of the site are available. The lower limit of detection of each instrument type, for which a representative background reading is not now available, will be estimated by methodology herein before use in a final status survey.

E.1.2. SCANNING SENSITIVITY[2]

Surfaces are scanned to detect a small area of radioactive contamination. The minimum detectable areal density of radioactive contamination depends on both the instrumentation and the surveyor. The minimum detectable net count rate of a scanning instrument[3] is

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[1] A/100 = 1 when Lucas calibration is applied to Bicron AB-100, Ludlum 43-89, or equivalent detector

[2] MARSSIM, §6.7.2.

[3] Abelquist. E.W., *et.al.*, *Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions*, NUREG-1507, §6.1, Dec. 1997.

$$MDCR = d'\sqrt{b_i}\,\frac{60}{i} = s_i\,\frac{60}{i}$$

where: MDCR = minimum detectable net count rate (ct/min)

d' = 1.38 when false positive decision error, $\alpha = 0.60$, and correct decision fraction, $1-\beta = 0.95$ {ref 4}

i = observation interval (sec) = $\sqrt{\text{detector area}} \div$ scan speed

s_i = minimum detectable number of net source counts in observation interval (ct)

b_i = background counts in observation interval (ct)

60 = conversion, 60 (sec/min)

The minimum detectable areal activity density by scanning is:

$$\text{Scan MDC} = \frac{MDCR}{\sqrt{p}\,E_c E_p}$$

where:

Scan MDC = minimum detectable areal activity density by scanning (dpm/100 cm^2)

p = surveyor efficiency, assumed[5] to be 0.5.

and where the scan spped is specified in section 4.2.

When an AB-100 detector is used for scanning, it is done in window open mode. Detection sensitivity is expressed per 100 cm^2 according to Lucas and Colyott.

Each composite areal U series and Th series radioactivity density on surface, AD_c, is thereby expressed in units comparable with the composite limit, $Limit_{composite}$, for a U series and Th series mixture.

With background readings from a reference area and or a reference material, similarly interpreted, the measurements are amenable to statistical comparison of populations of background + AD_c versus survey unit measurements to test compliance with criteria in C-T Phase II Decommissioning Plan, section 5.

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[4] Abelquist. E.W., et.al., Table 6.1 p. 6.23.

[5] Abelquist, E.W., *et.al.*, §6.7.1.

APPENDIX F

RADIONUCLIDE ANALYSIS IN SOIL BY IN-GROUND GAMMA SPECTROMETRY

Mallinckrodt Inc.

C-T Phase II Decommissioning Plan

May 15, 2003

NRC Docket: 40-06563
NRC License: STB-401

APPENDIX F

RADIONUCLIDE ANALYSIS IN SOIL BY IN-GROUND GAMMA SPECTROMETRY

F 1.1. APPLICATION

This describes a gamma spectrometry method using a sodium iodide crystal detector coupled to a multi-channel analyzer to measure radioactivity attributable to uranium series and thorium series in soil surrounding the detector.

F 1.2. DESCRIPTION

The gamma spectrometer consists of a NaI(Tl) crystal detector, photomultiplier, preamplifier, multi-channel spectrum analyzer (MCA), and computer. All are sufficiently transportable for outdoor use. The detector may be connected with the MCA by a long cabling to allow lowering it into a hole augered into the ground. The MCA has provision for storing a small number of spectra independently of the computer. Spectra will be downloaded to a portable computer for interpretation. The analysis and archiving method enable data review in extensive detail.

F 1.3. CHARACTERISTICS

Gamma spectrometry with the detector in the ground is advantageous over soil removal sampling in that it samples a larger volume of soil than is convenient in removal sampling. Further, the method provides immediate feedback on the possible presence of radioactivity. Increase in counting rate is the first indicator of excess radioactivity. Analysis of the spectrum will then yield the nuclide mix, which, when considered with the release limits, may aid in a remediation decision.

It is notable that a core sample is not exactly the same material as that remaining in the ground surrounding the cavity from which it was taken. In-ground measurement "samples" a larger quantity of soil, perhaps more than 10 times more, than a core sample. That suppresses the variability inherent in exceedingly small samples.

F 1.4. MATHEMATICAL BASIS.

Calibration spectra will be recorded in such a way that deconvolution of any observed spectrum using the calibration spectra will yield the soil radionuclide concentration. The mathematical basis for this process is described below.

A calibration spectrum of each radionuclide family to be interpreted by measurement is acquired in a source environment simulating that of measurement in-ground. The same number of calibration observations, albeit differing in concentration, are acquired as the number of nuclide families which are to be determined.

After calibration spectra are derived, measurement is performed by lowering a scintillation detector into an augered hole in soil where a pulse height spectrum accumulated. The spectrum

recorded is a composite of spectra, each presented by a key radionuclide and its short-lived progeny. After accumulation of a spectrum of unknowns, the analyzer software is operated in an iterative calculation wherein aliquots of standard spectra are added together until the spectrum shape of the added aliquots matches that of the unknown as judged by minimizing the square of the errors between the observed spectrum and the weighted sum of the standard spectra. Then, knowing the amount of each aliquot of calibration standard, the matching quantity and or concentration of each measured radionuclide in a composite spectrum may be reported. Mathematically this may be expressed as:

$$\mathbf{S(E) = A_U\, S_U(E) + A_{Th}\, S_{Th}(E) + A_{Ra}\, S_{Ra}(E) + A_K\, S_K(E)} \qquad \text{eqtn F1}$$

where: $\mathbf{S_i}$ (E) = spectra of 1024 channels having calibration factor (counts/sec per pCi/g) stored in each channel

$\mathbf{A_i}$ = radioactivity concentration of radionuclide *i* (pCi/gm)

so that, when the $\mathbf{A_i}$ are chosen by iteration, the counts in the unknown spectrum are predicted. The $\mathbf{A_i}$ may then be taken to represent the radioactivity concentration of each nuclide or nuclide family related to the standard spectra.

The goodness of fit to the measured spectrum is calculated at each iteration by summing the squares of the differences between the right side of equation F1 and the left side, *i.e.*, the original measured spectrum. This sum, called the weighted sum of squares (wss) is used as an index of improvement as the process proceeds. When, by statistical criteria, it becomes clear that the solution may not be improved, the process is terminated.

F 1.5. CALIBRATION

Energy pulse height calibration is performed by using the signal detected from a small cesium-137 button source to normalize the spectra to photon energy.

The objective of quantitative calibration is to produce standard spectra representative of uranium, thorium, radium, and potassium. Implicit in the method is a calibration which is traceable to the NIST or other recognized provider and a data reduction method which uses the calibrations to interpret the acquired spectra.

Standard sources of natural uranium, thorium-232 and daughters, radium-226 and daughters, and potassium-40 are planned to be fabricated by filling containers with silica sand which has been doped with a known quantity of liquid radionuclide standard material to simulate an in-ground source. The specific activities of the radionuclide standards are traceable to NIST and the spectrum shapes.

F 1.6. BACKGROUND

A drum of silica sand may be prepared as an environment for subtraction of ambient background from the standard source drums. This in-ground gamma spectrometry measurement method is expected to achieve detectability to a level below that found in uncontaminated cinder-fill soil.

Alternatively, for backgrounding spectra collected in field application, one may want to consider only the radioactivity in the detector and that due to cosmic rays. For this purpose, the detector may be operated in 4-inches of lead bricks. The spectrum accumulated would be subtracted from all field spectra.

F 1.7. LOWER LIMIT OF DETECTION

The lower limit of detection (LLD) of a gamma spectrometer used in-ground will be determined. The LLD of key radionuclides in soil is expected to be as low as is detectable by the same instrument configured with lead-shielded detector in a counting room setting. Reasons to expect comparably low LLD are that

- instrumentation used in the field is practically the same as used in a counting room.
- the quantity of gamma-emitting soil surrounding a detector in the ground is about 10 to 15 times more than a soil sample typically taken to a counting room.
- soil surrounding a detector in the ground is its own shield against background radiation
- the background radioactivity concentration in-ground or in a core sample from the same location should be the same.

APPENDIX G

DERIVATION OF $DCGL_W$ ON PAVEMENT

Mallinckrodt, Inc.

C-T Phase II Decommissioning Plan

August 8, 2008

NRC Docket: 40-06563

NRC License: STB-401

APPENDIX G
DERIVATION OF DCGLw ON PAVEMENT

1. INTRODUCTION

Most land area in Plant 5 is covered by pavement, buildings, or building slabs. Characterization survey data indicate that only 3 of 1670 direct measurements [ref. CT 2 DP §4, Table 4-3] on pavement in Plant 5 exceeded the DCGL initially proposed for pavement in C-T Phase II DP §5, Dose Modeling. Only one scabble sample of pavement contained more than, 0.05 wt % source material, a threshold concentration for licensing according to 10 CFR Part 40.13(a) [ref. CT 2 DP §4.8.3]. It would be rational to survey the pavement and building slabs separately from underlying cinder fill in order to "clear" the pavement from survey and release considerations associated with the cinder fill. Since potential contamination on pavement and building slabs would be mainly on the surface and potential contamination in cinder fill would be within its volume it would be logical to derive and express DCGL in units of areal density and mass concentration respectively.

This appendix describes a revised derivation of DCGLw applicable to pavement and building slabs. Responses to NRC staff requests for additional information about this topic are also incorporated into this appendix.

2. COMPENSATION FOR GAMMA RADIATION FROM CINDER FILL THROUGH PAVEMENT

When deriving DCGL, one consideration is whether exposure to pavement and to soil beneath are independent. In essence, the scenario of exposure to bare soil, on which DCGL for soil were derived, and the scenario of exposure to pavement, on which DCGL for pavement are derived, cannot occur simultaneously. Without pavement, the source and exposure pathways to contamination on pavement are absent, and exposure to topsoil can occur. Thus, DCGL derived for soil are independent of presence of or contribution from pavement.

Alternatively, when pavement exists atop soil, it would be a complete barrier against airborne and ingestion pathways of exposure to conceivable residue in the soil and an incomplete shield against gamma radiation penetrating from conceivable residue in the soil beneath. If pavement were to erode or be removed, so would any source on or embedded in the pavement be removed. Analysis of the amount of radiological dose that could be caused by gamma radiation from C-T residue in soil penetrating pavement has been done by dose modeling. If the maximum amount of dose allowed from contamination on pavement surface is specified to be no more than 25 mrem/yr minus the contribution from residue in cinder fill beneath the pavement, the corresponding DCGL on pavement will be uncoupled from the DCGL in cinder fill.

2.1. RADOINUCLIDE SOURCE IN CINDER FILL

Determination of the relative concentration relation of C-T radionuclides above background concentration in cinder fill is reported in Phase II Decommissioning Plan (DP)

Appendix C. The geometric mean of each distribution shown in DP Appendix C, Figures C-1 through C-5 and in Appendix C, Attachment B, is presented as the best estimate of the ratio of the respective key radionuclides. The mean ratios are summarized as:

Table G-1. Ln Mean Ratio in Cinder Fill

Th^{230} / U^{238}	=	1.1
Ra^{226} / U^{238}	=	2.8
Th^{230} / Ra^{226}	=	0.66
Ra^{228} / Th^{232}	=	1.6
Th^{228} / Th^{232}	=	1.3
Th^{228} / Ra^{228}	=	0.8

Fifteen years since cessation of C-T processing is enough time to allow thorium series radionuclides to grow or decay within about 0.20 of radioactive equilibrium. Considering uncertainty in alpha spectrometry of separate radioelements at low concentration, the thorium series might rationally be assumed to be in radioactive equilibrium in Plant 5 soil samples.

The characterization survey data suggest that a reasonably representative range of source terms would be a U / Th ratio of approximately 3, with uranium isotopes in radioactive equilibrium, with thorium series in radioactive equilibrium, and with excess Th^{230} and Ra^{226}.

When assessing shielding effect of pavement on radiological dose caused by C-T residue in cinder fill, the relative concentration on long-lived radionuclides in cinder fill is represented by these ratios as:

Table G-2. Relative Radionuclide Concentration in Cinder Fill

Nuclide	Relative Concentration (pCi/g soil)			Concentration Causing 25 mrem/yr[A] (pCi/g soil)
U^{238}	3.0	=	3.0	9.959
U^{234}	3.0	=	3.0	9.959
U^{235}	3.0 x 0.0455	=	0.137	0.453
Ac^{227}	3.0 x 0.0455	=	0.137	0.453
Pa^{231}	3.0 x 0.0455	=	0.137	0.453
Th^{230}	3.0 x 1.1	=	3.3	10.96
Ra^{226}	3.0 x 2.8	=	8.4	27.89
Pb^{210}	3.0 x 2.8	=	8.4	27.89
Th^{232}	1.0	=	1.0	3.32
Ra^{228}	1.0	=	1.0	3.32
Th^{228}	1.0	=	1.0	3.32

[A] Concentration causing 25 mrem/yr = 3.32 x relative concentration of each radionuclide.

The "concentration causing 25 mrem/yr" of the source spectrum in cinder fill maintains the relative concentration of each radionuclide to each other while increasing each by a constant multiplier, 3.32, to describe a source that, altogether, causes 25 mrem/yr atop bare soil.

2.2. DOSE MODELING

As depth of C-T source material in cinder fill, beginning at bare land surface, increases, the cinder fill itself attenuates radiation from the intermingled source. With increasing depth of source, gamma radiation emanating from land surface asymptotically reaches a maximum, or plateau, intensity. Response in CT Phase II DP, §5, Figure 5-1 to NRC Request for Additional Information item 41 demonstrates that maximum dose rate reaches a plateau when the source is about 30 cm deep in the ground. Similarly, Figure G-2 confirms that only about 0.01 of gamma radiation would penetrate through 30 cm of pavement. Thus, assumption of a 100 cm deep zone of C-T source material in cinder fill is sufficient to produce maximum dose rate for the purpose of this modeling analysis.

2.3. ANALYSIS OF SHIELDING EFFECT OF PAVEMENT

Dose modeling to evaluate the effect of pavement on suppressing radiological dose was done by entering the same values of parameters into RESRAD version 6.3 as were used to derive DCGLw in bare soil except for the source radionuclide concentrations and pavement description. When entered into RESRAD version 6.3, as modeled to derive the DCGLw in bare soil, the spectrum of nuclide "concentration causing 25 mrem/yr" does yield a probabilistic peak of the mean dose = 25.0 mrem/yr. The time of the peak of the mean dose occurs during the first year of exposure. [ref. RESRAD case 446iuth]

Modeling to estimate the effect of pavement on attenuating dose from residual radionuclides in cinder fill soil was done by simulating a range of thicknesses of pavement atop the same one-meter-deep source of C-T residue in the cinder fill described in Table G-2. When pavement was assumed present, inhalation and ingestion pathways originating in the soil were assumed to be prevented by the pavement barrier. Pavement density was estimated to be 1.9 g/cm^3 to simulate a gravel-asphalt mix. (By comparison, concrete pavement density would be about 2.2 g/cm^3 and would increase attenuation). Erosion of pavement and soil was assumed to be practically negligible at 1.x 10^{-4} m/yr and would be of no effect since maximum potential dose occurs in the first year of exposure.

Results of the RESRAD simulations of effect of a range of pavement thickness on radiological dose are displayed graphically in Figures G-1 and G-2. [ref. RESRAD cases 446iuth and 448uth2 through 455uth15]

Figure G-1. Effect of Pavement Thickness on Radiological Dose from Cinder Fill

Source Spectrum is Ln Mean of Characterization Survey Data
Dose Modeling by RESRAD v. 6.3

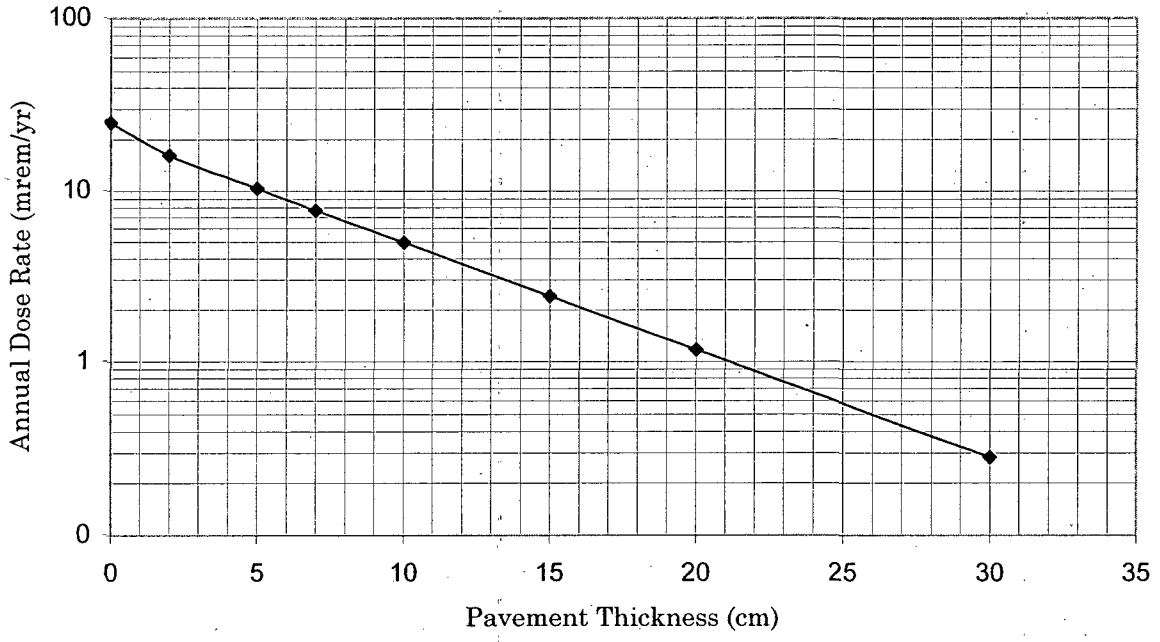
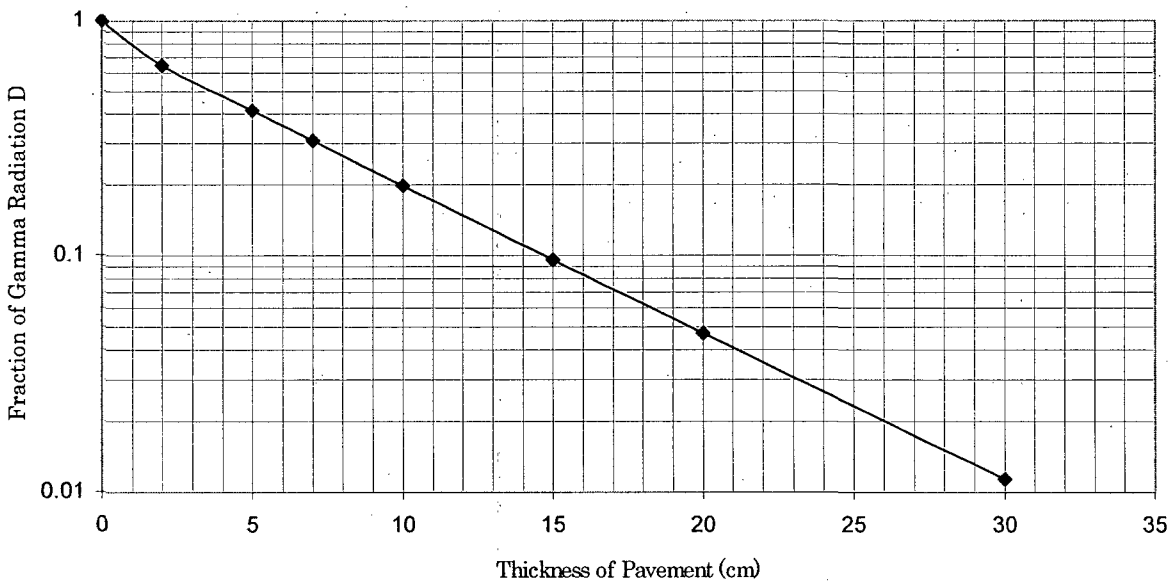


Figure G-2. Fraction of Gamma Radiation Penetrating Pavement

Source Spectrum is Ln Mean Radionuclide Concentration in Cinder Fill
Dose Modeling by RESRAD v. 6.3



When pavement is at a nominal 4-inch thickness, *i.e.*, 10 cm, potential radiological dose atop the pavement is 0.2 of the potential dose atop bare soil. That is, the spectrum of radionuclide concentrations in the characterization survey of cinder fill that would produce 25 mrem/yr atop bare cinder fill, would produce only 4.95 mrem/yr atop 4-inch-thick macadam pavement and even less atop concrete pavement.

Thus, with the aid of dose modeling of outdoor exposure to gamma radiation penetrating nominal 4-inch-thick pavement by RESRAD, one finds that one or more meters of soil containing $DCGL_W$ concentration of the source spectrum, i.e., relative concentration ratios, would be estimated to contribute 4.95 mrem/yr through the pavement. Subtracting that from 25 mrem/yr allotted to DCGL would imply reduction of conceivable contribution from residue on pavement itself to 20 mrem/yr and would eliminate question of allocation of maximum acceptable total dose.

Although it is unlikely that both soil and pavement would be contaminated to more than 0.80 of either $DCGL_W$, and thus are practically independent, $DCGL_W$ on pavement in is being reduced by 0.20 to correspond to 20 mrem/yr. Together with revisions in response to NRC request for additional information item 48, values in Table G-7 herein become the revised $DCGL_W$ to be applied. As a consequence $DCGL_{EMC}$ will also be reduced to nominally 0.80 of 25 mrem/yr.

3. DERIVATION OF $DCGL_W$ ON PAVEMENT, COMPENSATED FOR GAMMA RADIATION FROM CINDER FILL

3.1. INTRODUCTION

The objective in dose modeling was to determine the maximum **areal density** of contaminant on or near the surface that would not cause more than 25 mrem/yr when potential gamma radiation from residue in underlying cinder fill is included.

Dose factors were computed by RESRAD for an industrial work scenario on pavement. The RESRAD output for each radionuclide can be interpreted as a dose factor (mrem/y per pCi/m^2), which in turn may be interpreted as a maximum acceptable average areal density of the radionuclide on a surface, also called the $DCGL_w$, corresponding to a maximum acceptable potential radiological dose equivalent.

3.2. MODELING EXPOSURE

In the industrial land use scenario and outdoor environment of interest with contaminant assumed on the surface of pavement, the potential exposure pathways would mainly be by direct gamma irradiation, inhalation of dust suspended into air, and ingestion of dust. Among these, the model simulating suspension of dust into outdoor air in RESRAD is appropriate; whereas the indoor ventilation model in RESRAD-BUILD would be less adaptable. The conceptual models for ingestion and inhalation in RESRAD are a function of radioactivity concentration in the surface dust or soil and not on its depth. Consequently, RESRAD was employed because it would be preferable for exposure to an outdoor source on pavement via these pathways. Inhalation was treated probabilistically [ref. RESRAD case 457putrae3].

Although it is unlikely that both soil and pavement would be contaminated to more than 0.8 of either DCGLw, and thus are practically independent, DCGLw on pavement is being reduced by 0.2 to the equivalent of 20 mrem/yr, which become the revised DCGLw to be applied. As a consequence, DCGLEMC will also be reduced to the equivalent of 20 mrem/yr.

3.3. RADIONUCLIDE SOURCE ON PAVEMENT

The Columbium-Tantalum Characterization Plan, described in Decommissioning Plan §4.0, provided for survey of paved surfaces in the former C-T process and support areas of Plant 5. Twenty-four scabble samples of pavement in the Plant 5 area were collected and analyzed for use in determination of release limits.[1] The locations of scabble sampling are shown in Decommissioning Plan §4, Figure 4-2. The data collected from the scabble results are reproduced in Table G-3 herein. They enabled the relative distribution of key radionuclide concentrations, or spectrum, to be interpreted.

Relative concentration of long-lived radionuclides in the scabble samples was determined by graphical analysis of their correlation. Figures G-3 thru G-6 display the relations, or ratios. The natural log mean ratio, at the 50th cumulative percent occurrence, provides the best single-valued representation of relative concentration of the principal radionuclides. Thereby, the relative concentrations of the principal radionuclides in pavement scabble samples are:

Table G-4. Ln Mean Ratio on Pavement

Radionuclide	Relative Concentration
U_{nat}/Th series	3
Th^{230}/U_{nat}	0.78
Ra^{226}/U_{nat}	1.4
Th^{230}/Ra^{226}	0.6

These ratios translate to relative concentrations in a source to model contamination on pavement by C-T residue in Table G-5. The relative radionuclide concentrations in this spectrum are entered into RESRAD to derive the dose factors (mrem/yr)/(pCi/g).

[1] Mallinckrodt Chemical, Inc. Radiological Characterization Data Set for the Mallinckrodt Chemical C-T Plant. Thermo Nutech, Oak Ridge, TN. Volume 1, "Results of Radiological Surveys for Background Radiation"; Volume 3, "Radiological Survey Data and Field Drawings"; and volumes 4 and 5, "Results of Radiological Analysis of Samples". October 1998.

Table G-3. Analytical Results of Scabble Samples from Plant 5 Street Surfaces
ref. CT Phase II Decommissioning Plan, Table 4-2

Location ID	Radionuclide Concentration										Percent by weight of source material
	U-234 (pCi/g)	U-235 (pCi/g)	U-238 (pCi/g)	U_{total} (pCi/g)	Th-230 (pCi/g)	Ra-226 (pCi/g)	Th-234 (pCi/g)	Th-232 (pCi/g)	Ra-228 (pCi/g)	Th-228 (pCi/g)	
SC-01	10.5	0.34	12.2	42.5	21	23.7	8.5	20.7	12.3	22	0.02
SC-02	25.2	1.6	27.2	74.5	5	34.7	22.5	1.9	1.5	2.8	0.01
SC-03	11.3	0.4	11.9	27.1	7.8	7.6	3.6	2.5	3	2.7	0.00
SC-04	6.4	0.31	6.7	4.5	3.8	2.8	1.6	3.7	3.4	4.5	0.00
SC-05	31.2	1.3	30.9	106.9	129.4	339.8	61	32.8	32.8	34.9	0.03
SC-06	91.4	3.6	91.3	256.7	66.6	106.7	30.7	28	19.7	29.9	0.04
SC-07	56.6	3.1	58.5	177.5	32.7	157.3	40.7	32.5	26.6	34.2	0.04
SC-08	21	1.2	21.8	70.7	17	89.9	12.8	10.2	5.7	11.7	0.01
SC-09	45	1.7	47.7	118.3	25.7	153.7	36.7	31.7	66.4	35.2	0.04
SC-10	122.2	7.5	125.2	339.9	58.2	978.7	73.1	57.4	42.1	68.9	0.07
SC-11	15.3	1.2	16.1	49.3	22.8	8.3	13.9	12.8	7.2	13.2	0.01
SC-12	19.6	1	17.8	72.7	51.3	32.9	49.2	7.5	6.3	9.8	0.01
SC-13	28.2	0.73	28.4	76.7	12.4	73.6	30.6	2.2	2.4	3	0.01
SC-14	18.8	0.73	18.1	41.7	14.6	40.7	25.9	8.1	9.9	8.1	0.01
SC-15	32.6	1.4	33.5	129.3	17.5	46.8	26.6	4.8	4.3	5.2	0.01
SC-16	17.4	1.1	16.9	48.5	36.6	104.4	30.7	5.6	5.6	5.9	0.01
SC-17	29.1	1.3	26.5	84.3	21.7	65.5	47.4	9.7	10.5	12.1	0.01
SC-18	8.6	0.31	8.5	31.5	5.4	3.6	5.5	1.4	1.3	1.8	0.00
SC-19	8.8	0.46	9.3	27.9	6.2	3.5	5.1	1.9	1.4	1.9	0.00
SC-20	29.9	1.4	32.9	82.3	20.2	10.8	26.5	6.1	4.8	6.3	0.01
SC-21	25.2	1.7	27.2	86.7	19.6	13.8	28.1	5.4	5.9	4.9	0.01
SC-22	215.8	9.9	204	530.96	94.1	263	161	15.4	16.5	17.8	0.04
SC-23	35.7	1.9	38.7	90.7	5.7	3.2	16.5	1.4	1.5	1.2	0.01
SC-24	4.5	0.23	5	9.8	13.5	6.6	5.2	3.4	2	3	0.00

Figure G-3

Distribution of Natural Uranium -to- Thorium Series Ratio in Pavement Scabble Samples

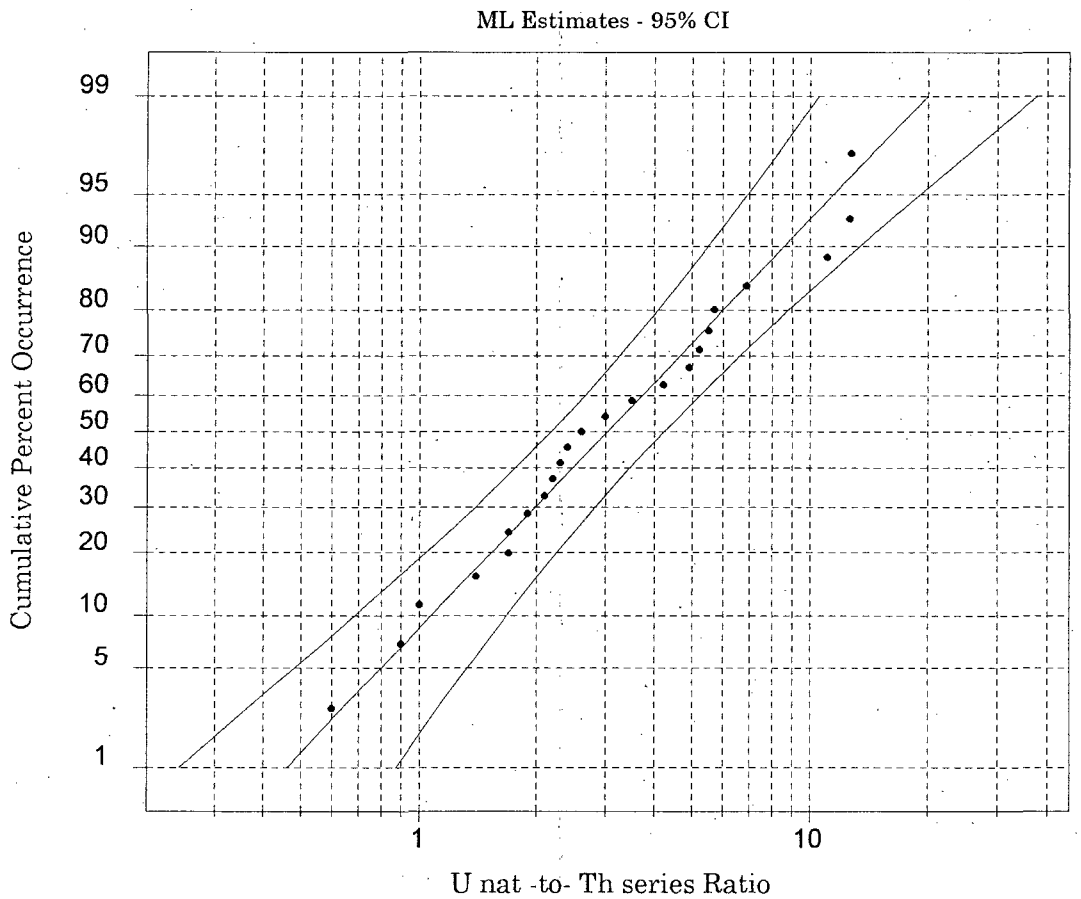


Figure G-4

Distribution of Thorium-230 -to- Natural Uranium Ratio in Pavement Scabble Samples

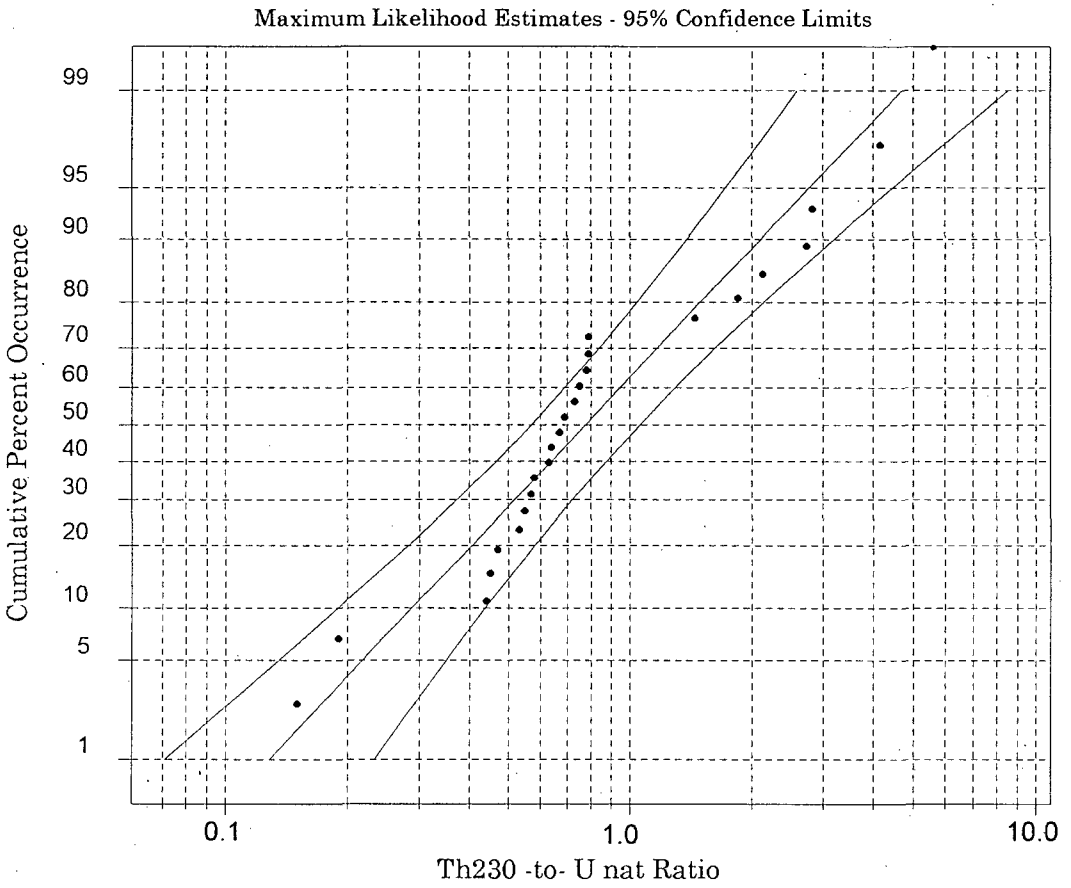


Figure G-5

Distribution of Radium-226 -to- Natural Uranium Ratio in Pavement Scabble Samples

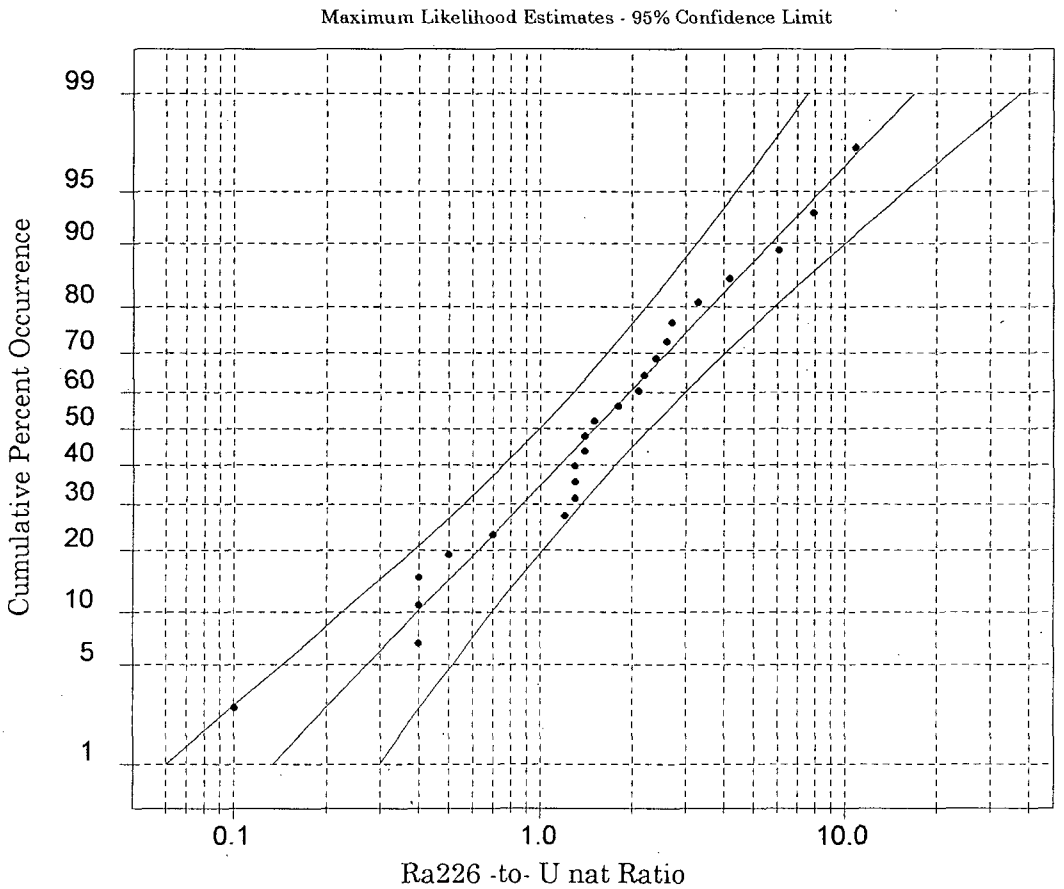
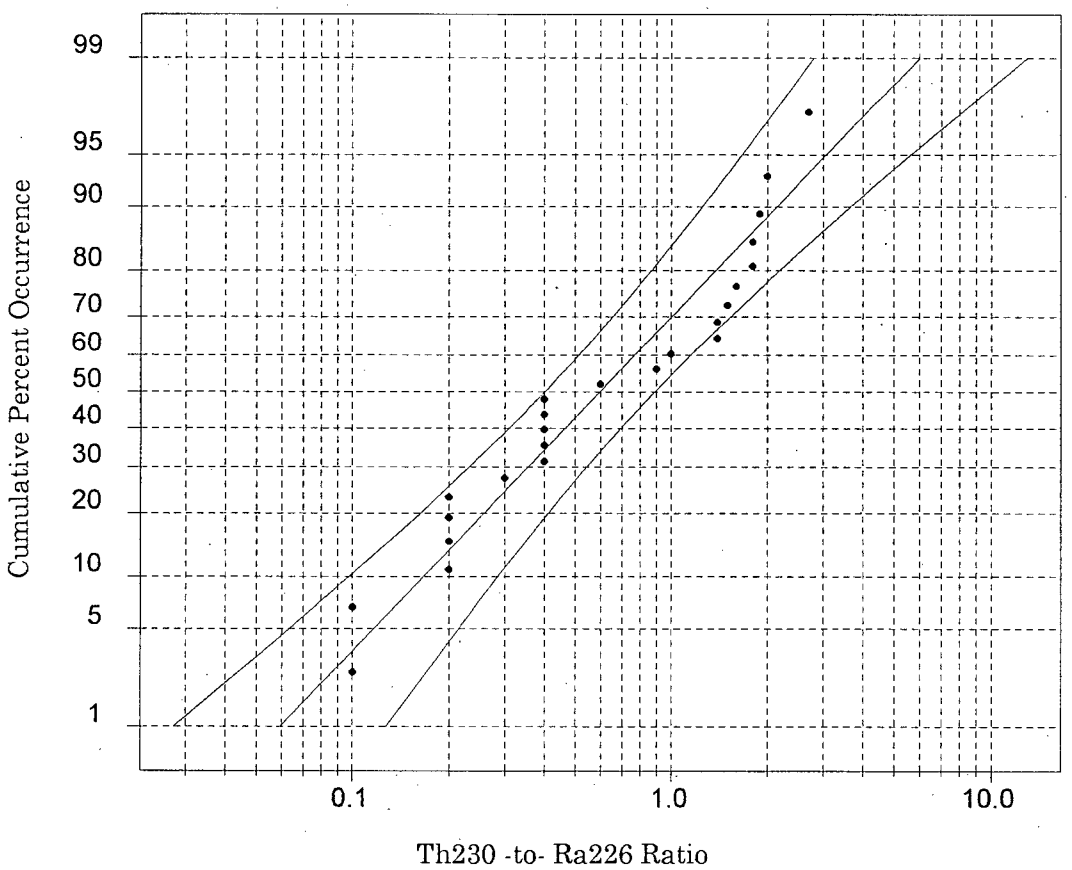


Figure G-6

Distribution of Thorium-230 -to- Radium-226 Ratio in Pavement Scabble Samples

ML Estimates - 95% CI



3.4. DOSE MODELING

3.4.1. Dose vs. Source Depth

RESRAD models simulate exposure to a source originating as a mass concentration in soil.[2] In order to simulate surficial contamination on pavement out-of-doors, a mass concentration equivalent of areal density of source material on pavement needs to be estimated. Assumption of as much as 0.1 cm source thickness is sufficient for contamination of worker hands or clothing and potential for ingestion and removal from the surface to become suspended in air for potential inhalation. That is, modeling removal for either ingestion or inhalation pathways does not depend on a thicker source.

A common sense perspective on the assumption of as much as 0.1 cm source thickness on pavement in Plant 5 may be realized by estimating the volume it would occupy. That volume would be 30 cubic yards, or three 10-cubic-yard, semi-trailer truck loads. Even if 2/3 of Plant 5 pavement were vacuum-cleaned (the remaining area occupied by structures), it would be quite unrealistic to expect to accumulate as much as two 10-cubic-yard, semi-trailer truck loads of sediment on the pavement remaining from more than 15 years ago.

Another interest is whether contamination might be beneath, or deeper than 0.1 cm thick surface contamination. The pertinent objective is to derive the maximum acceptable average areal density, or $DCGL_W$, in units pCi/100 cm^2 or dis/(min ·100 cm^2) of surficial contamination, regardless of its depth of embedment.

To examine this issue, modeling has been done assuming residual U and Th series as a function of source thickness or embedment into pavement. The objective is to derive the maximum areal density of CT residue **on or embedded in** an outdoor surface, including pavement and CT process building slabs, that would cause no more than 25 mrem/yr. Deterministic modeling was acceptable to examine this issue since the aim is relative optimization of dose as a function of source depth. Whether concentrating a source on a surface or assuming it is embedded into pavement or a building slab would produce maximum annual dose becomes a central question to be investigated. To do this,

- A reasonable spectrum of radionuclides in CT residue is represented by a ratio of 3 U series + 0.0455 x 3 U^{235} series + 1 Th series in radioactive equilibrium.
- The relative radioactivity fraction in this ratio and the basis dose factor[3] of each key radionuclide are used with a sum-of-fractions expression to derive the areal density and equivalent mass concentration in dust (soil at 1.5 pCi/g density) on pavement surface that would produce 25 mrem/yr.
- Enter this areal density equivalent mass concentration into RESRAD with the same parameter values otherwise used as a basis to derive the areal $DCGL_W$ in CT 2 DP §5, Table 5-3 to verify whether it calculates 25 mrem/yr maximum total dose rate.

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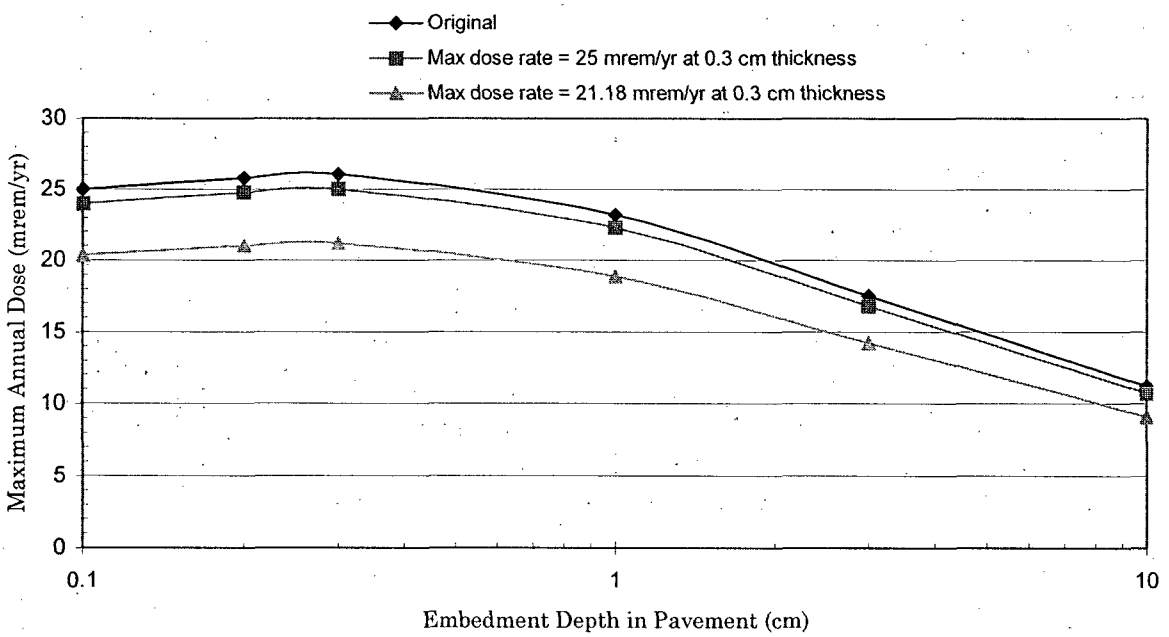
[2] Whereas, RESRAD-BUILD simulates indoor contamination with indoor dust suspension and ventilation models. Both are inappropriate for outdoor airborne exposure modeling.

[3] The basis dose factor (mrem/yr)/(pCi/g) on which the areal $DCGL_W$ in CT 2 DP is derived.

- Assume the same radionuclide spectrum at the same areal density were embedded into pavement (represented by 1.5 g/cm^3 soil). Use RESRAD to compute maximum total dose rate as a function of increasing depth of embedment.

A premise of CT 2 DP, §5, original Table 5-3 was that an equivalent areal density of CT residue would produce less dose when embedded than when accumulated on the surface; hence the source was originally modeled as concentrated into a 0.1 cm layer on the surface. Unexpectedly, maximum total dose occurs when the source is 0.2 to 0.3 cm thick, or deep, as illustrated in Figure G-7, curve "♦ Original." This observation prompted derivation of DCGLw assuming 0.3 cm contaminant thickness of the long-lived radionuclides in the uranium series, the actinium (U^{235}) series, and the thorium series, assuming short-lived nuclides (<180 day half-life) to be in transient radioactive equilibrium with their parent. The result of this refinement is illustrated in Figure G-7 by the curve, "■ Max. Dose Rate = 25 mrem/yr at 0.3 cm thickness". Thus, if contamination were on the surface or even if it were unevenly embedded into pavement or a building slab, assuming 0.3 cm source thickness when deriving DCGLw by dose modeling would assure maximum annual dose as a function of source areal density. [Fig. G-7 ref. RESRAD cases 181 through 201]

Figure G-7. Refinement of CT 2 DP §5 Model for Pavement



If the inventory corresponding to the areal DCGLw derived for the surface of pavement were embedded or migrated downward into pavement, the dose would diminish because of internal shielding of gamma radiation by pavement material. The inventory to be allowed on pavement surface corresponding to the areal DCGLw proposed in

Table G-6 would be less than inventory in about 4 cm of topsoil at the $DCGL_W$ specified in CT 2 DP Table 5-1 (rev. March 20, 2006).

That is, in a nominally representative mixture of 3 U series -to- 1 Th series, the areal density at the $DCGL_W$ on pavement or a building slab is the same as the areal density equivalent of the $DCGL_W$ concentration in about 4 cm of soil. Or, if radioactive source material at the $DCGL_W$ in the top 4 cm of topsoil were concentrated at the surface, the areal density would be the same as the $DCGL_W$ applicable on the surface of pavement or a building slab. In perspective, then, the relation in radioactivity between the $DCGL_W$ derived for application on pavement or a building slab and separately in topsoil is a reasonable one.

3.4.2. Erosion of Pavement

Assumption that pavement does not erode was questioned. The reason for assuming no erosion of pavement was to simulate sustaining the surficial source in order to maximize potential dose. Else, source material on pavement would erode along with the pavement, thereby diminishing the source. Whereas, apparent concern of agency staff about maintenance of pavement for 1000 years seems to imagine it to be needed to shield against gamma irradiation by residue in soil beneath. Consider, however,

- $DCGL_W$ in topsoil was derived assuming bare soil.
- Gamma radiation from residual source in soil beneath pavement would, at its $DCGL_W$, contribute about 5.0 mrem/yr, or 0.80 of 25 mrem/yr, by irradiation through pavement.
- Weathering is likely to remove surficial residue from pavement, or if ever present, has already done so already.
- It is reasonable to expect surficial contamination on outdoor pavement to be removed by weathering more rapidly than erosion of pavement would allow gamma radiation penetrating from beneath it to increase.
- Even if a surficial source initially at its $DCGL_W$ were to migrate into pavement or a slab, it would diminish to the $DCGL_W$ appropriate for soil, specified in CT 2 DP §5, Table 5-1 (rev. March 20, 2006), within about 4 cm depth into the pavement or slab, such that the combined dose rate would be no greater than for soil alone, even as the pavement was eroding.

That the erosion rate of source sediment on pavement is assumed to be zero maintains the source in RESRAD simulation present on the pavement surface indefinitely in order to assess whether maximum dose might be greater in future than near the beginning time of simulation. Since the maximum dose occurs near the beginning time of simulation, the assumption of zero erosion rate of source from pavement surface is otherwise of no practical consequence to the $DCGL_W$ derived with the aid of RESRAD.

If the pavement were to erode, a surficial source would be expected to disappear more readily, or at least would disappear at the rate of erosion of the pavement. That is, as pavement erodes, dose from surficial source, even if embedded into pavement, would diminish more than dose from source in soil beneath would increase. In either prospect, the source inventory per unit area on or in pavement may be as much as allowed by Table G-6 and the 25 mrem/yr dose criterion would still be satisfied. Another perspective is that

modeling a source on pavement as a thin, surficial source maximizes potential radiological dose per unit areal density. If the source were embedded into pavement, ease of removal for contamination of worker hands or clothing and potential for ingestion would be diminished. Likewise, ease of removal from the surface to become suspended in air for potential inhalation would be diminished. Furthermore, unlike an embedded source, a surficial source is without shielding by its substrate.

3.4.3. Radionuclide Source

Subtracting 5 mrem/yr apportioned to C-T residue in cinder fill from 25 mrem/yr allotted to DCGL would imply reduction of conceivable contribution from residue on pavement alone itself to 0.8 of the DCGLw derived for pavement and would eliminate question of allocation of maximum acceptable total dose.

Table G-5. Relative Radioactivity Spectrum in Pavement Scabble Samples

Radionuclide	Relative Concentration (pCi/g)
U^{238}	3.0
U^{234}	3.0
U^{235}	0.0455 x 3.0 = 0.1365
Ac^{227}	0.0455 x 3.0 = 0.1365
Pa^{231}	0.0455 x 3.0 = 0.1365
Th^{230}	0.78 x 3.0 = 2.34
Ra^{226}	1.4 x 3.0 = 4.2
Pb^{210}	1.4 x 3.0 = 4.2
Th^{232}	1.0
Ra^{228}	1.0
Th^{228}	1.0

Although it is unlikely that both soil and pavement would be contaminated to more than 0.8 of either DCGLw, and thus are practically independent, DCGLw on pavement is being reduced by 0.2 to the equivalent of 20 mrem/yr, which become the revised DCGLw to be applied. As a consequence, DCGLEMC will also be reduced to the equivalent of 20 mrem/yr.

Relative concentrations of the principal radionuclides in the pavement scabble samples, in Table G-5 and Table G-6, column 2, were increased by a constant multiple, to the concentration in Table G-6, column 3 and entered into RESRAD.

3.4.4. Dose Factors

In the case of an areal source on pavement, RESRAD computed the peak of the mean dose from all contributing radionuclides to be 20 mrem/yr, occurring in the first year of exposure. Contributions of principal radionuclides and, implicitly, their short-lived progeny to the dose are tabulated in Table G-6. [ref. RESRAD case 457putrae3]

Table G-6. Scabble Sample Spectrum on Pavement

Radionuclide	Relative Concentration (pCi/g)	Concentration Entered into RESRAD (pCi/g)	Dose Computed by RESRAD (mrem/yr)
U^{238}	3.0	225.2	0.193
U^{234}	3.0	225.2	0.0158
U^{235}	0.1365	10.25	0.0459
Ac^{227}	0.1365	10.25	0.14
Pa^{231}	0.1365	10.25	0.0352
Th^{230}	2.34	175.7	0.0266
Ra^{226}	4.2	315.3	14.3
Pb^{210}	4.2	315.3	0.403
Th^{232}	1.0	75.08	0.178
Ra^{228}	1.0	75.08	2.24
Th^{228}	1.0	75.08	2.4
		total dose =	20.0

These dose factors are combined logically for U_{nat}, Th^{230} subseries, and Th series in Table G-7 in units (mrem/yr)/(pCi/g). The dose factor of the thorium series is the sum of doses caused by the principal radionuclides Th^{232}, Ra^{228}, Th^{228}, and their short-lived progeny, divided by the concentration of Th^{232}, the reference radionuclide. Specifically,

$$DF_{\text{Th series}} = \frac{\text{dose}_{\text{Th232}} + \text{dose}_{\text{Ra228}} + \text{dose}_{\text{Th228}}}{\text{concentration}_{\text{Th232}}}$$

$$DF_{\text{Th series}} = \frac{(0.178 + 2.24 + 2.4)\text{mrem/yr}}{75.08 \text{ pCi Th}^{232}/\text{g}} = 6.42 \times 10^{-2} \frac{\text{mrem/yr}}{\text{pCi Th}^{232}/\text{g}}$$

Similarly, the radiological dose computed by RESRAD for U^{238}, U^{234}, U^{235}, Ac^{227}, and Pa^{231} and their short-lived progeny, divided by the concentration of U^{238} derives the dose factor, 1.9 x10^{-3} (mrem/yr)/(pCi/g U^{238}) for U_{nat} referenced per pCi U^{238}/g source.

Likewise, the dose factor of the Th^{230} subseries is the sum of doses caused by Th^{230}, Ra^{226}, Pb^{210}, and their short-lived progeny, divided by the concentration of Ra^{226}. Thereby,

the dose factor for the Th^{230} subseries is referenced to Ra^{226} because Ra^{226} would be the most practical to measure and poses the most potential dose.

3.4.5. DCGLw

The next step is to express the areal density of radionuclide source that would cause 20 mrem/yr to an industrial worker. A formula for that is:

$$AD = \frac{20\ \text{mrem/yr}}{\dfrac{\text{DF mrem/yr}}{\dfrac{\text{pCi}}{\text{g}} \times 1.5 \dfrac{\text{g}}{\text{cm}^3} \times \dfrac{0.3\ \text{cm} \times 100\ \text{cm}^2}{100\ \text{cm}^2}}} = \frac{900}{\text{DF}} \frac{\text{pCi}}{100\ \text{cm}^2}$$

where: AD = areal density of source on pavement that produces 20 mrem/yr (pCi/100 cm^2)
DF = dose factor of radionuclide or nuclide series (mrem/yr)/(pCi/g)
1.5 = mass density of source (g/cm^3)
0.3 = thickness of radioactive source on pavement as modeled in RESRAD (cm)
100 = factor to normalize expression of areal density to standard area (cm^2)

Table G-7. Areal C-T Contamination Limits on Pavement Surface

Radionuclide	Dose Factor	Areal Density Equal to 20 mrem/yr	
	(mrem/yr)/(pCi/g)	(pCi/100 sq cm)	(dpm/100 sq cm)
U-238	8.57E-04	1.05E+06	2.33E+06
U-234	7.02E-05	1.28E+07	2.85E+07
U-235+DI	2.16E-02	4.17E+04	9.26E+04
Th-230	1.51E-04	5.94E+06	1.32E+07
Ra-226	4.54E-02	1.98E+04	4.41E+04
Pb-210	1.28E-03	7.04E+05	1.56E+06
Th-232	2.37E-03	3.80E+05	8.43E+05
Ra-228	2.98E-02	3.02E+04	6.70E+04
Th-228	3.20E-02	2.82E+04	6.25E+04
U nat [b, c]	1.91E-03	4.71E+05	1.05E+06
Th^{230}+Ra^{226}+Pb^{210} [d]	4.67E-02	1.93E+04	4.28E+04
Th series [a]	6.42E-02	1.40E+04	3.11E+04

[a] Th^{232} series is the limit for Th^{232} with all its progeny nuclides present in equilibrium concentration (*i.e.*, radioactivity concentration of each equal to the Th^{232} concentration). Because Th^{232} progeny grows in to equilibrium within about 30 years, and because the C-T facilities have existed for nearly that long, Th^{232} progeny can be expected to be near equilibrium.

[b] U nat is the limit for U^{238} with U^{234}, and their short-lived progeny present in equilibrium and the U^{235} series is present in equilibrium in the proportion occurring in natural uranium.

[c] Radioactivity ratio of U^{235} -to- U^{238} = 0.0455 in natural uranium.

[d] Th^{230} series includes Th^{230}, Ra^{226}, Pb^{210}, and their short-lived progeny and is referenced to Ra^{226} radioactivity concentration.

An areal density that produces 20 mrem/yr may be expressed in alternate units by the formula:

$$AD = \frac{900}{DF}\frac{pCi}{100\ cm^2} \times 2.22\frac{dis}{min \cdot pCi} = \frac{2.00 \times 10^3}{DF}\frac{dis}{min \cdot 100\ cm^2}$$

Values of areal density derived by these formulae and that could cause 20 mrem/yr are tabulated in Table G-7. **These are the DCGLw for industrial work on outdoor pavement or slabs.**

When radioactivity of each long-lived radionuclide relative to each other is known, a **composite DCGLw** may be derived. In the pavement scabble samples in which principal radionuclides were measured and DCGLw has been derived for subseries, a composite DCGLw may be derived by the **sum-of-fractions** convention.

$$DCGL_W = \frac{3 + 4.2 + 1}{\frac{3}{1.05 \times 10^6} + \frac{4.2}{4.28 \times 10^4} + \frac{1}{3.11 \times 10^4}} = 6.16 \times 10^4 \frac{dis}{min \cdot 100\ cm^2}$$

where

DCGLw = composite DCGLw on pavement referenced per disintegration of parent U^{238}, Ra^{226}, or Th^{232} in the mixture (dis/(min ·100 cm²))

3 = relative concentration of U_{nat} referenced to U^{238} parent

4.2 = relative concentration of Th^{230} subseries referenced to Ra^{226}

1 = relative concentration of Th series referenced to parent Th^{232}

1.05×10^6 = DCGLw of U_{nat} referenced to U^{238} parent (dis/(min ·100 cm²))

4.28×10^4 = DCGLw of Th^{230} subseries referenced to Ra^{226} (dis/(min ·100 cm²))

3.11×10^4 = DCGLw of Th series referenced to parent Th^{232} (dis/(min ·100 cm²))

4. SPECIFICATION OF DCGLw IN MEASURABLE UNITS

The maximum acceptable average areal radioactivity density on a surface, or DCGLw, is expressed in units, pCi/100 cm², and in units, atomic disintegrations/(min ·100 cm²) in Table G-7 for components of the source. In order to assess compliance of surficial contamination with DCGL, a practical means of measurement is needed. It would be practical to state the contamination limit in units consistent with the measurement. Radioactive contamination on surfaces is often surveyed by gross activity detection and would be practical for the C-T source material.

Of the three common radiations emitted by naturally radioactive series, alpha rays are unable to penetrate sufficiently from rough or dirty surfaces while background gamma rays penetrate excessively from the substrate. Beta rays remain as the practical radiation to measure as an indication of the surficial source. A method of interpreting a surface radioactivity limit and gross beta measurement in comparable units is described in C-T Phase I Decommissioning Plan, Appendix D.

Note that the radionuclide source, in units, pCi/100 cm^2, is directly proportional to dose and thus is the parameter that must be limited. When the source is a mixture of radionuclides, expressed in units, pCi/100 cm^2 or (dis/(min·100 cm^2)), a composite value is derived by the **sum-of-fractions** convention to assure that the mixture would cause no more than 20 mrem/yr. The number of beta (+ i.c.e.) per disintegration of a radionuclide is an indicator of the source but is not a direct indicator of the dose it causes; for there is not a one-to-one correlation between number of beta + i.c.e. per atomic tranformation among the radionuclides. Consequently, the corresponding number of beta + i.c.e. is derived separately from the DCGL for the radionuclide spectrum, or mixture, to correlate with the radionuclide mix that would produce 20 mrem/yr and not as a sum-of-fractions.

Since it is practical to measure total beta radiation, an essential step is to determine the total beta + internal conversion electron emission per atomic transformation of the source radionuclide spectrum or of a reference radionuclide.

4.1. RADIONUCLIDE SPECTRUM ON PAVEMENT

Principal radionuclides in the uranium series, thorium series, and actinium series were measured in 24 samples scabbled on pavement in Plant 5. Results are in CT Phase II DP Table 4-2 and are reproduced herein as Table G-3. Lognormal distribution graphics of analytical data, in CT Phase II DP, Table 4-2, indicate that the log mean U_{nat} -to- Th series activity ratio is about 3 -to- 1. Ra^{226} is about 1.5 times more abundant than the U_{nat} parent. Th^{230} averages about 0.8 of U_{nat} parent and about 0.6 of Ra^{226}, and for deriving $DCGL_W$, is conservatively be assumed exist in equal radioactivity with Ra^{226}.

Table G-8. Relative Concentration in Pavement Scabble Samples

Radionuclide	Relative Concentration (pCi/g sample)	
	Factors	Value
U^{238}	3.0 =	3.0
U^{234}	3.0 =	3.0
U^{235} + d	.0455 x 3.0 =	0.1365
Th^{230}	078 x 3.0 =	2.34
Ra^{226}	1.4 x 3.0 =	4.2
Pb^{210}	1.4 x 3.0 =	4.2
Th^{232}	1.0 =	1.0
Ra^{228}	1.0 =	1.0
Th^{228}	1.0 =	1.0

4.2. BETA EMISSION

Naturally-occurring radioactive decay series each emit beta radiation and internal conversion electrons of sufficient energy to be detected by conventional radiation survey instrumentation. The number of beta plus internal conversion electrons (i.c.e.) having > 0.08 Mev energy, sufficient to penetrate a 9 mg/cm^2 detector window, are tabulated for each of the radioactive decay series of interest.

Table G-9. Beta + I.C.E. Emission by Radionuclides in the Uranium Series

Radionuclide	Probability of Creation per Decay	
	Beta	I.C. Electron[A]
U^{238}		0.0015
Th^{234}	0.98	0.038
Pa^{234m}	1.	0.004
U^{234}		0.0014
Th^{230}		<<
Ra^{226}		0.023
Rn^{222}		
Po^{218}		
Pb^{214}	1.	0.27
Bi^{214}	1.	0.015
Po^{214}		
Pb^{210}	<<	<<
Bi^{210}	1.	
Po^{210}		
total[B]	4.98	0.35

[A] I.C.E. = internal conversion electron

[B] total beta + i.c.e. = 5.33

Table G-10. Beta Emission by Radionuclides in the Actinium Series

Radionuclide	Probability of Creation per Decay	
	Beta	I.C. Electron[A]
U^{235}		
Th^{231}	1.	
Pa^{231}		
Ac^{227}		
Fr^{223}	0.0137[B]	
Ra^{223}		
Rn^{219}		
Po^{215}		
Pb^{211}	1.	
At^{215}		
Bi^{211}		
Po^{211}		
Tl^{207}	0.994[B]	
total[C]	3.008	

[A] internal conversion electron data not identified in available database

[B] branching fraction included

[C] total beta + i.c.e. = 3.008

Table G-11. Beta + I.C.E. Emission by Radionuclides in the Thorium Series

Radionuclide	Probability of Creation per Decay	
	Beta	I.C. Electron
Th^{232}		0.001
Ra^{228}	<<	<<
Ac^{228}	0.97	0.14
Th^{228}		0.019
Ra^{224}		0.011
Rn^{220}		
Po^{216}		
Pb^{212}	1.0	0.43
Bi^{212}	0.64	0.0012
Po^{212}		
Tl^{208}	0.36[A]	0.032[A]
total[B]	2.97	0.634

[A] branching fraction included
[B] total beta + i.c.e. = 3.604

The DCGLw of C-T source radionuclides has been combined into 3 decay sets:

- U_{nat} including U^{238}, Th^{234}, Pa^{234}, U^{234}, and in naturally-occurring proportion, the Actinide series
- Th^{230} subseries including Th^{230}, Ra^{226}, Pb^{210} and their short-lived progeny
- Th series including Th^{232}, Ra^{228}, Th^{228}, and their short-lived progeny

The number of beta + i.c.e. emitted by each of these decay sets is tallied in order to be able to estimate the number of beta + i.c.e. emitted by an identified proportion of each set in an entire source.

$$\beta \text{ by } U_{nat} = U^{238} \text{ thru } U^{234} + 0.0455\ U^{235} \text{ series}$$
$$= 2.2049 + 0.0455 \times 3.008\ \beta/U^{238} \text{ dis}$$
$$= 2.162\ \beta/U^{238} \text{ dis}$$
$$\beta \text{ by } Th^{230} \text{ subseries} = 3.308\ \beta/\ Ra^{226} \text{ dis}$$
$$\beta \text{ by Th series} = 3.604\ \beta/\ Th^{232} \text{ dis}$$

where the number of beta emitted is referenced to a principal parent radionuclide in the set whose radioactivity concentration is measurable and which is also the reference for statement of the DCGLw of the same set.

In the pavement scabble samples, the ratio of radioactivity of the principal reference radionuclides is:

U^{238} representing U_{nat} = 3
Ra^{226} representing Th^{230} subseries = 1.4 x 3 = 4.2
Th^{232} representing Th series = 1

One may estimate β_{limit}, the total number of beta emitted by this spectrum, capable of penetrating a 9 mg/cm^2 detector window, and corresponding to the DCGLw of this scabble sample mix.

4.2.1. First Method.

The β emission (+i.c.e. implied) corresponding to the DCGLw applicable to C-T contamination on pavement as represented by the set of scabble samples may be estimated by adding the three contributing nuclide groups. DCGLw = 6.16 x 10^4 dis/(min ·100 cm^2) was derived in §3.4.5 of this appendix for source ratios

3 = relative concentration of U_{nat} referenced to U^{238} parent

4.2 = relative concentration of Th^{230} subseries referenced to Ra^{226}

1 = relative concentration of Th series referenced to parent Th^{232}

Component contributions to the DCGLw are:

$$U_{nat} \text{ part ref to } U^{238} = \frac{3}{8.2} \times 6.16 \times 10^4 = 2.25 \times 10^4 \frac{\text{dis } U^{238}}{\text{min} \cdot 100 \text{ cm}^2}$$

$$Th^{230} \text{ subseries ref to } Ra^{226} = \frac{4.2}{8.2} \times 6.16 \times 10^4 = 3.15 \times 10^4 \frac{\text{dis } Ra^{226}}{\text{min} \cdot 100 \text{ cm}^2}$$

$$\text{Th series ref to } Th^{232} = \frac{1}{8.2} \times 6.16 \times 10^4 = 7.51 \times 10^3 \frac{\text{dis } Th^{232}}{\text{min} \cdot 100 \text{ cm}^2}$$

Each component radionuclide group emits β +i.c.e. They add to produce total β (+i.c.e. implied) emission corresponding to the DCGLw. Thus,

$$\beta_{lim} = \beta(U_{nat}) + \beta(Th^{230} \text{ subseries}) + \beta(\text{Th series})$$

$$\beta_{lim} = 2.25 \times 10^4 \frac{\text{dis } U^{238}}{\text{min} \cdot 100 \text{ cm}^2} \times 2.162 \frac{\beta}{U^{238} \text{ dis}} + 3.15 \times 10^4 \frac{\text{dis } Ra^{226}}{\text{min} \cdot 100 \text{ cm}^2} \times 3.308 \frac{\beta}{Ra^{226} \text{ dis}} +$$

$$+ 7.51 \times 10^3 \frac{\text{dis } Th^{232}}{\text{min} \cdot 100 \text{ cm}^2} \times 3.604 \frac{\beta}{Th^{232} \text{ dis}}$$

β_{lim} = 1.80 x 10^5 β/(min ·100 cm^2)

4.2.2. Second Method.

A variation on the method estimates the β emission corresponding to the DCGLw expressed by composite data. The composite number of beta emitted per a parent disintegration is:

composite β/dis = $\beta(U_{nat}) + \beta(Th^{230} \text{ subseries}) + \beta(\text{Th series})$

$$\text{composite } \beta/\text{dis} = \frac{3 \times 2.162 + 4.2 \times 3.308 + 1 \times 3.604}{3 + 4.2 + 1}$$

composite β/dis = 2.925 β/dis of one of the reference nuclides U^{238}, Ra^{226}, or Th^{232}

The composite β_{lim} of that mixture of radionuclides represented by pavement scabble samples is

$$\text{composite } \beta_{\text{lim}} \text{ of mix} = \text{DCGL}_{\text{W}} \text{ of mix} \frac{\text{dis}}{\text{min} \cdot 100\,\text{cm}^2} \times \text{composite } \frac{\beta}{\text{dis}}$$

$$\text{composite } \beta_{\text{lim}} \text{ of mix} = 6.16 \times 10^4 \frac{\text{dis}}{\text{min} \cdot 100\,\text{cm}^2} \times 2.925 \frac{\beta}{\text{dis}}$$

composite β_{lim} of mix = 1.80×10^5 $\beta/(\text{min} \cdot 100\ \text{cm}^2)$

4.3. SUMMARY

Applying the radionuclide distribution observed in pavement scabble samples estimate the areal density equal to 20 mrem/yr by dose modeling derives a composite

$\text{DCGL}_W = 6.2 \times 10^4$ dis/(min ·100 cm^2),

where a *disintegration* is per atomic tranformation of principal radionuclide U^{238}, Ra^{226}, or Th^{232} while accounting for the contribution to dose of each radionuclide in each subseries.

This composite DCGL_W may be expressed in measurable units to compare with total beta + internal conversion electrons emitted by the source.

$\text{DCGL}_W = 1.8 \times 10^5$ β/(min ·100 cm^2)

The DCGL_W is not very sensitive to radionuclide variability. If, for instance, the source were entirely uranium series + actinium series in natural proportion to uranium, both in radioactive equilibrium, the DCGL_W would = 2.2×10^5 β/(min ·100 cm^2); or if the source were entirely thorium series in equilibrium, the DCGL_W would = 1.1×10^5 β/(min ·100 cm^2). Thus, to enable practical survey by measuring gross beta radiation, $\text{DCGL}_W = 1.8 \times 10^5$ β/(min ·100 cm^2) is proposed. Measurement methodology is described in C-T Phase I Decommissioning Plan, Appendix D, §3 "Beta Radiation Measurement."

Attachment G-A

Derivation of DCGL on Pavement Surface

Ref. Appendix G, Table G-7

Ref. C-T Phase II Decommissioning Plan, Table 5-4

RESRAD case 457putrae3

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Dose Conversion Factor (and Related) Parameter Summary
Dose Library: FGR 11

Menu	Parameter	Current Value#	Base Case*	Parameter Name
A-1	DCF's for external ground radiation, (mrem/yr)/(pCi/g)			
A-1	Ac-227 (Source: FGR 12)	4.951E-04	4.951E-04	DCF1(1)
A-1	Ac-228 (Source: FGR 12)	5.978E+00	5.978E+00	DCF1(2)
A-1	At-218 (Source: FGR 12)	5.847E-03	5.847E-03	DCF1(3)
A-1	Bi-210 (Source: FGR 12)	3.606E-03	3.606E-03	DCF1(4)
A-1	Bi-211 (Source: FGR 12)	2.559E-01	2.559E-01	DCF1(5)
A-1	Bi-212 (Source: FGR 12)	1.171E+00	1.171E+00	DCF1(6)
A-1	Bi-214 (Source: FGR 12)	9.808E+00	9.808E+00	DCF1(7)
A-1	Fr-223 (Source: FGR 12)	1.980E-01	1.980E-01	DCF1(8)
A-1	Pa-231 (Source: FGR 12)	1.906E-01	1.906E-01	DCF1(9)
A-1	Pa-234 (Source: FGR 12)	1.155E+01	1.155E+01	DCF1(10)
A-1	Pa-234m (Source: FGR 12)	8.967E-02	8.967E-02	DCF1(11)
A-1	Pb-210 (Source: FGR 12)	2.447E-03	2.447E-03	DCF1(12)
A-1	Pb-211 (Source: FGR 12)	3.064E-01	3.064E-01	DCF1(13)
A-1	Pb-212 (Source: FGR 12)	7.043E-01	7.043E-01	DCF1(14)
A-1	Pb-214 (Source: FGR 12)	1.341E+00	1.341E+00	DCF1(15)
A-1	Po-210 (Source: FGR 12)	5.231E-05	5.231E-05	DCF1(16)
A-1	Po-211 (Source: FGR 12)	4.764E-02	4.764E-02	DCF1(17)
A-1	Po-212 (Source: FGR 12)	0.000E+00	0.000E+00	DCF1(18)
A-1	Po-214 (Source: FGR 12)	5.138E-04	5.138E-04	DCF1(19)
A-1	Po-215 (Source: FGR 12)	1.016E-03	1.016E-03	DCF1(20)
A-1	Po-216 (Source: FGR 12)	1.042E-04	1.042E-04	DCF1(21)
A-1	Po-218 (Source: FGR 12)	5.642E-05	5.642E-05	DCF1(22)
A-1	Ra-223 (Source: FGR 12)	6.034E-01	6.034E-01	DCF1(23)
A-1	Ra-224 (Source: FGR 12)	5.119E-02	5.119E-02	DCF1(24)
A-1	Ra-226 (Source: FGR 12)	3.176E-02	3.176E-02	DCF1(25)
A-1	Ra-228 (Source: FGR 12)	0.000E+00	0.000E+00	DCF1(26)
A-1	Rn-219 (Source: FGR 12)	3.083E-01	3.083E-01	DCF1(27)
A-1	Rn-220 (Source: FGR 12)	2.298E-03	2.298E-03	DCF1(28)
A-1	Rn-222 (Source: FGR 12)	2.354E-03	2.354E-03	DCF1(29)
A-1	Th-227 (Source: FGR 12)	5.212E-01	5.212E-01	DCF1(30)
A-1	Th-228 (Source: FGR 12)	7.940E-03	7.940E-03	DCF1(31)
A-1	Th-230 (Source: FGR 12)	1.209E-03	1.209E-03	DCF1(32)
A-1	Th-231 (Source: FGR 12)	3.643E-02	3.643E-02	DCF1(33)
A-1	Th-232 (Source: FGR 12)	5.212E-04	5.212E-04	DCF1(34)
A-1	Th-234 (Source: FGR 12)	2.410E-02	2.410E-02	DCF1(35)
A-1	Tl-207 (Source: FGR 12)	1.980E-02	1.980E-02	DCF1(36)
A-1	Tl-208 (Source: FGR 12)	2.298E+01	2.298E+01	DCF1(37)
A-1	Tl-210 (Source: no data)	0.000E+00	-2.000E+00	DCF1(38)
A-1	U-234 (Source: FGR 12)	4.017E-04	4.017E-04	DCF1(39)
A-1	U-235 (Source: FGR 12)	7.211E-01	7.211E-01	DCF1(40)
A-1	U-238 (Source: FGR 12)	1.031E-04	1.031E-04	DCF1(41)
B-1	Dose conversion factors for inhalation, mrem/pCi:			
B-1	Ac-227+D	6.724E+00	6.700E+00	DCF2(1)
B-1	Pa-231	1.280E+00	1.280E+00	DCF2(2)
B-1	Pb-210+D	2.320E-02	1.360E-02	DCF2(3)
B-1	Ra-226+D	8.594E-03	8.580E-03	DCF2(4)
B-1	Ra-228+D	5.078E-03	4.770E-03	DCF2(5)
B-1	Th-228+D	3.454E-01	3.420E-01	DCF2(6)

Dose Conversion Factor (and Related) Parameter Summary (continued)
Dose Library: FGR 11

Menu	Parameter	Current Value#	Base Case*	Parameter Name
B-1	Th-230	3.260E-01	3.260E-01	DCF2(7)
B-1	Th-232	1.640E+00	1.640E+00	DCF2(8)
B-1	U-234	1.320E-01	1.320E-01	DCF2(9)
B-1	U-235+D	1.230E-01	1.230E-01	DCF2(10)
B-1	U-238	1.180E-01	1.180E-01	DCF2(11)
B-1	U-238+D	1.180E-01	1.180E-01	DCF2(12)
D-1	Dose conversion factors for ingestion, mrem/pCi:			
D-1	Ac-227+D	1.480E-02	1.410E-02	DCF3(1)
D-1	Pa-231	1.060E-02	1.060E-02	DCF3(2)
D-1	Pb-210+D	7.276E-03	5.370E-03	DCF3(3)
D-1	Ra-226+D	1.321E-03	1.320E-03	DCF3(4)
D-1	Ra-228+D	1.442E-03	1.440E-03	DCF3(5)
D-1	Th-228+D	8.086E-04	3.960E-04	DCF3(6)
D-1	Th-230	5.480E-04	5.480E-04	DCF3(7)
D-1	Th-232	2.730E-03	2.730E-03	DCF3(8)
D-1	U-234	2.830E-04	2.830E-04	DCF3(9)
D-1	U-235+D	2.673E-04	2.660E-04	DCF3(10)
D-1	U-238	2.550E-04	2.550E-04	DCF3(11)
D-1	U-238+D	2.687E-04	2.550E-04	DCF3(12)
D-34	Food transfer factors:			
D-34	Ac-227+D , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(1,1)
D-34	Ac-227+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	2.000E-05	2.000E-05	RTF(1,2)
D-34	Ac-227+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	2.000E-05	2.000E-05	RTF(1,3)
D-34				
D-34	Pa-231 , plant/soil concentration ratio, dimensionless	1.000E-02	1.000E-02	RTF(2,1)
D-34	Pa-231 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	5.000E-03	5.000E-03	RTF(2,2)
D-34	Pa-231 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(2,3)
D-34				
D-34	Pb-210+D , plant/soil concentration ratio, dimensionless	1.000E-02	1.000E-02	RTF(3,1)
D-34	Pb-210+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	8.000E-04	8.000E-04	RTF(3,2)
D-34	Pb-210+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	3.000E-04	3.000E-04	RTF(3,3)
D-34				
D-34	Ra-226+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(4,1)
D-34	Ra-226+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(4,2)
D-34	Ra-226+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(4,3)
D-34				
D-34	Ra-228+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(5,1)
D-34	Ra-228+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(5,2)
D-34	Ra-228+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(5,3)
D-34				
D-34	Th-228+D , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(6,1)
D-34	Th-228+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(6,2)
D-34	Th-228+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(6,3)
D-34				
D-34	Th-230 , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(7,1)
D-34	Th-230 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(7,2)
D-34	Th-230 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(7,3)
D-34				

Dose Conversion Factor (and Related) Parameter Summary (continued)
Dose Library: FGR 11

Menu	Parameter	Current Value#	Base Case*	Parameter Name
D-34	Th-232 , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(8,1)
D-34	Th-232 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(8,2)
D-34	Th-232 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(8,3)
D-34				
D-34	U-234 , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(9,1)
D-34	U-234 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(9,2)
D-34	U-234 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(9,3)
D-34				
D-34	U-235+D , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(10,1)
D-34	U-235+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(10,2)
D-34	U-235+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(10,3)
D-34				
D-34	U-238 , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(11,1)
D-34	U-238 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(11,2)
D-34	U-238 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(11,3)
D-34				
D-34	U-238+D , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(12,1)
D-34	U-238+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(12,2)
D-34	U-238+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(12,3)
D-5	Bioaccumulation factors, fresh water, L/kg:			
D-5	Ac-227+D , fish	1.500E+01	1.500E+01	BIOFAC(1,1)
D-5	Ac-227+D , crustacea and mollusks	1.000E+03	1.000E+03	BIOFAC(1,2)
D-5				
D-5	Pa-231 , fish	1.000E+01	1.000E+01	BIOFAC(2,1)
D-5	Pa-231 , crustacea and mollusks	1.100E+02	1.100E+02	BIOFAC(2,2)
D-5				
D-5	Pb-210+D , fish	3.000E+02	3.000E+02	BIOFAC(3,1)
D-5	Pb-210+D , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC(3,2)
D-5				
D-5	Ra-226+D , fish	5.000E+01	5.000E+01	BIOFAC(4,1)
D-5	Ra-226+D , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(4,2)
D-5				
D-5	Ra-228+D , fish	5.000E+01	5.000E+01	BIOFAC(5,1)
D-5	Ra-228+D , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(5,2)
D-5				
D-5	Th-228+D , fish	1.000E+02	1.000E+02	BIOFAC(6,1)
D-5	Th-228+D , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(6,2)
D-5				
D-5	Th-230 , fish	1.000E+02	1.000E+02	BIOFAC(7,1)
D-5	Th-230 , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(7,2)
D-5				
D-5	Th-232 , fish	1.000E+02	1.000E+02	BIOFAC(8,1)
D-5	Th-232 , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(8,2)
D-5				
D-5	U-234 , fish	1.000E+01	1.000E+01	BIOFAC(9,1)
D-5	U-234 , crustacea and mollusks	6.000E+01	6.000E+01	BIOFAC(9,2)
D-5				
D-5	U-235+D , fish	1.000E+01	1.000E+01	BIOFAC(10,1)
D-5	U-235+D , crustacea and mollusks	6.000E+01	6.000E+01	BIOFAC(10,2)

Dose Conversion Factor (and Related) Parameter Summary (continued)
Dose Library: FGR 11

Menu	Parameter	Current Value#	Base Case*	Parameter Name
D-5	U-238 , fish	1.000E+01	1.000E+01	BIOFAC(11,1)
D-5	U-238 , crustacea and mollusks	6.000E+01	6.000E+01	BIOFAC(11,2)
D-5				
D-5	U-238+D , fish	1.000E+01	1.000E+01	BIOFAC(12,1)
D-5	U-238+D , crustacea and mollusks	6.000E+01	6.000E+01	BIOFAC(12,2)

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

Site-Specific Parameter Summary

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-03	2.000E+00	---	THICKO
R011	Length parallel to aquifer flow (m)	not used	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	2.500E+01	3.000E+01	---	BRDL
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	3.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	3.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	3.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(9)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): Ac-227	1.025E+01	0.000E+00	---	S1(1)
R012	Initial principal radionuclide (pCi/g): Pa-231	1.025E+01	0.000E+00	---	S1(2)
R012	Initial principal radionuclide (pCi/g): Pb-210	3.153E+02	0.000E+00	---	S1(3)
R012	Initial principal radionuclide (pCi/g): Ra-226	3.153E+02	0.000E+00	---	S1(4)
R012	Initial principal radionuclide (pCi/g): Ra-228	7.508E+01	0.000E+00	---	S1(5)
R012	Initial principal radionuclide (pCi/g): Th-228	7.508E+01	0.000E+00	---	S1(6)
R012	Initial principal radionuclide (pCi/g): Th-230	1.757E+02	0.000E+00	---	S1(7)
R012	Initial principal radionuclide (pCi/g): Th-232	7.508E+01	0.000E+00	---	S1(8)
R012	Initial principal radionuclide (pCi/g): U-234	2.252E+02	0.000E+00	---	S1(9)
R012	Initial principal radionuclide (pCi/g): U-235	1.025E+01	0.000E+00	---	S1(10)
R012	Initial principal radionuclide (pCi/g): U-238	2.252E+02	0.000E+00	---	S1(11)
R012	Concentration in groundwater (pCi/L): Ac-227	not used	0.000E+00	---	W1(1)
R012	Concentration in groundwater (pCi/L): Pa-231	not used	0.000E+00	---	W1(2)
R012	Concentration in groundwater (pCi/L): Pb-210	not used	0.000E+00	---	W1(3)
R012	Concentration in groundwater (pCi/L): Ra-226	not used	0.000E+00	---	W1(4)
R012	Concentration in groundwater (pCi/L): Ra-228	not used	0.000E+00	---	W1(5)
R012	Concentration in groundwater (pCi/L): Th-228	not used	0.000E+00	---	W1(6)
R012	Concentration in groundwater (pCi/L): Th-230	not used	0.000E+00	---	W1(7)
R012	Concentration in groundwater (pCi/L): Th-232	not used	0.000E+00	---	W1(8)
R012	Concentration in groundwater (pCi/L): U-234	not used	0.000E+00	---	W1(9)
R012	Concentration in groundwater (pCi/L): U-235	not used	0.000E+00	---	W1(10)
R012	Concentration in groundwater (pCi/L): U-238	not used	0.000E+00	---	W1(11)
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)	1.500E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	0.000E+00	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	4.000E-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)	4.000E+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

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R013	Precipitation (m/yr)	1.000E+00	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	0.000E+00	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	9.900E-01	2.000E-01	---	RUNOFF
R013	Watershed area for nearby stream or pond (m**2)	not used	1.000E+06	---	WAREA
R013	Accuracy for water/soil computations	not used	1.000E-03	---	EPS
R014	Density of saturated zone (g/cm**3)	not used	1.500E+00	---	DENSAQ
R014	Saturated zone total porosity	not used	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	not used	2.000E-01	---	EPSZ
R014	Saturated zone field capacity	not used	2.000E-01	---	FCSZ
R014	Saturated zone hydraulic conductivity (m/yr)	not used	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	not used	2.000E-02	---	HGWT
R014	Saturated zone b parameter	not used	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	not used	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	not used	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	not used	ND	---	MODEL
R014	Well pumping rate (m**3/yr)	not used	2.500E+02	---	UW
R015	Number of unsaturated zone strata	not used	1	---	NS
R015	Unsat. zone 1, thickness (m)	not used	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	not used	1.500E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	not used	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	not used	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, field capacity	not used	2.000E-01	---	FCUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	not used	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	not used	1.000E+01	---	HCUZ(1)
R016	Distribution coefficients for Ac-227				
R016	Contaminated zone (cm**3/g)	8.250E+02	2.000E+01	---	DCNUCC(1)
R016	Unsaturated zone 1 (cm**3/g)	not used	2.000E+01	---	DCNUCU(1,1)
R016	Saturated zone (cm**3/g)	not used	2.000E+01	---	DCNUCS(1)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.346E-03	ALEACH(1)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(1)
R016	Distribution coefficients for Pa-231				
R016	Contaminated zone (cm**3/g)	3.800E+02	5.000E+01	---	DCNUCC(2)
R016	Unsaturated zone 1 (cm**3/g)	not used	5.000E+01	---	DCNUCU(2,1)
R016	Saturated zone (cm**3/g)	not used	5.000E+01	---	DCNUCS(2)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.922E-03	ALEACH(2)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(2)
R016	Distribution coefficients for Pb-210				
R016	Contaminated zone (cm**3/g)	2.392E+03	1.000E+02	---	DCNUCC(3)
R016	Unsaturated zone 1 (cm**3/g)	not used	1.000E+02	---	DCNUCU(3,1)
R016	Saturated zone (cm**3/g)	not used	1.000E+02	---	DCNUCS(3)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	4.645E-04	ALEACH(3)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(3)

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for Ra-226				
R016	Contaminated zone (cm**3/g)	3.533E+03	7.000E+01	---	DCNUCC(4)
R016	Unsaturated zone 1 (cm**3/g)	not used	7.000E+01	---	DCNUCU(4,1)
R016	Saturated zone (cm**3/g)	not used	7.000E+01	---	DCNUCS(4)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	3.145E-04	ALEACH(4)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(4)
R016	Distribution coefficients for Ra-228				
R016	Contaminated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCC(5)
R016	Unsaturated zone 1 (cm**3/g)	not used	7.000E+01	---	DCNUCU(5,1)
R016	Saturated zone (cm**3/g)	not used	7.000E+01	---	DCNUCS(5)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.582E-02	ALEACH(5)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(5)
R016	Distribution coefficients for Th-228				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(6)
R016	Unsaturated zone 1 (cm**3/g)	not used	6.000E+04	---	DCNUCU(6,1)
R016	Saturated zone (cm**3/g)	not used	6.000E+04	---	DCNUCS(6)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.852E-05	ALEACH(6)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(6)
R016	Distribution coefficients for Th-230				
R016	Contaminated zone (cm**3/g)	5.884E+03	6.000E+04	---	DCNUCC(7)
R016	Unsaturated zone 1 (cm**3/g)	not used	6.000E+04	---	DCNUCU(7,1)
R016	Saturated zone (cm**3/g)	not used	6.000E+04	---	DCNUCS(7)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.888E-04	ALEACH(7)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(7)
R016	Distribution coefficients for Th-232				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(8)
R016	Unsaturated zone 1 (cm**3/g)	not used	6.000E+04	---	DCNUCU(8,1)
R016	Saturated zone (cm**3/g)	not used	6.000E+04	---	DCNUCS(8)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.852E-05	ALEACH(8)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(8)
R016	Distribution coefficients for U-234				
R016	Contaminated zone (cm**3/g)	1.260E+02	5.000E+01	---	DCNUCC(9)
R016	Unsaturated zone 1 (cm**3/g)	not used	5.000E+01	---	DCNUCU(9,1)
R016	Saturated zone (cm**3/g)	not used	5.000E+01	---	DCNUCS(9)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	8.803E-03	ALEACH(9)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(9)
R016	Distribution coefficients for U-235				
R016	Contaminated zone (cm**3/g)	1.260E+02	5.000E+01	---	DCNUCC(10)
R016	Unsaturated zone 1 (cm**3/g)	not used	5.000E+01	---	DCNUCU(10,1)
R016	Saturated zone (cm**3/g)	not used	5.000E+01	---	DCNUCS(10)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	8.803E-03	ALEACH(10)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(10)

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for U-238				
R016	Contaminated zone (cm**3/g)	1.260E+02	5.000E+01	---	DCNUCC(11)
R016	Unsaturated zone 1 (cm**3/g)	not used	5.000E+01	---	DCNUCU(11,1)
R016	Saturated zone (cm**3/g)	not used	5.000E+01	---	DCNUCS(11)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	8.803E-03	ALEACH(11)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(11)
R017	Inhalation rate (m**3/yr)	1.227E+04	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	3.500E-05	1.000E-04	---	MLINH
R017	Exposure duration	3.000E+01	3.000E+01	---	ED
R017	Shielding factor, inhalation	6.000E-01	4.000E-01	---	SHF3
R017	Shielding factor, external gamma	1.700E-01	7.000E-01	---	SHF1
R017	Fraction of time spent indoors	1.825E-01	5.000E-01	---	FIND
R017	Fraction of time spent outdoors (on site)	4.563E-02	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)	not used	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	not used	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	not used	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	not used	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	not used	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	not used	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	3.650E+01	3.650E+01	---	SOIL

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R018	Drinking water intake (L/yr)	not used	5.100E+02	---	DWI
R018	Contamination fraction of drinking water	not used	1.000E+00	---	FDW
R018	Contamination fraction of household water	not used	1.000E+00	---	FHHW
R018	Contamination fraction of livestock water	not used	1.000E+00	---	FLW
R018	Contamination fraction of irrigation water	not used	1.000E+00	---	FIRW
R018	Contamination fraction of aquatic food	not used	5.000E-01	---	FR9
R018	Contamination fraction of plant food	not used	-1	---	FPLANT
R018	Contamination fraction of meat	not used	-1	---	FMEAT
R018	Contamination fraction of milk	not used	-1	---	FMILK
R019	Livestock fodder intake for meat (kg/day)	not used	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	not used	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	not used	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	not used	1.600E+02	---	LWI6
R019	Livestock soil intake (kg/day)	not used	5.000E-01	---	LSI
R019	Mass loading for foliar deposition (g/m**3)	not used	1.000E-04	---	MLFD
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	not used	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	not used	1.000E+00	---	FGWDW
R019	Household water fraction from ground water	not used	1.000E+00	---	FGWHH
R019	Livestock water fraction from ground water	not used	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	not used	1.000E+00	---	FGWIR
R19B	Wet weight crop yield for Non-Leafy (kg/m**2)	not used	7.000E-01	---	YV(1)
R19B	Wet weight crop yield for Leafy (kg/m**2)	not used	1.500E+00	---	YV(2)
R19B	Wet weight crop yield for Fodder (kg/m**2)	not used	1.100E+00	---	YV(3)
R19B	Growing Season for Non-Leafy (years)	not used	1.700E-01	---	TE(1)
R19B	Growing Season for Leafy (years)	not used	2.500E-01	---	TE(2)
R19B	Growing Season for Fodder (years)	not used	8.000E-02	---	TE(3)
R19B	Translocation Factor for Non-Leafy	not used	1.000E-01	---	TIV(1)
R19B	Translocation Factor for Leafy	not used	1.000E+00	---	TIV(2)
R19B	Translocation Factor for Fodder	not used	1.000E+00	---	TIV(3)
R19B	Dry Foliar Interception Fraction for Non-Leafy	not used	2.500E-01	---	RDRY(1)
R19B	Dry Foliar Interception Fraction for Leafy	not used	2.500E-01	---	RDRY(2)
R19B	Dry Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RDRY(3)
R19B	Wet Foliar Interception Fraction for Non-Leafy	not used	2.500E-01	---	RWET(1)
R19B	Wet Foliar Interception Fraction for Leafy	not used	2.500E-01	---	RWET(2)
R19B	Wet Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RWET(3)
R19B	Weathering Removal Constant for Vegetation	not used	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

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
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
TITL	Maximum number of integration points for risk	1	---	---	KYMAX

Summary of Pathway Selections

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

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

Initial Soil Concentrations, pCi/g	
Ac-227	1.025E+01
Pa-231	1.025E+01
Pb-210	3.153E+02
Ra-226	3.153E+02
Ra-228	7.508E+01
Th-228	7.508E+01
Th-230	1.757E+02
Th-232	7.508E+01
U-234	2.252E+02
U-235	1.025E+01
U-238	2.252E+02

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

t (years):	0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
TDOSE(t):	2.160E+01	2.155E+01	2.143E+01	2.110E+01	2.072E+01	2.003E+01	1.844E+01	1.453E+01
M(t):	8.641E-01	8.620E-01	8.573E-01	8.441E-01	8.287E-01	8.012E-01	7.376E-01	5.813E-01

Maximum TDOSE(t): 2.160E+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	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ac-227	1.168E-01	0.0054	8.300E-03	0.0004	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.484E-02	0.0012
Pa-231	1.345E-02	0.0006	1.737E-03	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.846E-02	0.0009
Pb-210	2.771E-02	0.0013	8.815E-04	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.761E-01	0.0174
Ra-226	1.543E+01	0.7143	3.454E-04	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.521E-02	0.0035
Ra-228	2.402E+00	0.1112	5.321E-04	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.841E-02	0.0009
Th-228	2.584E+00	0.1196	2.663E-03	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.481E-03	0.0004
Th-230	4.633E-03	0.0002	7.013E-03	0.0003	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.604E-02	0.0007
Th-232	1.394E-01	0.0065	1.510E-02	0.0007	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.524E-02	0.0016
U-234	2.140E-03	0.0001	3.624E-03	0.0002	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.057E-02	0.0005
U-235	4.902E-02	0.0023	1.537E-04	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.546E-04	0.0000
U-238	1.953E-01	0.0090	3.240E-03	0.0002	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.003E-02	0.0005
Total	2.096E+01	0.9705	4.359E-02	0.0020	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.939E-01	0.0275

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.
Ac-227	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.499E-01	0.0069
Pa-231	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.365E-02	0.0016
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.047E-01	0.0187
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	1.550E+01	0.7178
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	2.421E+00	0.1121
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	2.596E+00	0.1202
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.769E-02	0.0013
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	1.897E-01	0.0088
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.633E-02	0.0008
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.963E-02	0.0023
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.085E-01	0.0097
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	2.160E+01	1.0000

*Sum of all water independent and dependent pathways.

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 2.500E+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
Ac-227	1.709E+03	1.767E+03	1.888E+03	2.382E+03	4.625E+03	4.719E+04	3.597E+07	*7.232E+13
Pa-231	7.614E+03	6.701E+03	5.461E+03	3.526E+03	2.191E+03	1.871E+03	3.236E+03	2.540E+04
Pb-210	1.948E+04	2.010E+04	2.141E+04	2.670E+04	5.018E+04	4.567E+05	2.511E+08	*7.634E+13
Ra-226	5.084E+02	5.084E+02	5.084E+02	5.087E+02	5.118E+02	5.344E+02	6.199E+02	1.046E+03
Ra-228	7.752E+02	6.593E+02	6.321E+02	1.194E+03	1.707E+04	2.386E+08	*2.726E+14	*2.726E+14
Th-228	7.232E+02	1.039E+03	2.144E+03	2.709E+04	3.802E+07	*8.195E+14	*8.195E+14	*8.195E+14
Th-230	1.586E+05	1.398E+05	1.129E+05	6.755E+04	3.155E+04	1.124E+04	4.288E+03	1.797E+03
Th-232	9.892E+03	3.675E+03	1.531E+03	5.916E+02	4.148E+02	4.066E+02	4.081E+02	4.134E+02
U-234	3.448E+05	3.478E+05	3.540E+05	3.764E+05	4.481E+05	8.099E+05	2.721E+06	1.891E+06
U-235	5.163E+03	5.209E+03	5.301E+03	5.637E+03	6.715E+03	1.235E+04	6.806E+04	*2.161E+06
U-238	2.700E+04	2.724E+04	2.772E+04	2.948E+04	3.516E+04	6.511E+04	*3.361E+05	*3.361E+05

*At specific activity limit

Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
at tmin = time of minimum single radionuclide soil guideline
and at tmax = time of maximum total dose = 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)
Ac-227	1.025E+01	0.000E+00	1.463E-02	1.709E+03	1.463E-02	1.709E+03
Pa-231	1.025E+01	73.7 ± 0.1	1.370E-02	1.824E+03	3.283E-03	7.614E+03
Pb-210	3.153E+02	0.000E+00	1.284E-03	1.948E+04	1.284E-03	1.948E+04
Ra-226	3.153E+02	2.593 ± 0.005	4.918E-02	5.084E+02	4.917E-02	5.084E+02
Ra-228	7.508E+01	2.295 ± 0.005	3.999E-02	6.252E+02	3.225E-02	7.752E+02
Th-228	7.508E+01	0.000E+00	3.457E-02	7.232E+02	3.457E-02	7.232E+02
Th-230	1.757E+02	1.000E+03	1.391E-02	1.797E+03	1.576E-04	1.586E+05
Th-232	7.508E+01	67.0 ± 0.1	6.152E-02	4.064E+02	2.527E-03	9.892E+03
U-234	2.252E+02	0.000E+00	7.252E-05	3.448E+05	7.252E-05	3.448E+05
U-235	1.025E+01	0.000E+00	4.842E-03	5.163E+03	4.842E-03	5.163E+03
U-238	2.252E+02	0.000E+00	9.260E-04	2.700E+04	9.260E-04	2.700E+04

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

Nuclide (j)	Parent (i)	THF(i)	DOSE(j,t), mrem/yr t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Ac-227	Ac-227	1.000E+00	1.499E-01	1.450E-01	1.357E-01	1.076E-01	5.540E-02	5.430E-03	7.123E-06	5.825E-16
Ac-227	Pa-231	1.000E+00	2.397E-03	7.078E-03	1.594E-02	4.232E-02	8.836E-02	1.137E-01	6.625E-02	8.441E-03
Ac-227	U-235	1.000E+00	1.692E-08	1.169E-07	6.005E-07	4.850E-06	3.083E-05	1.393E-04	1.882E-04	3.037E-05
Ac-227	∑DOSE(j)		1.523E-01	1.521E-01	1.517E-01	1.499E-01	1.438E-01	1.192E-01	6.645E-02	8.472E-03
Pa-231	Pa-231	1.000E+00	3.126E-02	3.117E-02	3.098E-02	3.035E-02	2.862E-02	2.329E-02	1.293E-02	1.647E-03
Pa-231	U-235	1.000E+00	3.299E-07	9.845E-07	2.271E-06	6.539E-06	1.691E-05	3.742E-05	3.865E-05	5.929E-06
Pa-231	∑DOSE(j)		3.126E-02	3.117E-02	3.098E-02	3.036E-02	2.863E-02	2.332E-02	1.296E-02	1.653E-03
Pb-210	Pb-210	1.000E+00	4.047E-01	3.921E-01	3.682E-01	2.952E-01	1.571E-01	1.726E-02	3.140E-05	8.060E-15
Pb-210	Ra-226	1.000E+00	6.321E-03	1.869E-02	4.227E-02	1.137E-01	2.470E-01	3.674E-01	3.314E-01	1.964E-01
Pb-210	Th-230	1.000E+00	5.100E-07	3.537E-06	1.831E-05	1.523E-04	1.056E-03	6.602E-03	2.313E-02	6.061E-02
Pb-210	U-234	1.000E+00	1.471E-12	2.187E-11	2.502E-10	6.185E-09	1.247E-07	2.460E-06	1.930E-05	7.336E-05
Pb-210	U-238	9.999E-01	8.340E-19	2.563E-17	6.336E-16	4.625E-14	2.707E-12	1.726E-10	3.400E-09	2.140E-08
Pb-210	∑DOSE(j)		4.110E-01	4.108E-01	4.104E-01	4.091E-01	4.052E-01	3.913E-01	3.546E-01	2.571E-01
Ra-226	Ra-226	1.000E+00	1.550E+01	1.549E+01	1.546E+01	1.538E+01	1.515E+01	1.438E+01	1.238E+01	7.338E+00
Ra-226	Th-230	1.000E+00	1.871E-03	5.610E-03	1.308E-02	3.911E-02	1.125E-01	3.587E-01	9.769E-01	2.363E+00
Ra-226	U-234	1.000E+00	7.180E-09	5.012E-08	2.633E-07	2.303E-06	1.822E-05	1.603E-04	8.562E-04	2.873E-03
Ra-226	U-238	9.999E-01	5.082E-15	7.593E-14	8.780E-13	2.255E-11	5.035E-10	1.322E-08	1.602E-07	8.429E-07
Ra-226	∑DOSE(j)		1.550E+01	1.549E+01	1.548E+01	1.542E+01	1.527E+01	1.474E+01	1.336E+01	9.704E+00
Ra-228	Ra-228	1.000E+00	1.945E+00	1.697E+00	1.292E+00	4.975E-01	3.253E-02	2.325E-06	3.321E-18	0.000E+00
Ra-228	Th-232	1.000E+00	1.199E-01	3.391E-01	6.973E-01	1.400E+00	1.810E+00	1.836E+00	1.830E+00	1.806E+00
Ra-228	∑DOSE(j)		2.065E+00	2.037E+00	1.989E+00	1.897E+00	1.843E+00	1.836E+00	1.830E+00	1.806E+00
Th-228	Ra-228	1.000E+00	4.760E-01	1.150E+00	1.677E+00	1.075E+00	7.746E-02	5.543E-06	7.918E-18	0.000E+00
Th-228	Th-228	1.000E+00	2.596E+00	1.807E+00	8.753E-01	6.928E-02	4.937E-05	4.767E-16	0.000E+00	0.000E+00
Th-228	Th-232	1.000E+00	1.993E-02	1.217E-01	4.787E-01	1.723E+00	2.665E+00	2.730E+00	2.720E+00	2.685E+00
Th-228	∑DOSE(j)		3.091E+00	3.078E+00	3.031E+00	2.868E+00	2.743E+00	2.730E+00	2.720E+00	2.685E+00
Th-230	Th-230	1.000E+00	2.582E-02	2.581E-02	2.580E-02	2.576E-02	2.566E-02	2.531E-02	2.433E-02	2.118E-02
Th-230	U-234	1.000E+00	1.485E-07	4.437E-07	1.026E-06	2.984E-06	7.943E-06	1.964E-05	3.015E-05	2.839E-05
Th-230	U-238	9.999E-01	1.401E-13	9.759E-13	5.099E-12	4.378E-11	3.284E-10	2.400E-09	7.841E-09	9.336E-09
Th-230	∑DOSE(j)		2.582E-02	2.581E-02	2.580E-02	2.577E-02	2.567E-02	2.533E-02	2.436E-02	2.121E-02
Th-232	Th-232	1.000E+00	4.990E-02	4.990E-02	4.989E-02	4.989E-02	4.987E-02	4.981E-02	4.962E-02	4.898E-02
U-234	U-234	1.000E+00	1.633E-02	1.619E-02	1.590E-02	1.495E-02	1.254E-02	6.769E-03	1.163E-03	2.446E-06
U-234	U-238	9.999E-01	2.311E-08	6.880E-08	1.578E-07	4.451E-07	1.084E-06	1.929E-06	9.913E-07	6.948E-09
U-234	∑DOSE(j)		1.633E-02	1.619E-02	1.590E-02	1.495E-02	1.254E-02	6.771E-03	1.164E-03	2.453E-06
U-235	U-235	1.000E+00	4.963E-02	4.920E-02	4.834E-02	4.545E-02	3.811E-02	2.058E-02	3.538E-03	7.456E-06
U-238	U-238	5.400E-05	7.525E-07	7.459E-07	7.329E-07	6.891E-07	5.778E-07	3.120E-07	5.364E-08	1.130E-10
U-238	U-238	9.999E-01	2.085E-01	2.067E-01	2.031E-01	1.910E-01	1.601E-01	8.647E-02	1.487E-02	3.133E-05
U-238	∑DOSE(j)		2.085E-01	2.067E-01	2.031E-01	1.910E-01	1.601E-01	8.647E-02	1.487E-02	3.133E-05

THF(i) is the thread fraction of the parent nuclide.

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	THF(i)	S(j,t), pCi/g t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Ac-227	Ac-227	1.000E+00	1.025E+01	9.915E+00	9.279E+00	7.356E+00	3.788E+00	3.712E-01	4.870E-04	3.982E-14
Ac-227	Pa-231	1.000E+00	0.000E+00	3.205E-01	9.276E-01	2.734E+00	5.891E+00	7.649E+00	4.462E+00	5.685E-01
Ac-227	U-235	1.000E+00	0.000E+00	3.401E-06	2.971E-05	2.978E-04	2.020E-03	9.328E-03	1.267E-02	2.045E-03
Ac-227	∑S(j):		1.025E+01	1.024E+01	1.021E+01	1.009E+01	9.681E+00	8.029E+00	4.475E+00	5.706E-01
Pa-231	Pa-231	1.000E+00	1.025E+01	1.022E+01	1.016E+01	9.953E+00	9.384E+00	7.636E+00	4.239E+00	5.400E-01
Pa-231	U-235	1.000E+00	0.000E+00	2.156E-04	6.393E-04	2.045E-03	5.462E-03	1.223E-02	1.267E-02	1.944E-03
Pa-231	∑S(j):		1.025E+01	1.022E+01	1.016E+01	9.955E+00	9.389E+00	7.649E+00	4.251E+00	5.419E-01
Pb-210	Pb-210	1.000E+00	3.153E+02	3.055E+02	2.868E+02	2.300E+02	1.224E+02	1.345E+01	2.446E-02	6.279E-12
Pb-210	Ra-226	1.000E+00	0.000E+00	9.644E+00	2.802E+01	8.372E+01	1.876E+02	2.817E+02	2.542E+02	1.507E+02
Pb-210	Th-230	1.000E+00	0.000E+00	1.170E-03	1.031E-02	1.064E-01	7.873E-01	5.030E+00	1.771E+01	4.647E+01
Pb-210	U-234	1.000E+00	0.000E+00	4.503E-09	1.191E-07	4.110E-06	9.139E-05	1.866E-03	1.476E-02	5.624E-02
Pb-210	U-238	9.999E-01	0.000E+00	3.192E-15	2.535E-13	2.920E-11	1.952E-09	1.303E-07	2.598E-06	1.641E-05
Pb-210	∑S(j):		3.153E+02	3.152E+02	3.149E+02	3.138E+02	3.108E+02	3.002E+02	2.720E+02	1.972E+02
Ra-226	Ra-226	1.000E+00	3.153E+02	3.151E+02	3.146E+02	3.130E+02	3.083E+02	2.926E+02	2.519E+02	1.493E+02
Ra-226	Th-230	1.000E+00	0.000E+00	7.608E-02	2.280E-01	7.576E-01	2.251E+00	7.261E+00	1.984E+01	4.804E+01
Ra-226	U-234	1.000E+00	0.000E+00	4.377E-07	3.914E-06	4.252E-05	3.591E-04	3.232E-03	1.737E-02	5.840E-02
Ra-226	U-238	9.999E-01	0.000E+00	4.130E-13	1.105E-11	3.962E-10	9.763E-09	2.655E-07	3.248E-06	1.713E-05
Ra-226	∑S(j):		3.153E+02	3.151E+02	3.148E+02	3.137E+02	3.106E+02	2.998E+02	2.718E+02	1.974E+02
Ra-228	Ra-228	1.000E+00	7.508E+01	6.551E+01	4.987E+01	1.920E+01	1.255E+00	8.974E-05	1.282E-16	0.000E+00
Ra-228	Th-232	1.000E+00	0.000E+00	8.461E+00	2.228E+01	4.939E+01	6.523E+01	6.625E+01	6.601E+01	6.516E+01
Ra-228	∑S(j):		7.508E+01	7.397E+01	7.215E+01	6.859E+01	6.649E+01	6.625E+01	6.601E+01	6.516E+01
Th-228	Ra-228	1.000E+00	0.000E+00	2.124E+01	3.937E+01	2.757E+01	2.011E+00	1.439E-04	2.055E-16	0.000E+00
Th-228	Th-228	1.000E+00	7.508E+01	5.226E+01	2.532E+01	2.004E+00	1.428E-03	1.379E-14	0.000E+00	0.000E+00
Th-228	Th-232	1.000E+00	0.000E+00	1.392E+00	9.185E+00	4.022E+01	6.456E+01	6.625E+01	6.601E+01	6.516E+01
Th-228	∑S(j):		7.508E+01	7.490E+01	7.387E+01	6.979E+01	6.657E+01	6.625E+01	6.601E+01	6.516E+01
Th-230	Th-230	1.000E+00	1.757E+02	1.757E+02	1.756E+02	1.754E+02	1.747E+02	1.723E+02	1.656E+02	1.442E+02
Th-230	U-234	1.000E+00	0.000E+00	2.018E-03	6.000E-03	1.939E-02	5.328E-02	1.333E-01	2.052E-01	1.932E-01
Th-230	U-238	9.999E-01	0.000E+00	2.856E-09	2.540E-08	2.708E-07	2.168E-06	1.621E-05	5.330E-05	6.354E-05
Th-230	∑S(j):		1.757E+02	1.757E+02	1.756E+02	1.754E+02	1.747E+02	1.724E+02	1.658E+02	1.444E+02
Th-232	Th-232	1.000E+00	7.508E+01	7.508E+01	7.508E+01	7.507E+01	7.504E+01	7.494E+01	7.466E+01	7.370E+01
U-234	U-234	1.000E+00	2.252E+02	2.232E+02	2.193E+02	2.062E+02	1.729E+02	9.335E+01	1.604E+01	3.373E-02
U-234	U-238	9.999E-01	0.000E+00	6.328E-04	1.865E-03	5.846E-03	1.471E-02	2.647E-02	1.365E-02	9.577E-05
U-234	∑S(j):		2.252E+02	2.232E+02	2.193E+02	2.062E+02	1.729E+02	9.338E+01	1.605E+01	3.383E-02
U-235	U-235	1.000E+00	1.025E+01	1.016E+01	9.983E+00	9.386E+00	7.871E+00	4.250E+00	7.307E-01	1.540E-03
U-238	U-238	5.400E-05	1.216E-02	1.205E-02	1.184E-02	1.114E-02	9.338E-03	5.042E-03	8.669E-04	1.827E-06
U-238	U-238	9.999E-01	2.252E+02	2.232E+02	2.193E+02	2.062E+02	1.729E+02	9.337E+01	1.605E+01	3.383E-02
U-238	∑S(j):		2.252E+02	2.232E+02	2.193E+02	2.062E+02	1.729E+02	9.338E+01	1.605E+01	3.383E-02

THF(i) is the thread fraction of the parent nuclide.

RESCALC.EXE execution time = 463.52 seconds

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Probabilistic Input

Number of Sample Runs: 1600

Number	Name	Distribution	Parameters							
1	MLINH	CONTINUOUS LINEAR	8	0	0	.000015	.0151	.000023	.1365	.0000
2	SHF1	DISCRETE CUMULATIVE	8	.0084	.01	.022	.09	.035	.21	.055

Probabilistic Total Dose Summary

Nuclide (j)	Peak Time	Peak Dose	DOSE(j,t), mrem/yr t= 0.00E+00	1.00E+00	3.00E+00	1.00E+01	3.00E+01	1.00E+02	3.00E+02	1.00E+03
Ac-227										
Min	0.00E+00	9.84E-02	9.84E-02	9.52E-02	8.91E-02	7.06E-02	3.64E-02	3.57E-03	4.68E-06	3.82E-16
Max	0.00E+00	3.88E-01	3.88E-01	3.75E-01	3.51E-01	2.78E-01	1.43E-01	1.40E-02	1.84E-05	1.51E-15
Avg	0.00E+00	1.40E-01	1.40E-01	1.36E-01	1.27E-01	1.01E-01	5.18E-02	5.08E-03	6.66E-06	5.45E-16
Std	0.00E+00	5.71E-02	5.71E-02	5.52E-02	5.17E-02	4.10E-02	2.11E-02	2.07E-03	2.71E-06	2.22E-16
Pa-231										
Min	7.24E+01	9.63E-02	2.71E-02	3.01E-02	3.58E-02	5.26E-02	8.14E-02	9.37E-02	5.41E-02	6.89E-03
Max	7.55E+01	3.43E-01	6.17E-02	7.37E-02	9.63E-02	1.63E-01	2.79E-01	3.35E-01	1.94E-01	2.48E-02
Avg	7.33E+01	1.32E-01	3.25E-02	3.67E-02	4.49E-02	6.89E-02	1.10E-01	1.29E-01	7.45E-02	9.49E-03
Std	6.19E-01	4.85E-02	6.59E-03	8.35E-03	1.17E-02	2.16E-02	3.88E-02	4.75E-02	2.76E-02	3.51E-03
Pb-210										
Min	0.00E+00	3.93E-01	3.93E-01	3.81E-01	3.58E-01	2.87E-01	1.53E-01	1.68E-02	3.05E-05	7.83E-15
Max	0.00E+00	4.60E-01	4.60E-01	4.46E-01	4.19E-01	3.36E-01	1.79E-01	1.96E-02	3.57E-05	9.17E-15
Avg	0.00E+00	4.03E-01	4.03E-01	3.90E-01	3.66E-01	2.94E-01	1.56E-01	1.72E-02	3.12E-05	8.02E-15
Std	0.00E+00	1.35E-02	1.35E-02	1.31E-02	1.23E-02	9.87E-03	5.25E-03	5.77E-04	1.05E-06	2.70E-16
Ra-226										
Min	0.00E+00	9.61E+00	9.57E+00	9.57E+00	9.58E+00	9.60E+00	9.59E+00	9.23E+00	7.96E+00	4.72E+00
Max	1.69E+01	4.60E+01	4.60E+01	4.60E+01	4.59E+01	4.58E+01	4.52E+01	4.31E+01	3.71E+01	2.20E+01
Avg	8.58E+00	1.43E+01	1.43E+01	1.43E+01	1.43E+01	1.43E+01	1.43E+01	1.37E+01	1.18E+01	6.98E+00
Std	4.75E+00	7.53E+00	7.54E+00	7.53E+00	7.52E+00	7.48E+00	7.38E+00	7.01E+00	6.03E+00	3.58E+00
Ra-228										
Min	2.29E+00	1.85E+00	1.50E+00	1.76E+00	1.83E+00	9.70E-01	6.78E-02	4.85E-06	6.93E-18	0.00E+00
Max	2.30E+00	8.90E+00	7.17E+00	8.44E+00	8.80E+00	4.66E+00	3.26E-01	2.33E-05	3.33E-17	0.00E+00
Avg	2.29E+00	2.78E+00	2.24E+00	2.63E+00	2.75E+00	1.45E+00	1.02E-01	7.27E-06	1.04E-17	0.00E+00
Std	1.88E-03	1.46E+00	1.17E+00	1.38E+00	1.44E+00	7.64E-01	5.34E-02	3.82E-06	5.46E-18	0.00E+00
Th-228										
Min	0.00E+00	1.60E+00	1.60E+00	1.11E+00	5.39E-01	4.27E-02	3.04E-05	2.94E-16	0.00E+00	0.00E+00
Max	0.00E+00	7.70E+00	7.70E+00	5.36E+00	2.60E+00	2.06E-01	1.47E-04	1.42E-15	0.00E+00	0.00E+00
Avg	0.00E+00	2.40E+00	2.40E+00	1.67E+00	8.09E-01	6.40E-02	4.56E-05	4.41E-16	0.00E+00	0.00E+00
Std	0.00E+00	1.26E+00	1.26E+00	8.79E-01	4.26E-01	3.37E-02	2.40E-05	2.32E-16	0.00E+00	0.00E+00
Th-230										
Min	1.00E+03	1.53E+00	2.01E-02	2.27E-02	2.73E-02	4.35E-02	8.96E-02	2.47E-01	6.43E-01	1.53E+00
Max	1.00E+03	7.11E+00	4.28E-02	5.39E-02	7.60E-02	1.53E-01	3.72E-01	1.11E+00	2.96E+00	7.11E+00
Avg	1.00E+03	2.27E+00	2.66E-02	3.01E-02	3.70E-02	6.12E-02	1.30E-01	3.63E-01	9.50E-01	2.27E+00
Std	0.00E+00	1.15E+00	3.03E-03	4.54E-03	7.95E-03	2.05E-02	5.61E-02	1.76E-01	4.77E-01	1.15E+00
Th-232										
Min	6.66E+01	2.86E+00	1.24E-01	3.23E-01	7.64E-01	1.97E+00	2.80E+00	2.86E+00	2.85E+00	2.81E+00
Max	6.72E+01	1.36E+01	4.78E-01	1.43E+00	3.55E+00	9.32E+00	1.33E+01	1.36E+01	1.36E+01	1.34E+01
Avg	6.69E+01	4.27E+00	1.78E-01	4.74E-01	1.14E+00	2.94E+00	4.19E+00	4.27E+00	4.25E+00	4.20E+00
Std	1.00E-01	2.22E+00	6.82E-02	2.24E-01	5.71E-01	1.52E+00	2.17E+00	2.22E+00	2.21E+00	2.18E+00
U-234										
Min	0.00E+00	1.25E-02	1.25E-02	1.24E-02	1.21E-02	1.14E-02	9.59E-03	5.31E-03	1.47E-03	1.87E-03
Max	0.00E+00	2.36E-02	2.36E-02	2.34E-02	2.30E-02	2.16E-02	1.82E-02	1.03E-02	4.29E-03	8.65E-03
Avg	0.00E+00	1.58E-02	1.58E-02	1.57E-02	1.54E-02	1.45E-02	1.22E-02	6.72E-03	1.97E-03	2.76E-03
Std	0.00E+00	1.47E-03	1.47E-03	1.46E-03	1.44E-03	1.35E-03	1.14E-03	6.70E-04	4.98E-04	1.40E-03
U-235										
Min	0.00E+00	3.06E-02	3.06E-02	3.04E-02	2.99E-02	2.81E-02	2.36E-02	1.28E-02	2.34E-03	2.94E-05
Max	0.00E+00	1.47E-01	1.47E-01	1.45E-01	1.43E-01	1.34E-01	1.13E-01	6.12E-02	1.10E-02	1.11E-04
Avg	0.00E+00	4.59E-02	4.59E-02	4.55E-02	4.47E-02	4.20E-02	3.53E-02	1.92E-02	3.49E-03	4.10E-05
Std	0.00E+00	2.39E-02	2.39E-02	2.37E-02	2.33E-02	2.19E-02	1.84E-02	9.99E-03	1.79E-03	1.62E-05

Probabilistic Total Dose Summary(cont.)

Nuclide (j)	Peak Time	Peak Dose	t= 0.00E+00	1.00E+00	3.00E+00	DOSE(j,t), mrem/yr 1.00E+01	3.00E+01	1.00E+02	3.00E+02	1.00E+03
U-238										
Min	0.00E+00	1.31E-01	1.31E-01	1.30E-01	1.27E-01	1.20E-01	1.00E-01	5.43E-02	9.33E-03	2.02E-05
Max	0.00E+00	5.97E-01	5.97E-01	5.92E-01	5.82E-01	5.47E-01	4.59E-01	2.48E-01	4.26E-02	9.23E-05
Avg	0.00E+00	1.93E-01	1.93E-01	1.92E-01	1.88E-01	1.77E-01	1.49E-01	8.02E-02	1.38E-02	2.99E-05
Std	0.00E+00	9.54E-02	9.54E-02	9.45E-02	9.29E-02	8.73E-02	7.32E-02	3.95E-02	6.80E-03	1.47E-05
∑ALL										
Min	0.00E+00	1.35E+01	1.35E+01	1.35E+01	1.34E+01	1.32E+01	1.30E+01	1.25E+01	1.15E+01	9.07E+00
Max	0.00E+00	6.31E+01	6.31E+01	6.29E+01	6.26E+01	6.16E+01	6.05E+01	5.85E+01	5.39E+01	4.25E+01
Avg	0.00E+00	2.00E+01	2.00E+01	2.00E+01	1.99E+01	1.95E+01	1.92E+01	1.86E+01	1.71E+01	1.35E+01
Std	0.00E+00	1.02E+01	1.02E+01	1.02E+01	1.02E+01	1.00E+01	9.82E+00	9.50E+00	8.76E+00	6.91E+00

∑ALL is total dose summed for all nuclides.

Probabilistic results summary : Scabble Ratios, 0.3 cm on pavement, industrial,
rad + eat + breathe, 10File: C:\RESRAD_FAMILY\RESRAD\USERFILES\457PUTRAE3.RAD
Cumulative Probability Summary for: Total Dose Over Pathways

Cumulative	Dose(t), mrem/yr							
Probability	t= 0.00E+00	1.00E+00	3.00E+00	1.00E+01	3.00E+01	1.00E+02	3.00E+02	1.00E+03
0.025	1.42E+01	1.42E+01	1.41E+01	1.39E+01	1.36E+01	1.32E+01	1.21E+01	9.54E+00
0.050	1.42E+01	1.42E+01	1.41E+01	1.39E+01	1.36E+01	1.32E+01	1.21E+01	9.54E+00
0.075	1.42E+01	1.42E+01	1.41E+01	1.39E+01	1.36E+01	1.32E+01	1.21E+01	9.55E+00
0.100	1.48E+01	1.48E+01	1.47E+01	1.45E+01	1.42E+01	1.38E+01	1.27E+01	9.97E+00
0.125	1.49E+01	1.48E+01	1.47E+01	1.45E+01	1.42E+01	1.38E+01	1.27E+01	9.98E+00
0.150	1.49E+01	1.48E+01	1.47E+01	1.45E+01	1.43E+01	1.38E+01	1.27E+01	9.98E+00
0.175	1.49E+01	1.48E+01	1.47E+01	1.45E+01	1.43E+01	1.38E+01	1.27E+01	9.98E+00
0.200	1.49E+01	1.48E+01	1.48E+01	1.45E+01	1.43E+01	1.38E+01	1.27E+01	9.99E+00
0.225	1.58E+01	1.58E+01	1.57E+01	1.55E+01	1.52E+01	1.47E+01	1.35E+01	1.06E+01
0.250	1.58E+01	1.58E+01	1.57E+01	1.55E+01	1.52E+01	1.47E+01	1.35E+01	1.07E+01
0.275	1.59E+01	1.58E+01	1.57E+01	1.55E+01	1.52E+01	1.47E+01	1.35E+01	1.07E+01
0.300	1.59E+01	1.58E+01	1.57E+01	1.55E+01	1.52E+01	1.47E+01	1.35E+01	1.07E+01
0.325	1.59E+01	1.58E+01	1.57E+01	1.55E+01	1.52E+01	1.47E+01	1.35E+01	1.07E+01
0.350	1.59E+01	1.58E+01	1.57E+01	1.55E+01	1.52E+01	1.47E+01	1.35E+01	1.07E+01
0.375	1.59E+01	1.58E+01	1.58E+01	1.55E+01	1.52E+01	1.47E+01	1.35E+01	1.07E+01
0.400	1.75E+01	1.74E+01	1.73E+01	1.71E+01	1.68E+01	1.62E+01	1.49E+01	1.18E+01
0.425	1.75E+01	1.74E+01	1.74E+01	1.71E+01	1.68E+01	1.62E+01	1.49E+01	1.18E+01
0.450	1.75E+01	1.75E+01	1.74E+01	1.71E+01	1.68E+01	1.62E+01	1.49E+01	1.18E+01
0.475	1.75E+01	1.75E+01	1.74E+01	1.71E+01	1.68E+01	1.62E+01	1.49E+01	1.18E+01
0.500	1.75E+01	1.75E+01	1.74E+01	1.71E+01	1.68E+01	1.62E+01	1.49E+01	1.18E+01
0.525	1.75E+01	1.75E+01	1.74E+01	1.71E+01	1.68E+01	1.62E+01	1.49E+01	1.18E+01
0.550	1.75E+01	1.75E+01	1.74E+01	1.71E+01	1.68E+01	1.62E+01	1.49E+01	1.18E+01
0.575	1.75E+01	1.75E+01	1.74E+01	1.71E+01	1.68E+01	1.62E+01	1.49E+01	1.18E+01
0.600	1.75E+01	1.75E+01	1.74E+01	1.71E+01	1.68E+01	1.62E+01	1.49E+01	1.18E+01
0.625	1.75E+01	1.75E+01	1.74E+01	1.71E+01	1.68E+01	1.63E+01	1.50E+01	1.18E+01
0.650	2.01E+01	2.00E+01	1.99E+01	1.96E+01	1.93E+01	1.86E+01	1.71E+01	1.35E+01
0.675	2.01E+01	2.00E+01	1.99E+01	1.96E+01	1.93E+01	1.86E+01	1.72E+01	1.35E+01
0.700	2.01E+01	2.00E+01	1.99E+01	1.96E+01	1.93E+01	1.86E+01	1.72E+01	1.35E+01
0.725	2.01E+01	2.00E+01	1.99E+01	1.96E+01	1.93E+01	1.86E+01	1.72E+01	1.35E+01
0.750	2.01E+01	2.00E+01	1.99E+01	1.96E+01	1.93E+01	1.86E+01	1.72E+01	1.35E+01
0.775	2.01E+01	2.01E+01	1.99E+01	1.96E+01	1.93E+01	1.86E+01	1.72E+01	1.35E+01
0.800	2.01E+01	2.01E+01	1.99E+01	1.96E+01	1.93E+01	1.86E+01	1.72E+01	1.35E+01
0.825	2.01E+01	2.01E+01	2.00E+01	1.96E+01	1.93E+01	1.86E+01	1.72E+01	1.35E+01
0.850	2.01E+01	2.01E+01	2.00E+01	1.97E+01	1.93E+01	1.86E+01	1.72E+01	1.35E+01
0.875	2.01E+01	2.01E+01	2.00E+01	1.97E+01	1.93E+01	1.87E+01	1.72E+01	1.35E+01
0.900	2.46E+01	2.45E+01	2.44E+01	2.40E+01	2.36E+01	2.28E+01	2.10E+01	1.65E+01
0.925	2.46E+01	2.45E+01	2.44E+01	2.40E+01	2.36E+01	2.28E+01	2.10E+01	1.66E+01
0.950	6.30E+01	6.28E+01	6.25E+01	6.15E+01	6.04E+01	5.84E+01	5.38E+01	4.25E+01
0.975	6.30E+01	6.29E+01	6.25E+01	6.16E+01	6.04E+01	5.85E+01	5.39E+01	4.25E+01
1.000	6.31E+01	6.29E+01	6.26E+01	6.16E+01	6.05E+01	5.85E+01	5.39E+01	4.25E+01

Probabilistic results summary : Scabble Ratios, 0.3 cm on pavement, industrial,
rad + eat + breathe, 10File: C:\RESRAD_FAMILY\RESRAD\USERFILES\457PUTRAE3.RAD

Peak of the mean dose (averaged over observations) at graphical times

epetition	Time of peak mean dose	Peak mean dose
	Years	mrem/yr
1	0.000E+00	2.001E+01
2	0.000E+00	2.001E+01
3	0.000E+00	2.001E+01
4	0.000E+00	2.001E+01

Attachment G-B

Derivation of Area Factors for Elevated Measurements on Pavement

Ref. C-T Phase II Decommissioning Plan, §5.9.2, Figure 5-4

Contaminated Area (m^2)	RESRAD Probabilistic Case
10000.	457putrae3
1000.	467uth1k
100.	466uth100
30.	465uth30
20.	468uth20
10.	464uth10

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-03	2.000E+00	---	THICK0
R011	Length parallel to aquifer flow (m)	not used	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	2.500E+01	3.000E+01	---	BRDL
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	3.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	3.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	3.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(9)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): Ac-227	1.025E+01	0.000E+00	---	S1(1)
R012	Initial principal radionuclide (pCi/g): Pa-231	1.025E+01	0.000E+00	---	S1(2)
R012	Initial principal radionuclide (pCi/g): Pb-210	3.153E+02	0.000E+00	---	S1(3)
R012	Initial principal radionuclide (pCi/g): Ra-226	3.153E+02	0.000E+00	---	S1(4)
R012	Initial principal radionuclide (pCi/g): Ra-228	7.508E+01	0.000E+00	---	S1(5)
R012	Initial principal radionuclide (pCi/g): Th-228	7.508E+01	0.000E+00	---	S1(6)
R012	Initial principal radionuclide (pCi/g): Th-230	1.757E+02	0.000E+00	---	S1(7)
R012	Initial principal radionuclide (pCi/g): Th-232	7.508E+01	0.000E+00	---	S1(8)
R012	Initial principal radionuclide (pCi/g): U-234	2.252E+02	0.000E+00	---	S1(9)
R012	Initial principal radionuclide (pCi/g): U-235	1.025E+01	0.000E+00	---	S1(10)
R012	Initial principal radionuclide (pCi/g): U-238	2.252E+02	0.000E+00	---	S1(11)
R012	Concentration in groundwater (pCi/L): Ac-227	not used	0.000E+00	---	W1(1)
R012	Concentration in groundwater (pCi/L): Pa-231	not used	0.000E+00	---	W1(2)
R012	Concentration in groundwater (pCi/L): Pb-210	not used	0.000E+00	---	W1(3)
R012	Concentration in groundwater (pCi/L): Ra-226	not used	0.000E+00	---	W1(4)
R012	Concentration in groundwater (pCi/L): Ra-228	not used	0.000E+00	---	W1(5)
R012	Concentration in groundwater (pCi/L): Th-228	not used	0.000E+00	---	W1(6)
R012	Concentration in groundwater (pCi/L): Th-230	not used	0.000E+00	---	W1(7)
R012	Concentration in groundwater (pCi/L): Th-232	not used	0.000E+00	---	W1(8)
R012	Concentration in groundwater (pCi/L): U-234	not used	0.000E+00	---	W1(9)
R012	Concentration in groundwater (pCi/L): U-235	not used	0.000E+00	---	W1(10)
R012	Concentration in groundwater (pCi/L): U-238	not used	0.000E+00	---	W1(11)
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)	1.500E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	0.000E+00	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	4.000E-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)	4.000E+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

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R013	Precipitation (m/yr)	1.000E+00	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	0.000E+00	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	9.900E-01	2.000E-01	---	RUNOFF
R013	Watershed area for nearby stream or pond (m**2)	not used	1.000E+06	---	WAREA
R013	Accuracy for water/soil computations	not used	1.000E-03	---	EPS
R014	Density of saturated zone (g/cm**3)	not used	1.500E+00	---	DENSAQ
R014	Saturated zone total porosity	not used	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	not used	2.000E-01	---	EPSZ
R014	Saturated zone field capacity	not used	2.000E-01	---	FCSZ
R014	Saturated zone hydraulic conductivity (m/yr)	not used	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	not used	2.000E-02	---	HGWT
R014	Saturated zone b parameter	not used	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	not used	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	not used	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	not used	ND	---	MODEL
R014	Well pumping rate (m**3/yr)	not used	2.500E+02	---	UW
R015	Number of unsaturated zone strata	not used	1	---	NS
R015	Unsat. zone 1, thickness (m)	not used	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	not used	1.500E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	not used	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	not used	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, field capacity	not used	2.000E-01	---	FCUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	not used	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	not used	1.000E+01	---	HCUZ(1)
R016	Distribution coefficients for Ac-227				
R016	Contaminated zone (cm**3/g)	8.250E+02	2.000E+01	---	DCNUCC(1)
R016	Unsaturated zone 1 (cm**3/g)	not used	2.000E+01	---	DCNUCU(1,1)
R016	Saturated zone (cm**3/g)	not used	2.000E+01	---	DCNUCS(1)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.346E-03	ALEACH(1)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(1)
R016	Distribution coefficients for Pa-231				
R016	Contaminated zone (cm**3/g)	3.800E+02	5.000E+01	---	DCNUCC(2)
R016	Unsaturated zone 1 (cm**3/g)	not used	5.000E+01	---	DCNUCU(2,1)
R016	Saturated zone (cm**3/g)	not used	5.000E+01	---	DCNUCS(2)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.922E-03	ALEACH(2)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(2)
R016	Distribution coefficients for Pb-210				
R016	Contaminated zone (cm**3/g)	2.392E+03	1.000E+02	---	DCNUCC(3)
R016	Unsaturated zone 1 (cm**3/g)	not used	1.000E+02	---	DCNUCU(3,1)
R016	Saturated zone (cm**3/g)	not used	1.000E+02	---	DCNUCS(3)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	4.645E-04	ALEACH(3)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(3)

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for Ra-226				
R016	Contaminated zone (cm**3/g)	3.533E+03	7.000E+01	---	DCNUCC(4)
R016	Unsaturated zone 1 (cm**3/g)	not used	7.000E+01	---	DCNUCU(4,1)
R016	Saturated zone (cm**3/g)	not used	7.000E+01	---	DCNUCS(4)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	3.145E-04	ALEACH(4)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(4)
R016	Distribution coefficients for Ra-228				
R016	Contaminated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCC(5)
R016	Unsaturated zone 1 (cm**3/g)	not used	7.000E+01	---	DCNUCU(5,1)
R016	Saturated zone (cm**3/g)	not used	7.000E+01	---	DCNUCS(5)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.582E-02	ALEACH(5)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(5)
R016	Distribution coefficients for Th-228				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(6)
R016	Unsaturated zone 1 (cm**3/g)	not used	6.000E+04	---	DCNUCU(6,1)
R016	Saturated zone (cm**3/g)	not used	6.000E+04	---	DCNUCS(6)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.852E-05	ALEACH(6)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(6)
R016	Distribution coefficients for Th-230				
R016	Contaminated zone (cm**3/g)	5.884E+03	6.000E+04	---	DCNUCC(7)
R016	Unsaturated zone 1 (cm**3/g)	not used	6.000E+04	---	DCNUCU(7,1)
R016	Saturated zone (cm**3/g)	not used	6.000E+04	---	DCNUCS(7)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.888E-04	ALEACH(7)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(7)
R016	Distribution coefficients for Th-232				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(8)
R016	Unsaturated zone 1 (cm**3/g)	not used	6.000E+04	---	DCNUCU(8,1)
R016	Saturated zone (cm**3/g)	not used	6.000E+04	---	DCNUCS(8)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.852E-05	ALEACH(8)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(8)
R016	Distribution coefficients for U-234				
R016	Contaminated zone (cm**3/g)	1.260E+02	5.000E+01	---	DCNUCC(9)
R016	Unsaturated zone 1 (cm**3/g)	not used	5.000E+01	---	DCNUCU(9,1)
R016	Saturated zone (cm**3/g)	not used	5.000E+01	---	DCNUCS(9)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	8.803E-03	ALEACH(9)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(9)
R016	Distribution coefficients for U-235				
R016	Contaminated zone (cm**3/g)	1.260E+02	5.000E+01	---	DCNUCC(10)
R016	Unsaturated zone 1 (cm**3/g)	not used	5.000E+01	---	DCNUCU(10,1)
R016	Saturated zone (cm**3/g)	not used	5.000E+01	---	DCNUCS(10)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	8.803E-03	ALEACH(10)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(10)

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for U-238				
R016	Contaminated zone (cm**3/g)	1.260E+02	5.000E+01	---	DCNUCC(11)
R016	Unsaturated zone 1 (cm**3/g)	not used	5.000E+01	---	DCNUCU(11,1)
R016	Saturated zone (cm**3/g)	not used	5.000E+01	---	DCNUCS(11)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	8.803E-03	ALEACH(11)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(11)
R017	Inhalation rate (m**3/yr)	1.227E+04	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	3.500E-05	1.000E-04	---	MLINH
R017	Exposure duration	3.000E+01	3.000E+01	---	ED
R017	Shielding factor, inhalation	6.000E-01	4.000E-01	---	SHF3
R017	Shielding factor, external gamma	1.700E-01	7.000E-01	---	SHF1
R017	Fraction of time spent indoors	1.825E-01	5.000E-01	---	FIND
R017	Fraction of time spent outdoors (on site)	4.563E-02	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)	not used	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	not used	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	not used	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	not used	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	not used	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	not used	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	3.650E+01	3.650E+01	---	SOIL

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R018	Drinking water intake (L/yr)	not used	5.100E+02	---	DWI
R018	Contamination fraction of drinking water	not used	1.000E+00	---	FDW
R018	Contamination fraction of household water	not used	1.000E+00	---	FHHW
R018	Contamination fraction of livestock water	not used	1.000E+00	---	FLW
R018	Contamination fraction of irrigation water	not used	1.000E+00	---	FIRW
R018	Contamination fraction of aquatic food	not used	5.000E-01	---	FR9
R018	Contamination fraction of plant food	not used	-1	---	FPLANT
R018	Contamination fraction of meat	not used	-1	---	FMEAT
R018	Contamination fraction of milk	not used	-1	---	FMILK
R019	Livestock fodder intake for meat (kg/day)	not used	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	not used	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	not used	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	not used	1.600E+02	---	LWI6
R019	Livestock soil intake (kg/day)	not used	5.000E-01	---	LSI
R019	Mass loading for foliar deposition (g/m**3)	not used	1.000E-04	---	MLFD
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	not used	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	not used	1.000E+00	---	FGWDW
R019	Household water fraction from ground water	not used	1.000E+00	---	FGWHH
R019	Livestock water fraction from ground water	not used	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	not used	1.000E+00	---	FGWIR
R19B	Wet weight crop yield for Non-Leafy (kg/m**2)	not used	7.000E-01	---	YV(1)
R19B	Wet weight crop yield for Leafy (kg/m**2)	not used	1.500E+00	---	YV(2)
R19B	Wet weight crop yield for Fodder (kg/m**2)	not used	1.100E+00	---	YV(3)
R19B	Growing Season for Non-Leafy (years)	not used	1.700E-01	---	TE(1)
R19B	Growing Season for Leafy (years)	not used	2.500E-01	---	TE(2)
R19B	Growing Season for Fodder (years)	not used	8.000E-02	---	TE(3)
R19B	Translocation Factor for Non-Leafy	not used	1.000E-01	---	TIV(1)
R19B	Translocation Factor for Leafy	not used	1.000E+00	---	TIV(2)
R19B	Translocation Factor for Fodder	not used	1.000E+00	---	TIV(3)
R19B	Dry Foliar Interception Fraction for Non-Leafy	not used	2.500E-01	---	RDRY(1)
R19B	Dry Foliar Interception Fraction for Leafy	not used	2.500E-01	---	RDRY(2)
R19B	Dry Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RDRY(3)
R19B	Wet Foliar Interception Fraction for Non-Leafy	not used	2.500E-01	---	RWET(1)
R19B	Wet Foliar Interception Fraction for Leafy	not used	2.500E-01	---	RWET(2)
R19B	Wet Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RWET(3)
R19B	Weathering Removal Constant for Vegetation	not used	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	0.000E+00	---	CO2F

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
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
TITL	Maximum number of integration points for risk	1	---	---	KYMAX

Summary of Pathway Selections

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

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

Initial Soil Concentrations, pCi/g	
Ac-227	1.025E+01
Pa-231	1.025E+01
Pb-210	3.153E+02
Ra-226	3.153E+02
Ra-228	7.508E+01
Th-228	7.508E+01
Th-230	1.757E+02
Th-232	7.508E+01
U-234	2.252E+02
U-235	1.025E+01
U-238	2.252E+02

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

t (years):	0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
TDOSE(t):	2.159E+01	2.154E+01	2.142E+01	2.109E+01	2.071E+01	2.002E+01	1.843E+01	1.453E+01
M(t):	8.637E-01	8.616E-01	8.570E-01	8.438E-01	8.283E-01	8.009E-01	7.373E-01	5.811E-01

Maximum TDOSE(t): 2.159E+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	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	frac
Ac-227	1.167E-01	0.0054	8.300E-03	0.0004	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.484E-02	0.0C
Pa-231	1.345E-02	0.0006	1.737E-03	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.846E-02	0.0C
Pb-210	2.771E-02	0.0013	8.815E-04	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.761E-01	0.01
Ra-226	1.542E+01	0.7142	3.454E-04	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.521E-02	0.0C
Ra-228	2.402E+00	0.1113	5.321E-04	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.841E-02	0.0C
Th-228	2.584E+00	0.1197	2.663E-03	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.481E-03	0.0C
Th-230	4.631E-03	0.0002	7.013E-03	0.0003	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.604E-02	0.0C
Th-232	1.394E-01	0.0065	1.510E-02	0.0007	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.524E-02	0.0C
U-234	2.139E-03	0.0001	3.624E-03	0.0002	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.057E-02	0.0C
U-235	4.902E-02	0.0023	1.537E-04	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.546E-04	0.0C
U-238	1.952E-01	0.0090	3.240E-03	0.0002	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.003E-02	0.0C
Total	2.096E+01	0.9705	4.359E-02	0.0020	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.939E-01	0.02

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	frac
Ac-227	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.499E-01	0.0C
Pa-231	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.365E-02	0.0C
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.047E-01	0.01
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	1.550E+01	0.71
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	2.421E+00	0.11
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	2.595E+00	0.12
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.769E-02	0.0C
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	1.897E-01	0.0C
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.633E-02	0.0C
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.963E-02	0.0C
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.085E-01	0.0C
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	2.159E+01	1.0C

*Sum of all water independent and dependent pathways.

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

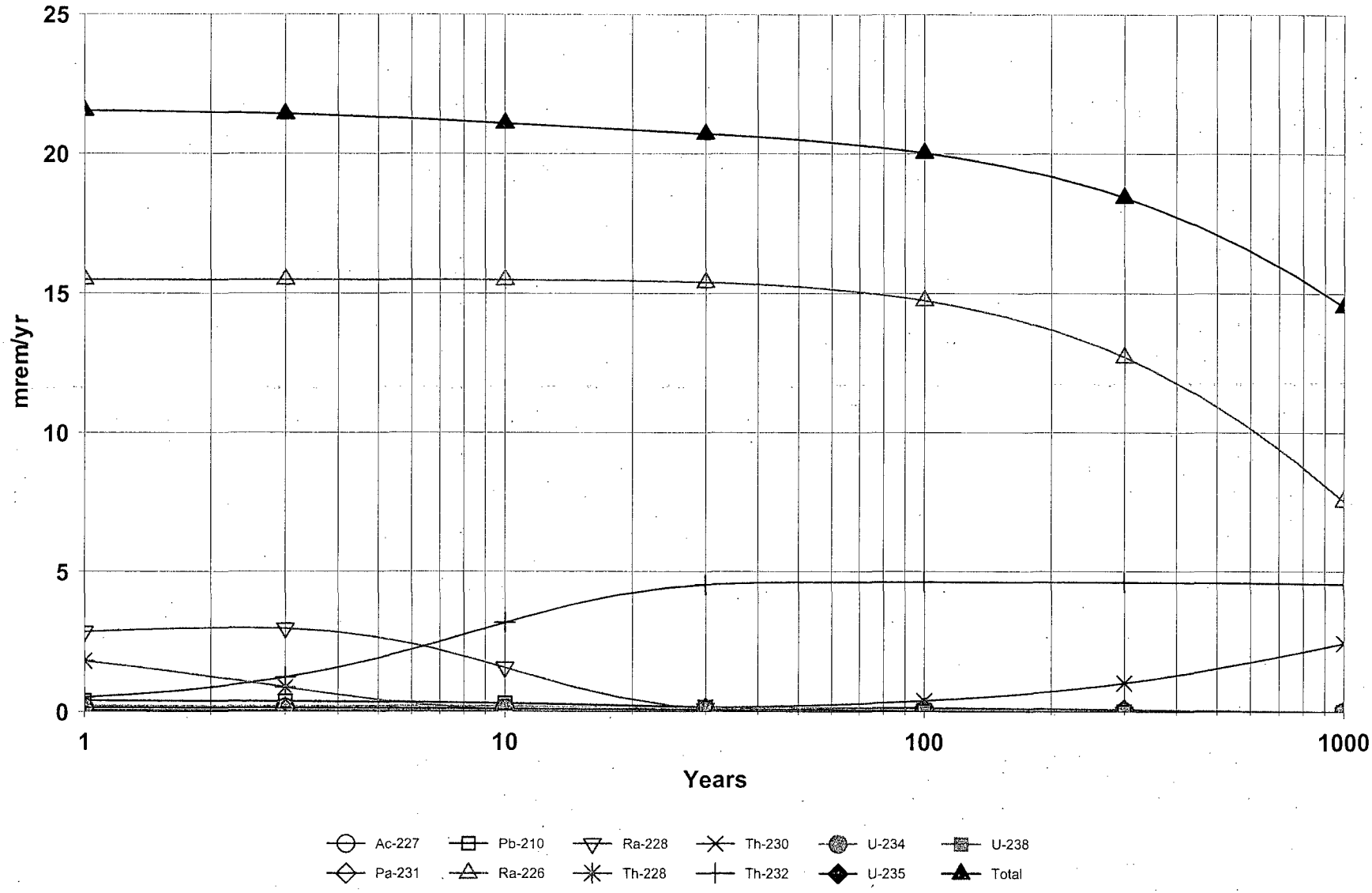
Nuclide (i)	t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Ac-227	1.710E+03	1.768E+03	1.889E+03	2.383E+03	4.627E+03	4.721E+04	3.599E+07	*7.232E+13
Pa-231	7.615E+03	6.702E+03	5.462E+03	3.527E+03	2.191E+03	1.872E+03	3.238E+03	2.541E+04
Pb-210	1.948E+04	2.010E+04	2.141E+04	2.670E+04	5.018E+04	4.567E+05	2.511E+08	*7.634E+13
Ra-226	5.087E+02	5.086E+02	5.086E+02	5.089E+02	5.121E+02	5.347E+02	6.202E+02	1.047E+03
Ra-228	7.752E+02	6.593E+02	6.322E+02	1.194E+03	1.707E+04	2.386E+08	*2.726E+14	*2.726E+14
Th-228	7.232E+02	1.039E+03	2.145E+03	2.709E+04	3.803E+07	*8.195E+14	*8.195E+14	*8.195E+14
Th-230	1.587E+05	1.398E+05	1.129E+05	6.758E+04	3.156E+04	1.125E+04	4.290E+03	1.798E+03
Th-232	9.893E+03	3.675E+03	1.531E+03	5.916E+02	4.148E+02	4.066E+02	4.081E+02	4.135E+02
U-234	3.448E+05	3.478E+05	3.540E+05	3.764E+05	4.481E+05	8.099E+05	2.722E+06	1.892E+06
U-235	5.163E+03	5.209E+03	5.301E+03	5.637E+03	6.716E+03	1.235E+04	6.807E+04	*2.161E+06
U-238	2.700E+04	2.724E+04	2.772E+04	2.949E+04	3.516E+04	6.512E+04	*3.361E+05	*3.361E+05

*At specific activity limit

Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
at tmin = time of minimum single radionuclide soil guideline
and at tmax = time of maximum total dose = 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)
Ac-227	1.025E+01	0.000E+00	1.462E-02	1.710E+03	1.462E-02	1.710E+03
Pa-231	1.025E+01	73.7 ± 0.1	1.370E-02	1.825E+03	3.283E-03	7.615E+03
Pb-210	3.153E+02	0.000E+00	1.284E-03	1.948E+04	1.284E-03	1.948E+04
Ra-226	3.153E+02	2.602 ± 0.005	4.915E-02	5.086E+02	4.915E-02	5.087E+02
Ra-228	7.508E+01	2.295 ± 0.005	3.998E-02	6.253E+02	3.225E-02	7.752E+02
Th-228	7.508E+01	0.000E+00	3.457E-02	7.232E+02	3.457E-02	7.232E+02
Th-230	1.757E+02	1.000E+03	1.391E-02	1.798E+03	1.576E-04	1.587E+05
Th-232	7.508E+01	67.0 ± 0.1	6.151E-02	4.064E+02	2.527E-03	9.893E+03
U-234	2.252E+02	0.000E+00	7.251E-05	3.448E+05	7.251E-05	3.448E+05
U-235	1.025E+01	0.000E+00	4.842E-03	5.163E+03	4.842E-03	5.163E+03
U-238	2.252E+02	0.000E+00	9.258E-04	2.700E+04	9.258E-04	2.700E+04

DOSE: All Nuclides Summed, All Pathways Summed



457putrae3.RAD 05/19/2006 10:38 GRAPHICS.ASC Includes All Pathways

Probabilistic Input

Number of Sample Runs: 1600

Number	Name	Distribution	Parameters							
1	MLINH	CONTINUOUS LINEAR	8	0	0	.000015	.0151	.000023	.1365	.0C
2	SHF1	DISCRETE CUMULATIVE	8	.0084	.01	.022	.09	.035	.21	.05

Probabilistic Total Dose Summary

Nuclide (j)	Peak Time	Peak Dose	DOSE(j,t), mrem/yr t= 0.00E+00	1.00E+00	3.00E+00	1.00E+01	3.00E+01	1.00E+02	3.00E+02	1.00E+03
Ac-227										
Min	0.00E+00	9.84E-02	9.84E-02	9.52E-02	8.91E-02	7.06E-02	3.64E-02	3.56E-03	4.68E-06	3.82E-16
Max	0.00E+00	3.88E-01	3.88E-01	3.75E-01	3.51E-01	2.78E-01	1.43E-01	1.40E-02	1.84E-05	1.51E-15
Avg	0.00E+00	1.40E-01	1.40E-01	1.36E-01	1.27E-01	1.01E-01	5.18E-02	5.08E-03	6.66E-06	5.45E-16
Std	0.00E+00	5.70E-02	5.70E-02	5.52E-02	5.16E-02	4.09E-02	2.11E-02	2.07E-03	2.71E-06	2.22E-16
Pa-231										
Min	7.24E+01	9.62E-02	2.71E-02	3.01E-02	3.58E-02	5.26E-02	8.14E-02	9.36E-02	5.40E-02	6.89E-03
Max	7.55E+01	3.43E-01	6.17E-02	7.36E-02	9.62E-02	1.63E-01	2.79E-01	3.35E-01	1.94E-01	2.47E-02
Avg	7.33E+01	1.32E-01	3.25E-02	3.67E-02	4.49E-02	6.89E-02	1.10E-01	1.29E-01	7.44E-02	9.48E-03
Std	6.19E-01	4.84E-02	6.58E-03	8.35E-03	1.17E-02	2.16E-02	3.88E-02	4.75E-02	2.76E-02	3.51E-03
Pb-210										
Min	0.00E+00	3.93E-01	3.93E-01	3.81E-01	3.58E-01	2.87E-01	1.53E-01	1.68E-02	3.05E-05	7.83E-15
Max	0.00E+00	4.60E-01	4.60E-01	4.46E-01	4.19E-01	3.36E-01	1.79E-01	1.96E-02	3.57E-05	9.16E-15
Avg	0.00E+00	4.03E-01	4.03E-01	3.90E-01	3.66E-01	2.94E-01	1.56E-01	1.72E-02	3.12E-05	8.02E-15
Std	0.00E+00	1.35E-02	1.35E-02	1.31E-02	1.23E-02	9.87E-03	5.25E-03	5.77E-04	1.05E-06	2.70E-16
Ra-226										
Min	0.00E+00	9.60E+00	9.56E+00	9.57E+00	9.58E+00	9.60E+00	9.59E+00	9.23E+00	7.96E+00	4.72E+00
Max	1.70E+01	4.60E+01	4.60E+01	4.59E+01	4.59E+01	4.57E+01	4.52E+01	4.31E+01	3.71E+01	2.20E+01
Avg	8.59E+00	1.43E+01	1.43E+01	1.43E+01	1.43E+01	1.43E+01	1.42E+01	1.37E+01	1.18E+01	6.98E+00
Std	4.76E+00	7.53E+00	7.53E+00	7.53E+00	7.52E+00	7.48E+00	7.37E+00	7.00E+00	6.03E+00	3.57E+00
Ra-228										
Min	2.29E+00	1.85E+00	1.50E+00	1.76E+00	1.83E+00	9.70E-01	6.78E-02	4.85E-06	6.93E-18	0.00E+00
Max	2.30E+00	8.90E+00	7.17E+00	8.43E+00	8.80E+00	4.66E+00	3.26E-01	2.33E-05	3.33E-17	0.00E+00
Avg	2.29E+00	2.78E+00	2.24E+00	2.63E+00	2.75E+00	1.45E+00	1.02E-01	7.27E-06	1.04E-17	0.00E+00
Std	1.85E-03	1.46E+00	1.17E+00	1.38E+00	1.44E+00	7.64E-01	5.34E-02	3.82E-06	5.46E-18	0.00E+00
Th-228										
Min	0.00E+00	1.60E+00	1.60E+00	1.11E+00	5.39E-01	4.27E-02	3.04E-05	2.94E-16	0.00E+00	0.00E+00
Max	0.00E+00	7.70E+00	7.70E+00	5.36E+00	2.60E+00	2.06E-01	1.47E-04	1.41E-15	0.00E+00	0.00E+00
Avg	0.00E+00	2.40E+00	2.40E+00	1.67E+00	8.09E-01	6.40E-02	4.56E-05	4.41E-16	0.00E+00	0.00E+00
Std	0.00E+00	1.26E+00	1.26E+00	8.79E-01	4.26E-01	3.37E-02	2.40E-05	2.32E-16	0.00E+00	0.00E+00
Th-230										
Min	1.00E+03	1.53E+00	2.01E-02	2.27E-02	2.73E-02	4.34E-02	8.95E-02	2.46E-01	6.43E-01	1.53E+00
Max	1.00E+03	7.11E+00	4.28E-02	5.39E-02	7.60E-02	1.53E-01	3.72E-01	1.11E+00	2.96E+00	7.11E+00
Avg	1.00E+03	2.26E+00	2.66E-02	3.01E-02	3.70E-02	6.11E-02	1.30E-01	3.62E-01	9.49E-01	2.26E+00
Std	0.00E+00	1.15E+00	3.03E-03	4.54E-03	7.95E-03	2.04E-02	5.61E-02	1.76E-01	4.77E-01	1.15E+00
Th-232										
Min	6.66E+01	2.86E+00	1.24E-01	3.22E-01	7.64E-01	1.97E+00	2.80E+00	2.86E+00	2.85E+00	2.81E+00
Max	6.73E+01	1.36E+01	4.78E-01	1.43E+00	3.55E+00	9.32E+00	1.33E+01	1.36E+01	1.36E+01	1.34E+01
Avg	6.70E+01	4.27E+00	1.78E-01	4.74E-01	1.14E+00	2.94E+00	4.19E+00	4.27E+00	4.25E+00	4.20E+00
Std	1.11E-01	2.22E+00	6.82E-02	2.24E-01	5.71E-01	1.52E+00	2.17E+00	2.22E+00	2.21E+00	2.18E+00
U-234										
Min	0.00E+00	1.25E-02	1.25E-02	1.24E-02	1.21E-02	1.14E-02	9.59E-03	5.31E-03	1.47E-03	1.87E-03
Max	0.00E+00	2.36E-02	2.36E-02	2.34E-02	2.30E-02	2.16E-02	1.82E-02	1.03E-02	4.29E-03	8.65E-03
Avg	0.00E+00	1.58E-02	1.58E-02	1.57E-02	1.54E-02	1.45E-02	1.22E-02	6.72E-03	1.97E-03	2.76E-03
Std	0.00E+00	1.47E-03	1.47E-03	1.46E-03	1.44E-03	1.35E-03	1.14E-03	6.70E-04	4.98E-04	1.40E-03
U-235										
Min	0.00E+00	3.06E-02	3.06E-02	3.04E-02	2.99E-02	2.81E-02	2.36E-02	1.28E-02	2.34E-03	2.94E-05
Max	0.00E+00	1.47E-01	1.47E-01	1.45E-01	1.43E-01	1.34E-01	1.13E-01	6.12E-02	1.10E-02	1.11E-04
Avg	0.00E+00	4.59E-02	4.59E-02	4.55E-02	4.47E-02	4.20E-02	3.53E-02	1.92E-02	3.49E-03	4.10E-05
Std	0.00E+00	2.39E-02	2.39E-02	2.37E-02	2.33E-02	2.19E-02	1.84E-02	9.99E-03	1.79E-03	1.62E-05

Probabilistic Total Dose Summary(cont.)

Nuclide (j)	Peak Time	Peak Dose	DOSE(j,t), mrem/yr t= 0.00E+00	1.00E+00	3.00E+00	1.00E+01	3.00E+01	1.00E+02	3.00E+02	1.00E+03
U-238										
Min	0.00E+00	1.31E-01	1.31E-01	1.30E-01	1.27E-01	1.20E-01	1.00E-01	5.43E-02	9.33E-03	2.02E-05
Max	0.00E+00	5.97E-01	5.97E-01	5.92E-01	5.81E-01	5.47E-01	4.58E-01	2.48E-01	4.26E-02	9.22E-05
Avg	0.00E+00	1.93E-01	1.93E-01	1.92E-01	1.88E-01	1.77E-01	1.48E-01	8.02E-02	1.38E-02	2.99E-05
Std	0.00E+00	9.54E-02	9.54E-02	9.45E-02	9.29E-02	8.73E-02	7.32E-02	3.95E-02	6.80E-03	1.47E-05
∑ALL										
Min	0.00E+00	1.35E+01	1.35E+01	1.35E+01	1.34E+01	1.32E+01	1.29E+01	1.25E+01	1.15E+01	9.06E+00
Max	0.00E+00	6.30E+01	6.30E+01	6.29E+01	6.25E+01	6.16E+01	6.04E+01	5.85E+01	5.39E+01	4.25E+01
Avg	0.00E+00	2.00E+01	2.00E+01	2.00E+01	1.98E+01	1.95E+01	1.92E+01	1.85E+01	1.71E+01	1.35E+01
Std	0.00E+00	1.02E+01	1.02E+01	1.02E+01	1.02E+01	1.00E+01	9.81E+00	9.50E+00	8.75E+00	6.91E+00

∑ALL is total dose summed for all nuclides.

Probabilistic results summary : Scabble Ratios, 0.3 cm on pavement, industrial,
rad + eat + breathe, 10000 sq File: 457putrae3.RAD
Cumulative Probability Summary for: Total Dose Over Pathways

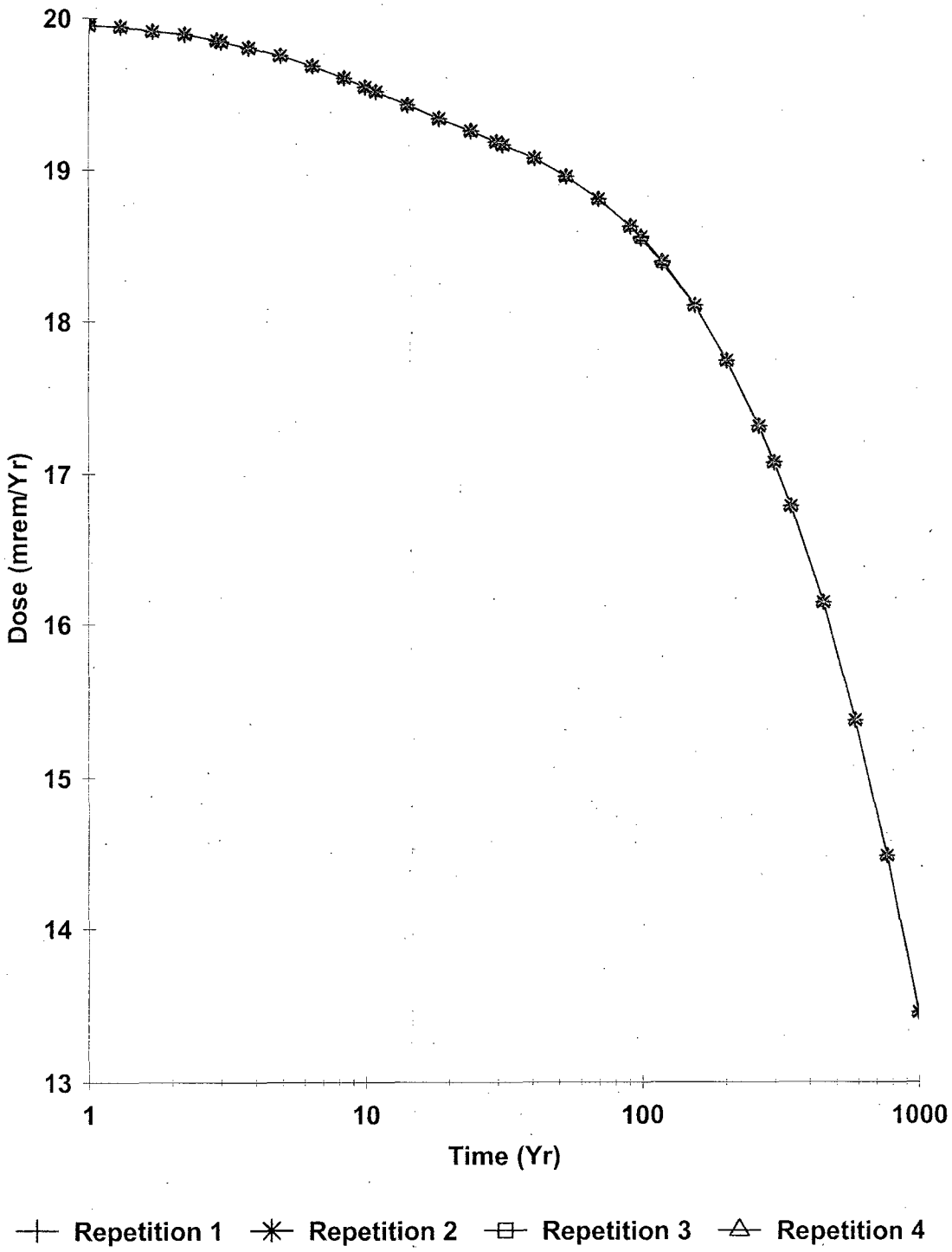
Cumulative Probability	Dose(t), mrem/yr t= 0.00E+00	1.00E+00	3.00E+00	1.00E+01	3.00E+01	1.00E+02	3.00E+02	1.00E+03
0.025	1.42E+01	1.42E+01	1.41E+01	1.39E+01	1.36E+01	1.32E+01	1.21E+01	9.53E+00
0.050	1.42E+01	1.42E+01	1.41E+01	1.39E+01	1.36E+01	1.32E+01	1.21E+01	9.54E+00
0.075	1.42E+01	1.42E+01	1.41E+01	1.39E+01	1.36E+01	1.32E+01	1.21E+01	9.54E+00
0.100	1.48E+01	1.48E+01	1.47E+01	1.45E+01	1.42E+01	1.38E+01	1.27E+01	9.97E+00
0.125	1.48E+01	1.48E+01	1.47E+01	1.45E+01	1.42E+01	1.38E+01	1.27E+01	9.97E+00
0.150	1.49E+01	1.48E+01	1.47E+01	1.45E+01	1.42E+01	1.38E+01	1.27E+01	9.98E+00
0.175	1.49E+01	1.48E+01	1.47E+01	1.45E+01	1.43E+01	1.38E+01	1.27E+01	9.98E+00
0.200	1.49E+01	1.48E+01	1.48E+01	1.45E+01	1.43E+01	1.38E+01	1.27E+01	9.99E+00
0.225	1.58E+01	1.58E+01	1.57E+01	1.55E+01	1.52E+01	1.47E+01	1.35E+01	1.06E+01
0.250	1.58E+01	1.58E+01	1.57E+01	1.55E+01	1.52E+01	1.47E+01	1.35E+01	1.06E+01
0.275	1.58E+01	1.58E+01	1.57E+01	1.55E+01	1.52E+01	1.47E+01	1.35E+01	1.06E+01
0.300	1.59E+01	1.58E+01	1.57E+01	1.55E+01	1.52E+01	1.47E+01	1.35E+01	1.07E+01
0.325	1.59E+01	1.58E+01	1.57E+01	1.55E+01	1.52E+01	1.47E+01	1.35E+01	1.07E+01
0.350	1.59E+01	1.58E+01	1.57E+01	1.55E+01	1.52E+01	1.47E+01	1.35E+01	1.07E+01
0.375	1.59E+01	1.58E+01	1.57E+01	1.55E+01	1.52E+01	1.47E+01	1.35E+01	1.07E+01
0.400	1.75E+01	1.74E+01	1.73E+01	1.71E+01	1.68E+01	1.62E+01	1.49E+01	1.18E+01
0.425	1.75E+01	1.74E+01	1.73E+01	1.71E+01	1.68E+01	1.62E+01	1.49E+01	1.18E+01
0.450	1.75E+01	1.74E+01	1.74E+01	1.71E+01	1.68E+01	1.62E+01	1.49E+01	1.18E+01
0.475	1.75E+01	1.74E+01	1.74E+01	1.71E+01	1.68E+01	1.62E+01	1.49E+01	1.18E+01
0.500	1.75E+01	1.75E+01	1.74E+01	1.71E+01	1.68E+01	1.62E+01	1.49E+01	1.18E+01
0.525	1.75E+01	1.75E+01	1.74E+01	1.71E+01	1.68E+01	1.62E+01	1.49E+01	1.18E+01
0.550	1.75E+01	1.75E+01	1.74E+01	1.71E+01	1.68E+01	1.62E+01	1.49E+01	1.18E+01
0.575	1.75E+01	1.75E+01	1.74E+01	1.71E+01	1.68E+01	1.62E+01	1.49E+01	1.18E+01
0.600	1.75E+01	1.75E+01	1.74E+01	1.71E+01	1.68E+01	1.62E+01	1.49E+01	1.18E+01
0.625	1.75E+01	1.75E+01	1.74E+01	1.71E+01	1.68E+01	1.63E+01	1.50E+01	1.18E+01
0.650	2.01E+01	2.00E+01	1.99E+01	1.96E+01	1.93E+01	1.86E+01	1.71E+01	1.35E+01
0.675	2.01E+01	2.00E+01	1.99E+01	1.96E+01	1.93E+01	1.86E+01	1.71E+01	1.35E+01
0.700	2.01E+01	2.00E+01	1.99E+01	1.96E+01	1.93E+01	1.86E+01	1.71E+01	1.35E+01
0.725	2.01E+01	2.00E+01	1.99E+01	1.96E+01	1.93E+01	1.86E+01	1.71E+01	1.35E+01
0.750	2.01E+01	2.00E+01	1.99E+01	1.96E+01	1.93E+01	1.86E+01	1.71E+01	1.35E+01
0.775	2.01E+01	2.00E+01	1.99E+01	1.96E+01	1.93E+01	1.86E+01	1.72E+01	1.35E+01
0.800	2.01E+01	2.00E+01	1.99E+01	1.96E+01	1.93E+01	1.86E+01	1.72E+01	1.35E+01
0.825	2.01E+01	2.00E+01	1.99E+01	1.96E+01	1.93E+01	1.86E+01	1.72E+01	1.35E+01
0.850	2.01E+01	2.01E+01	1.99E+01	1.96E+01	1.93E+01	1.86E+01	1.72E+01	1.35E+01
0.875	2.01E+01	2.01E+01	2.00E+01	1.97E+01	1.93E+01	1.87E+01	1.72E+01	1.35E+01
0.900	2.46E+01	2.45E+01	2.44E+01	2.40E+01	2.36E+01	2.28E+01	2.10E+01	1.65E+01
0.925	2.46E+01	2.45E+01	2.44E+01	2.40E+01	2.36E+01	2.28E+01	2.10E+01	1.65E+01
0.950	6.30E+01	6.28E+01	6.25E+01	6.15E+01	6.04E+01	5.84E+01	5.38E+01	4.25E+01
0.975	6.30E+01	6.28E+01	6.25E+01	6.15E+01	6.04E+01	5.84E+01	5.38E+01	4.25E+01
1.000	6.30E+01	6.29E+01	6.25E+01	6.16E+01	6.04E+01	5.85E+01	5.39E+01	4.25E+01

Probabilistic results summary : Scabble Ratios, 0.3 cm on pavement, industrial,
rad + eat + breathe, 10000 sq File: 457putrae3.RAD

Peak of the mean dose (averaged over observations) at graphical times

Repetition	Time of peak mean dose	Peak mean dose
	Years	mrem/yr
1	0.000E+00	2.000E+01
2	0.000E+00	2.000E+01
3	0.000E+00	2.000E+01
4	0.000E+00	2.000E+01

Case 457putrae3 Probabilistic Annual Dose from Scabbled Spectrum on Pavement



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+03	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	3.000E-03	2.000E+00	---	THICKO
R011	Length parallel to aquifer flow (m)	not used	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	2.500E+01	3.000E+01	---	BRDL
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	3.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	3.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	3.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(9)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): Ac-227	1.025E+01	0.000E+00	---	S1(1)
R012	Initial principal radionuclide (pCi/g): Pa-231	1.025E+01	0.000E+00	---	S1(2)
R012	Initial principal radionuclide (pCi/g): Pb-210	3.153E+02	0.000E+00	---	S1(3)
R012	Initial principal radionuclide (pCi/g): Ra-226	3.153E+02	0.000E+00	---	S1(4)
R012	Initial principal radionuclide (pCi/g): Ra-228	7.508E+01	0.000E+00	---	S1(5)
R012	Initial principal radionuclide (pCi/g): Th-228	7.508E+01	0.000E+00	---	S1(6)
R012	Initial principal radionuclide (pCi/g): Th-230	1.757E+02	0.000E+00	---	S1(7)
R012	Initial principal radionuclide (pCi/g): Th-232	7.508E+01	0.000E+00	---	S1(8)
R012	Initial principal radionuclide (pCi/g): U-234	2.252E+02	0.000E+00	---	S1(9)
R012	Initial principal radionuclide (pCi/g): U-235	1.025E+01	0.000E+00	---	S1(10)
R012	Initial principal radionuclide (pCi/g): U-238	2.252E+02	0.000E+00	---	S1(11)
R012	Concentration in groundwater (pCi/L): Ac-227	not used	0.000E+00	---	W1(1)
R012	Concentration in groundwater (pCi/L): Pa-231	not used	0.000E+00	---	W1(2)
R012	Concentration in groundwater (pCi/L): Pb-210	not used	0.000E+00	---	W1(3)
R012	Concentration in groundwater (pCi/L): Ra-226	not used	0.000E+00	---	W1(4)
R012	Concentration in groundwater (pCi/L): Ra-228	not used	0.000E+00	---	W1(5)
R012	Concentration in groundwater (pCi/L): Th-228	not used	0.000E+00	---	W1(6)
R012	Concentration in groundwater (pCi/L): Th-230	not used	0.000E+00	---	W1(7)
R012	Concentration in groundwater (pCi/L): Th-232	not used	0.000E+00	---	W1(8)
R012	Concentration in groundwater (pCi/L): U-234	not used	0.000E+00	---	W1(9)
R012	Concentration in groundwater (pCi/L): U-235	not used	0.000E+00	---	W1(10)
R012	Concentration in groundwater (pCi/L): U-238	not used	0.000E+00	---	W1(11)
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)	1.500E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	0.000E+00	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	4.000E-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)	4.000E+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

Contaminated Zone Dimensions	
Area:	1000.00 square meters
Thickness:	0.00 meters
Cover Depth:	0.00 meters

Initial Soil Concentrations, pCi/g	
Ac-227	1.025E+01
Pa-231	1.025E+01
Pb-210	3.153E+02
Ra-226	3.153E+02
Ra-228	7.508E+01
Th-228	7.508E+01
Th-230	1.757E+02
Th-232	7.508E+01
U-234	2.252E+02
U-235	1.025E+01
U-238	2.252E+02

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

t (years):	0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
TDOSE(t):	1.621E+01	1.617E+01	1.608E+01	1.584E+01	1.555E+01	1.503E+01	1.383E+01	1.090E+01
M(t):	6.484E-01	6.468E-01	6.434E-01	6.335E-01	6.219E-01	6.013E-01	5.533E-01	4.358E-01

Maximum TDOSE(t): 1.621E+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	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	frac
Ac-227	8.483E-02	0.0052	6.496E-03	0.0004	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.484E-02	0.0C
Pa-231	9.925E-03	0.0006	1.359E-03	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.846E-02	0.0C
Pb-210	2.314E-02	0.0014	6.899E-04	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.761E-01	0.02
Ra-226	1.147E+01	0.7076	2.704E-04	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.521E-02	0.0C
Ra-228	1.786E+00	0.1102	4.164E-04	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.841E-02	0.0C
Th-228	1.919E+00	0.1184	2.084E-03	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.481E-03	0.0C
Th-230	3.507E-03	0.0002	5.489E-03	0.0003	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.604E-02	0.0C
Th-232	1.037E-01	0.0064	1.182E-02	0.0007	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.524E-02	0.0C
U-234	1.817E-03	0.0001	2.836E-03	0.0002	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.057E-02	0.0C
U-235	3.460E-02	0.0021	1.203E-04	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.546E-04	0.0C
U-238	1.448E-01	0.0089	2.536E-03	0.0002	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.003E-02	0.0C
Total	1.558E+01	0.9613	3.412E-02	0.0021	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.939E-01	0.03

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	frac
Ac-227	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.162E-01	0.0C
Pa-231	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.975E-02	0.0C
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.999E-01	0.02
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	1.155E+01	0.71
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	1.805E+00	0.11
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	1.930E+00	0.11
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.504E-02	0.0C
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	1.508E-01	0.0C
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.522E-02	0.0C
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.518E-02	0.0C
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	1.573E-01	0.0C
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	1.621E+01	1.0C

*Sum of all water independent and dependent pathways.

Probabilistic Input

Number of Sample Runs: 1600

Number	Name	Distribution	Parameters							
1	MLINH	CONTINUOUS LINEAR	8	0	0	.000015	.0151	.000023	.1365	.00
2	SHF1	DISCRETE CUMULATIVE	8	.0084	.01	.022	.09	.035	.21	.05

Probabilistic Total Dose Summary

Nuclide (j)	Peak Time	Peak Dose	DOSE(j,t), mrem/yr t= 0.00E+00	1.00E+00	3.00E+00	1.00E+01	3.00E+01	1.00E+02	3.00E+02	1.00E+03
Ac-227										
Min	0.00E+00	7.84E-02	7.84E-02	7.58E-02	7.10E-02	5.63E-02	2.90E-02	2.84E-03	3.73E-06	3.05E-16
Max	0.00E+00	2.89E-01	2.89E-01	2.80E-01	2.62E-01	2.08E-01	1.07E-01	1.05E-02	1.37E-05	1.12E-15
Avg	0.00E+00	1.09E-01	1.09E-01	1.06E-01	9.88E-02	7.83E-02	4.03E-02	3.95E-03	5.18E-06	4.24E-16
Std	0.00E+00	4.15E-02	4.15E-02	4.01E-02	3.75E-02	2.98E-02	1.53E-02	1.50E-03	1.97E-06	1.61E-16
Pa-231										
Min	7.14E+01	7.93E-02	2.49E-02	2.72E-02	3.17E-02	4.51E-02	6.78E-02	7.70E-02	4.44E-02	5.66E-03
Max	7.51E+01	2.59E-01	5.05E-02	5.94E-02	7.62E-02	1.26E-01	2.13E-01	2.54E-01	1.47E-01	1.87E-02
Avg	7.24E+01	1.06E-01	2.89E-02	3.22E-02	3.85E-02	5.71E-02	8.91E-02	1.03E-01	5.94E-02	7.57E-03
Std	7.27E-01	3.53E-02	4.86E-03	6.14E-03	8.57E-03	1.58E-02	2.83E-02	3.46E-02	2.01E-02	2.56E-03
Pb-210										
Min	0.00E+00	3.90E-01	3.90E-01	3.78E-01	3.55E-01	2.85E-01	1.52E-01	1.67E-02	3.03E-05	7.78E-15
Max	0.00E+00	4.46E-01	4.46E-01	4.32E-01	4.06E-01	3.26E-01	1.73E-01	1.90E-02	3.46E-05	8.89E-15
Avg	0.00E+00	3.98E-01	3.98E-01	3.86E-01	3.62E-01	2.90E-01	1.55E-01	1.70E-02	3.09E-05	7.93E-15
Std	0.00E+00	1.13E-02	1.13E-02	1.10E-02	1.03E-02	8.25E-03	4.39E-03	4.82E-04	8.77E-07	2.25E-16
Ra-226										
Min	0.00E+00	7.21E+00	7.13E+00	7.14E+00	7.15E+00	7.18E+00	7.21E+00	6.97E+00	6.01E+00	3.56E+00
Max	2.58E+01	3.42E+01	3.42E+01	3.42E+01	3.42E+01	3.41E+01	3.37E+01	3.21E+01	2.77E+01	1.64E+01
Avg	1.69E+01	1.07E+01	1.07E+01	1.07E+01	1.07E+01	1.07E+01	1.07E+01	1.03E+01	8.85E+00	5.25E+00
Std	5.96E+00	5.59E+00	5.60E+00	5.60E+00	5.59E+00	5.57E+00	5.49E+00	5.21E+00	4.49E+00	2.66E+00
Ra-228										
Min	2.28E+00	1.38E+00	1.12E+00	1.31E+00	1.37E+00	7.23E-01	5.05E-02	3.62E-06	5.16E-18	0.00E+00
Max	2.30E+00	6.62E+00	5.34E+00	6.27E+00	6.54E+00	3.47E+00	2.42E-01	1.73E-05	2.48E-17	0.00E+00
Avg	2.29E+00	2.07E+00	1.67E+00	1.96E+00	2.04E+00	1.08E+00	7.57E-02	5.41E-06	7.73E-18	0.00E+00
Std	2.45E-03	1.08E+00	8.73E-01	1.03E+00	1.07E+00	5.67E-01	3.97E-02	2.84E-06	4.06E-18	0.00E+00
Th-228										
Min	0.00E+00	1.19E+00	1.19E+00	8.28E-01	4.01E-01	3.18E-02	2.26E-05	2.18E-16	0.00E+00	0.00E+00
Max	0.00E+00	5.72E+00	5.72E+00	3.98E+00	1.93E+00	1.53E-01	1.09E-04	1.05E-15	0.00E+00	0.00E+00
Avg	0.00E+00	1.78E+00	1.78E+00	1.24E+00	6.02E-01	4.76E-02	3.39E-05	3.28E-16	0.00E+00	0.00E+00
Std	0.00E+00	9.38E-01	9.38E-01	6.53E-01	3.16E-01	2.50E-02	1.78E-05	1.72E-16	0.00E+00	0.00E+00
Th-230										
Min	1.00E+03	1.16E+00	1.91E-02	2.11E-02	2.45E-02	3.66E-02	7.11E-02	1.89E-01	4.89E-01	1.16E+00
Max	1.00E+03	5.31E+00	3.66E-02	4.49E-02	6.14E-02	1.19E-01	2.82E-01	8.31E-01	2.21E+00	5.31E+00
Avg	1.00E+03	1.71E+00	2.42E-02	2.68E-02	3.19E-02	5.00E-02	1.01E-01	2.76E-01	7.17E-01	1.71E+00
Std	0.00E+00	8.57E-01	2.33E-03	3.44E-03	5.96E-03	1.52E-02	4.18E-02	1.31E-01	3.55E-01	8.57E-01
Th-232										
Min	6.66E+01	2.14E+00	1.02E-01	2.50E-01	5.79E-01	1.47E+00	2.10E+00	2.14E+00	2.13E+00	2.10E+00
Max	6.72E+01	1.01E+01	3.66E-01	1.07E+00	2.65E+00	6.94E+00	9.92E+00	1.01E+01	1.01E+01	9.96E+00
Avg	6.69E+01	3.19E+00	1.42E-01	3.63E-01	8.55E-01	2.20E+00	3.13E+00	3.19E+00	3.18E+00	3.14E+00
Std	9.09E-02	1.65E+00	5.07E-02	1.66E-01	4.24E-01	1.13E+00	1.61E+00	1.65E+00	1.64E+00	1.62E+00
U-234										
Min	0.00E+00	1.22E-02	1.22E-02	1.21E-02	1.19E-02	1.11E-02	9.36E-03	5.16E-03	1.31E-03	1.41E-03
Max	0.00E+00	2.12E-02	2.12E-02	2.10E-02	2.07E-02	1.94E-02	1.63E-02	9.17E-03	3.46E-03	6.46E-03
Avg	0.00E+00	1.48E-02	1.48E-02	1.47E-02	1.44E-02	1.36E-02	1.14E-02	6.26E-03	1.69E-03	2.08E-03
Std	0.00E+00	1.20E-03	1.20E-03	1.19E-03	1.17E-03	1.10E-03	9.29E-04	5.44E-04	3.79E-04	1.04E-03
U-235										
Min	0.00E+00	2.18E-02	2.18E-02	2.16E-02	2.12E-02	1.99E-02	1.67E-02	9.13E-03	1.68E-03	2.36E-05
Max	0.00E+00	1.04E-01	1.04E-01	1.03E-01	1.01E-01	9.49E-02	7.97E-02	4.33E-02	7.81E-03	8.29E-05
Avg	0.00E+00	3.25E-02	3.25E-02	3.23E-02	3.17E-02	2.98E-02	2.50E-02	1.36E-02	2.49E-03	3.21E-05
Std	0.00E+00	1.69E-02	1.69E-02	1.68E-02	1.65E-02	1.55E-02	1.30E-02	7.05E-03	1.26E-03	1.17E-05

Probabilistic Total Dose Summary(cont.)

Nuclide (j)	Peak Time	Peak Dose	DOSE(j,t), mrem/yr t= 0.00E+00	1.00E+00	3.00E+00	1.00E+01	3.00E+01	1.00E+02	3.00E+02	1.00E+03
U-238										
Min	0.00E+00	9.96E-02	9.96E-02	9.88E-02	9.70E-02	9.12E-02	7.65E-02	4.13E-02	7.10E-03	1.54E-05
Max	0.00E+00	4.46E-01	4.46E-01	4.42E-01	4.34E-01	4.08E-01	3.42E-01	1.85E-01	3.18E-02	6.88E-05
Avg	0.00E+00	1.46E-01	1.46E-01	1.45E-01	1.42E-01	1.34E-01	1.12E-01	6.06E-02	1.04E-02	2.26E-05
Std	0.00E+00	7.07E-02	7.07E-02	7.01E-02	6.89E-02	6.48E-02	5.43E-02	2.93E-02	5.04E-03	1.09E-05
∑ALL										
Min	0.00E+00	1.02E+01	1.02E+01	1.02E+01	1.01E+01	9.96E+00	9.78E+00	9.45E+00	8.69E+00	6.83E+00
Max	0.00E+00	4.70E+01	4.70E+01	4.69E+01	4.67E+01	4.59E+01	4.51E+01	4.36E+01	4.02E+01	3.17E+01
Avg	0.00E+00	1.50E+01	1.50E+01	1.50E+01	1.49E+01	1.47E+01	1.44E+01	1.39E+01	1.28E+01	1.01E+01
Std	0.00E+00	7.61E+00	7.61E+00	7.59E+00	7.55E+00	7.43E+00	7.30E+00	7.06E+00	6.51E+00	5.14E+00

∑ALL is total dose summed for all nuclides.

Probabilistic results summary : Scabble Ratios, 0.3 cm on pavement, industrial, rad + eat + breathe, 1000 sq m File: 467uth1K.RAD

Cumulative Probability Summary for: Total Dose Over Pathways

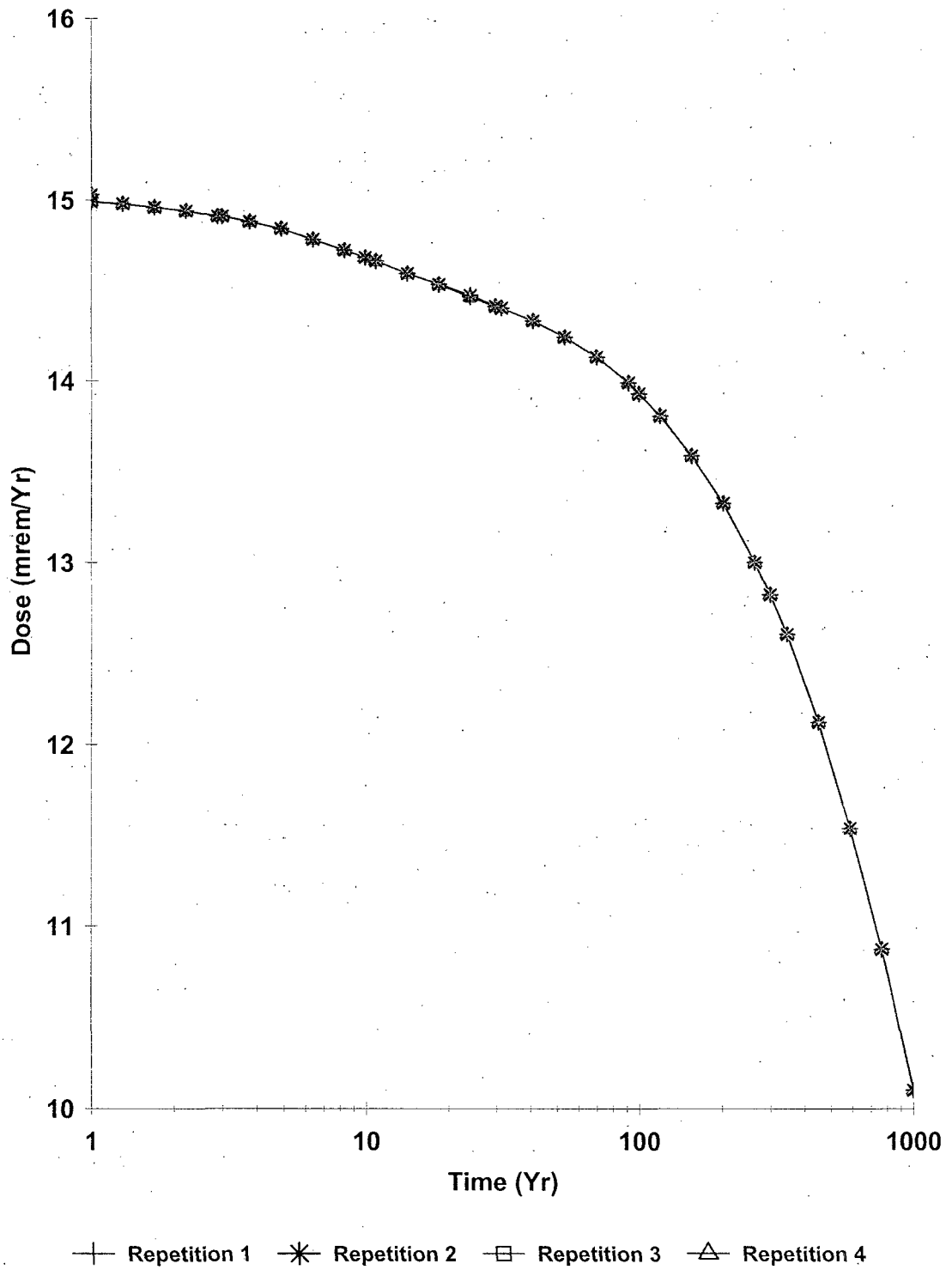
Cumulative Probability	Dose(t), mrem/yr t= 0.00E+00	1.00E+00	3.00E+00	1.00E+01	3.00E+01	1.00E+02	3.00E+02	1.00E+03
0.025	1.07E+01	1.07E+01	1.06E+01	1.05E+01	1.03E+01	9.93E+00	9.13E+00	7.18E+00
0.050	1.07E+01	1.07E+01	1.06E+01	1.05E+01	1.03E+01	9.93E+00	9.13E+00	7.19E+00
0.075	1.07E+01	1.07E+01	1.06E+01	1.05E+01	1.03E+01	9.94E+00	9.14E+00	7.19E+00
0.100	1.12E+01	1.12E+01	1.11E+01	1.09E+01	1.07E+01	1.04E+01	9.54E+00	7.51E+00
0.125	1.12E+01	1.12E+01	1.11E+01	1.09E+01	1.07E+01	1.04E+01	9.54E+00	7.51E+00
0.150	1.12E+01	1.12E+01	1.11E+01	1.09E+01	1.07E+01	1.04E+01	9.55E+00	7.51E+00
0.175	1.12E+01	1.12E+01	1.11E+01	1.09E+01	1.07E+01	1.04E+01	9.55E+00	7.51E+00
0.200	1.12E+01	1.12E+01	1.11E+01	1.10E+01	1.08E+01	1.04E+01	9.56E+00	7.52E+00
0.225	1.19E+01	1.19E+01	1.18E+01	1.17E+01	1.14E+01	1.11E+01	1.02E+01	8.01E+00
0.250	1.19E+01	1.19E+01	1.18E+01	1.17E+01	1.14E+01	1.11E+01	1.02E+01	8.01E+00
0.275	1.19E+01	1.19E+01	1.18E+01	1.17E+01	1.15E+01	1.11E+01	1.02E+01	8.01E+00
0.300	1.19E+01	1.19E+01	1.18E+01	1.17E+01	1.15E+01	1.11E+01	1.02E+01	8.01E+00
0.325	1.19E+01	1.19E+01	1.19E+01	1.17E+01	1.15E+01	1.11E+01	1.02E+01	8.01E+00
0.350	1.19E+01	1.19E+01	1.19E+01	1.17E+01	1.15E+01	1.11E+01	1.02E+01	8.02E+00
0.375	1.20E+01	1.19E+01	1.19E+01	1.17E+01	1.15E+01	1.11E+01	1.02E+01	8.02E+00
0.400	1.32E+01	1.31E+01	1.30E+01	1.28E+01	1.26E+01	1.22E+01	1.12E+01	8.83E+00
0.425	1.32E+01	1.31E+01	1.31E+01	1.29E+01	1.26E+01	1.22E+01	1.12E+01	8.83E+00
0.450	1.32E+01	1.31E+01	1.31E+01	1.29E+01	1.26E+01	1.22E+01	1.12E+01	8.84E+00
0.475	1.32E+01	1.31E+01	1.31E+01	1.29E+01	1.26E+01	1.22E+01	1.12E+01	8.84E+00
0.500	1.32E+01	1.31E+01	1.31E+01	1.29E+01	1.26E+01	1.22E+01	1.12E+01	8.84E+00
0.525	1.32E+01	1.31E+01	1.31E+01	1.29E+01	1.26E+01	1.22E+01	1.12E+01	8.84E+00
0.550	1.32E+01	1.31E+01	1.31E+01	1.29E+01	1.26E+01	1.22E+01	1.12E+01	8.84E+00
0.575	1.32E+01	1.31E+01	1.31E+01	1.29E+01	1.26E+01	1.22E+01	1.12E+01	8.84E+00
0.600	1.32E+01	1.31E+01	1.31E+01	1.29E+01	1.26E+01	1.22E+01	1.12E+01	8.84E+00
0.625	1.32E+01	1.32E+01	1.31E+01	1.29E+01	1.27E+01	1.22E+01	1.12E+01	8.86E+00
0.650	1.51E+01	1.50E+01	1.50E+01	1.47E+01	1.45E+01	1.40E+01	1.29E+01	1.01E+01
0.675	1.51E+01	1.51E+01	1.50E+01	1.47E+01	1.45E+01	1.40E+01	1.29E+01	1.01E+01
0.700	1.51E+01	1.51E+01	1.50E+01	1.47E+01	1.45E+01	1.40E+01	1.29E+01	1.01E+01
0.725	1.51E+01	1.51E+01	1.50E+01	1.47E+01	1.45E+01	1.40E+01	1.29E+01	1.01E+01
0.750	1.51E+01	1.51E+01	1.50E+01	1.47E+01	1.45E+01	1.40E+01	1.29E+01	1.01E+01
0.775	1.51E+01	1.51E+01	1.50E+01	1.47E+01	1.45E+01	1.40E+01	1.29E+01	1.01E+01
0.800	1.51E+01	1.51E+01	1.50E+01	1.48E+01	1.45E+01	1.40E+01	1.29E+01	1.01E+01
0.825	1.51E+01	1.51E+01	1.50E+01	1.48E+01	1.45E+01	1.40E+01	1.29E+01	1.01E+01
0.850	1.51E+01	1.51E+01	1.50E+01	1.48E+01	1.45E+01	1.40E+01	1.29E+01	1.01E+01
0.875	1.51E+01	1.51E+01	1.50E+01	1.48E+01	1.45E+01	1.40E+01	1.29E+01	1.02E+01
0.900	1.84E+01	1.84E+01	1.83E+01	1.80E+01	1.77E+01	1.71E+01	1.57E+01	1.24E+01
0.925	1.84E+01	1.84E+01	1.83E+01	1.80E+01	1.77E+01	1.71E+01	1.57E+01	1.24E+01
0.950	4.70E+01	4.69E+01	4.66E+01	4.59E+01	4.51E+01	4.36E+01	4.02E+01	3.17E+01
0.975	4.70E+01	4.69E+01	4.66E+01	4.59E+01	4.51E+01	4.36E+01	4.02E+01	3.17E+01
1.000	4.70E+01	4.69E+01	4.67E+01	4.59E+01	4.51E+01	4.36E+01	4.02E+01	3.17E+01

Probabilistic results summary : Scabble Ratios, 0.3 cm on pavement, industrial, rad + eat + breathe, 1000 sq m File: 467uth1K.RAD

Peak of the mean dose (averaged over observations) at graphical times

Repetition	Time of peak mean dose	Peak mean dose
	Years	mrem/yr
1	0.000E+00	1.503E+01
2	0.000E+00	1.503E+01
3	0.000E+00	1.503E+01
4	0.000E+00	1.503E+01

Case 467utk1k. Probabilistic Annual Dose from Source on Pavement



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+02	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	3.000E-03	2.000E+00	---	THICKO
R011	Length parallel to aquifer flow (m)	not used	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	2.500E+01	3.000E+01	---	BRDL
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	3.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	3.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	3.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(9)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): Ac-227	1.025E+01	0.000E+00	---	S1(1)
R012	Initial principal radionuclide (pCi/g): Pa-231	1.025E+01	0.000E+00	---	S1(2)
R012	Initial principal radionuclide (pCi/g): Pb-210	3.153E+02	0.000E+00	---	S1(3)
R012	Initial principal radionuclide (pCi/g): Ra-226	3.153E+02	0.000E+00	---	S1(4)
R012	Initial principal radionuclide (pCi/g): Ra-228	7.508E+01	0.000E+00	---	S1(5)
R012	Initial principal radionuclide (pCi/g): Th-228	7.508E+01	0.000E+00	---	S1(6)
R012	Initial principal radionuclide (pCi/g): Th-230	1.757E+02	0.000E+00	---	S1(7)
R012	Initial principal radionuclide (pCi/g): Th-232	7.508E+01	0.000E+00	---	S1(8)
R012	Initial principal radionuclide (pCi/g): U-234	2.252E+02	0.000E+00	---	S1(9)
R012	Initial principal radionuclide (pCi/g): U-235	1.025E+01	0.000E+00	---	S1(10)
R012	Initial principal radionuclide (pCi/g): U-238	2.252E+02	0.000E+00	---	S1(11)
R012	Concentration in groundwater (pCi/L): Ac-227	not used	0.000E+00	---	W1(1)
R012	Concentration in groundwater (pCi/L): Pa-231	not used	0.000E+00	---	W1(2)
R012	Concentration in groundwater (pCi/L): Pb-210	not used	0.000E+00	---	W1(3)
R012	Concentration in groundwater (pCi/L): Ra-226	not used	0.000E+00	---	W1(4)
R012	Concentration in groundwater (pCi/L): Ra-228	not used	0.000E+00	---	W1(5)
R012	Concentration in groundwater (pCi/L): Th-228	not used	0.000E+00	---	W1(6)
R012	Concentration in groundwater (pCi/L): Th-230	not used	0.000E+00	---	W1(7)
R012	Concentration in groundwater (pCi/L): Th-232	not used	0.000E+00	---	W1(8)
R012	Concentration in groundwater (pCi/L): U-234	not used	0.000E+00	---	W1(9)
R012	Concentration in groundwater (pCi/L): U-235	not used	0.000E+00	---	W1(10)
R012	Concentration in groundwater (pCi/L): U-238	not used	0.000E+00	---	W1(11)
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)	1.500E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	0.000E+00	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	4.000E-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)	4.000E+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

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for U-238				
R016	Contaminated zone (cm**3/g)	1.260E+02	5.000E+01	---	DCNUCC(11)
R016	Unsaturated zone 1 (cm**3/g)	not used	5.000E+01	---	DCNUCU(11,1)
R016	Saturated zone (cm**3/g)	not used	5.000E+01	---	DCNUCS(11)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	8.803E-03	ALEACH(11)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(11)
R017	Inhalation rate (m**3/yr)	1.227E+04	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	3.500E-05	1.000E-04	---	MLINH
R017	Exposure duration	3.000E+01	3.000E+01	---	ED
R017	Shielding factor, inhalation	6.000E-01	4.000E-01	---	SHF3
R017	Shielding factor, external gamma	1.700E-01	7.000E-01	---	SHF1
R017	Fraction of time spent indoors	1.825E-01	5.000E-01	---	FIND
R017	Fraction of time spent outdoors (on site)	4.563E-02	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)	not used	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	not used	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	not used	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	not used	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	not used	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	not used	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	3.650E+01	3.650E+01	---	SOIL

Contaminated Zone Dimensions	
Area:	100.00 square meters
Thickness:	0.00 meters
Cover Depth:	0.00 meters

Initial Soil Concentrations, pCi/g	
Ac-227	1.025E+01
Pa-231	1.025E+01
Pb-210	3.153E+02
Ra-226	3.153E+02
Ra-228	7.508E+01
Th-228	7.508E+01
Th-230	1.757E+02
Th-232	7.508E+01
U-234	2.252E+02
U-235	1.025E+01
U-238	2.252E+02

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

t (years):	0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
TDOSE(t):	9.587E+00	9.564E+00	9.512E+00	9.364E+00	9.193E+00	8.894E+00	8.196E+00	6.468E+00
M(t):	3.835E-01	3.825E-01	3.805E-01	3.746E-01	3.677E-01	3.558E-01	3.278E-01	2.587E-01

Maximum TDOSE(t): 9.587E+00 mrem/yr at t = 0.000E+00 years

Probabilistic Input

Number of Sample Runs: 1600

Number	Name	Distribution	Parameters							
1	MLINH	CONTINUOUS LINEAR	8	0	0	.000015	.0151	.000023	.1365	.0C
2	SHF1	DISCRETE CUMULATIVE	8	.0084	.01	.022	.09	.035	.21	.05

Probabilistic Total Dose Summary

Nuclide (j)	Peak Time	Peak Dose	DOSE(j,t), mrem/yr t= 0.00E+00	1.00E+00	3.00E+00	1.00E+01	3.00E+01	1.00E+02	3.00E+02	1.00E+03
Ac-227										
Min	0.00E+00	3.42E-02	3.42E-02	3.31E-02	3.10E-02	2.45E-02	1.26E-02	1.24E-03	1.63E-06	1.33E-16
Max	0.00E+00	1.60E-01	1.60E-01	1.55E-01	1.45E-01	1.15E-01	5.92E-02	5.80E-03	7.61E-06	6.22E-16
Avg	0.00E+00	5.31E-02	5.31E-02	5.13E-02	4.80E-02	3.81E-02	1.96E-02	1.92E-03	2.52E-06	2.06E-16
Std	0.00E+00	2.44E-02	2.44E-02	2.36E-02	2.21E-02	1.75E-02	9.00E-03	8.82E-04	1.16E-06	9.47E-17
Pa-231										
Min	7.49E+01	3.05E-02	5.79E-03	6.84E-03	8.84E-03	1.47E-02	2.50E-02	2.98E-02	1.73E-02	2.20E-03
Max	7.62E+01	1.39E-01	2.18E-02	2.67E-02	3.61E-02	6.39E-02	1.12E-01	1.36E-01	7.87E-02	1.00E-02
Avg	7.54E+01	4.69E-02	8.39E-03	1.00E-02	1.31E-02	2.23E-02	3.82E-02	4.59E-02	2.66E-02	3.39E-03
Std	2.30E-01	2.08E-02	2.97E-03	3.72E-03	5.15E-03	9.38E-03	1.67E-02	2.04E-02	1.18E-02	1.51E-03
Pb-210										
Min	0.00E+00	4.71E-02	4.71E-02	4.57E-02	4.29E-02	3.44E-02	1.83E-02	2.01E-03	3.66E-06	9.38E-16
Max	0.00E+00	8.40E-02	8.40E-02	8.14E-02	7.64E-02	6.13E-02	3.26E-02	3.58E-03	6.52E-06	1.67E-15
Avg	0.00E+00	5.22E-02	5.22E-02	5.06E-02	4.75E-02	3.81E-02	2.03E-02	2.23E-03	4.05E-06	1.04E-15
Std	0.00E+00	7.46E-03	7.46E-03	7.23E-03	6.78E-03	5.44E-03	2.89E-03	3.18E-04	5.78E-07	1.48E-16
Ra-226										
Min	0.00E+00	4.31E+00	4.31E+00	4.31E+00	4.31E+00	4.29E+00	4.25E+00	4.05E+00	3.49E+00	2.06E+00
Max	0.00E+00	2.08E+01	2.08E+01	2.08E+01	2.08E+01	2.07E+01	2.04E+01	1.94E+01	1.67E+01	9.91E+00
Avg	0.00E+00	6.48E+00	6.48E+00	6.47E+00	6.47E+00	6.44E+00	6.36E+00	6.06E+00	5.22E+00	3.09E+00
Std	0.00E+00	3.42E+00	3.42E+00	3.42E+00	3.41E+00	3.40E+00	3.35E+00	3.18E+00	2.74E+00	1.62E+00
Ra-228										
Min	2.29E+00	8.33E-01	6.72E-01	7.90E-01	8.24E-01	4.36E-01	3.05E-02	2.18E-06	3.12E-18	0.00E+00
Max	2.30E+00	4.02E+00	3.25E+00	3.82E+00	3.98E+00	2.11E+00	1.47E-01	1.06E-05	1.51E-17	0.00E+00
Avg	2.30E+00	1.25E+00	1.01E+00	1.19E+00	1.24E+00	6.55E-01	4.59E-02	3.28E-06	4.69E-18	0.00E+00
Std	1.09E-03	6.60E-01	5.32E-01	6.26E-01	6.53E-01	3.46E-01	2.42E-02	1.73E-06	2.47E-18	0.00E+00
Th-228										
Min	0.00E+00	7.20E-01	7.20E-01	5.01E-01	2.43E-01	1.92E-02	1.37E-05	1.32E-16	0.00E+00	0.00E+00
Max	0.00E+00	3.48E+00	3.48E+00	2.42E+00	1.17E+00	9.29E-02	6.62E-05	6.39E-16	0.00E+00	0.00E+00
Avg	0.00E+00	1.08E+00	1.08E+00	7.53E-01	3.65E-01	2.89E-02	2.06E-05	1.99E-16	0.00E+00	0.00E+00
Std	0.00E+00	5.71E-01	5.71E-01	3.97E-01	1.93E-01	1.52E-02	1.09E-05	1.05E-16	0.00E+00	0.00E+00
Th-230										
Min	1.00E+03	6.67E-01	3.55E-03	4.87E-03	6.95E-03	1.42E-02	3.47E-02	1.04E-01	2.78E-01	6.67E-01
Max	1.00E+03	3.20E+00	1.59E-02	2.09E-02	3.10E-02	6.60E-02	1.65E-01	4.97E-01	1.33E+00	3.20E+00
Avg	1.00E+03	1.00E+00	7.44E-03	9.01E-03	1.21E-02	2.30E-02	5.38E-02	1.57E-01	4.17E-01	1.00E+00
Std	0.00E+00	5.23E-01	1.62E-03	2.24E-03	3.72E-03	9.34E-03	2.55E-02	7.99E-02	2.17E-01	5.23E-01
Th-232										
Min	6.67E+01	1.27E+00	4.44E-02	1.34E-01	3.32E-01	8.72E-01	1.25E+00	1.27E+00	1.27E+00	1.25E+00
Max	6.73E+01	6.15E+00	2.09E-01	6.39E-01	1.60E+00	4.21E+00	6.02E+00	6.14E+00	6.12E+00	6.04E+00
Avg	6.70E+01	1.92E+00	7.03E-02	2.04E-01	5.02E-01	1.31E+00	1.88E+00	1.92E+00	1.91E+00	1.88E+00
Std	1.20E-01	1.00E+00	3.10E-02	1.01E-01	2.59E-01	6.87E-01	9.84E-01	1.00E+00	1.00E+00	9.88E-01
U-234										
Min	0.00E+00	2.28E-03	2.28E-03	2.26E-03	2.22E-03	2.08E-03	1.75E-03	1.00E-03	4.13E-04	8.12E-04
Max	0.00E+00	9.25E-03	9.25E-03	9.17E-03	9.01E-03	8.47E-03	7.13E-03	4.06E-03	1.83E-03	3.89E-03
Avg	0.00E+00	4.32E-03	4.32E-03	4.28E-03	4.21E-03	3.96E-03	3.33E-03	1.86E-03	6.76E-04	1.22E-03
Std	0.00E+00	9.25E-04	9.25E-04	9.17E-04	9.01E-04	8.48E-04	7.14E-04	4.11E-04	2.42E-04	6.36E-04
U-235										
Min	0.00E+00	1.22E-02	1.22E-02	1.21E-02	1.19E-02	1.12E-02	9.40E-03	5.11E-03	9.22E-04	9.76E-06
Max	0.00E+00	5.91E-02	5.91E-02	5.86E-02	5.75E-02	5.41E-02	4.54E-02	2.47E-02	4.44E-03	4.50E-05
Avg	0.00E+00	1.84E-02	1.84E-02	1.82E-02	1.79E-02	1.69E-02	1.42E-02	7.69E-03	1.39E-03	1.49E-05
Std	0.00E+00	9.66E-03	9.66E-03	9.58E-03	9.41E-03	8.85E-03	7.43E-03	4.03E-03	7.23E-04	6.87E-06

Probabilistic Total Dose Summary(cont.)

Nuclide (j)	Peak Time	Peak Dose	DOSE(j,t), mrem/yr t= 0.00E+00	1.00E+00	3.00E+00	1.00E+01	3.00E+01	1.00E+02	3.00E+02	1.00E+03
U-238										
Min	0.00E+00	5.46E-02	5.46E-02	5.41E-02	5.32E-02	5.00E-02	4.19E-02	2.26E-02	3.89E-03	8.44E-06
Max	0.00E+00	2.62E-01	2.62E-01	2.60E-01	2.55E-01	2.40E-01	2.01E-01	1.09E-01	1.87E-02	4.05E-05
Avg	0.00E+00	8.27E-02	8.27E-02	8.19E-02	8.05E-02	7.57E-02	6.35E-02	3.43E-02	5.89E-03	1.28E-05
Std	0.00E+00	4.22E-02	4.22E-02	4.19E-02	4.11E-02	3.87E-02	3.24E-02	1.75E-02	3.01E-03	6.53E-06
∑ALL										
Min	0.00E+00	5.91E+00	5.91E+00	5.90E+00	5.86E+00	5.77E+00	5.67E+00	5.48E+00	5.05E+00	3.99E+00
Max	0.00E+00	2.84E+01	2.84E+01	2.83E+01	2.82E+01	2.77E+01	2.72E+01	2.63E+01	2.43E+01	1.92E+01
Avg	0.00E+00	8.86E+00	8.86E+00	8.84E+00	8.79E+00	8.66E+00	8.50E+00	8.22E+00	7.58E+00	5.98E+00
Std	0.00E+00	4.64E+00	4.64E+00	4.63E+00	4.60E+00	4.53E+00	4.45E+00	4.31E+00	3.97E+00	3.14E+00

∑ALL is total dose summed for all nuclides.

Probabilistic results summary : Scabble Ratios, 0.3 cm on pavement, industrial,
rad + eat + breathe, 100 sq m File: 466uth100.RAD
Cumulative Probability Summary for: Total Dose Over Pathways

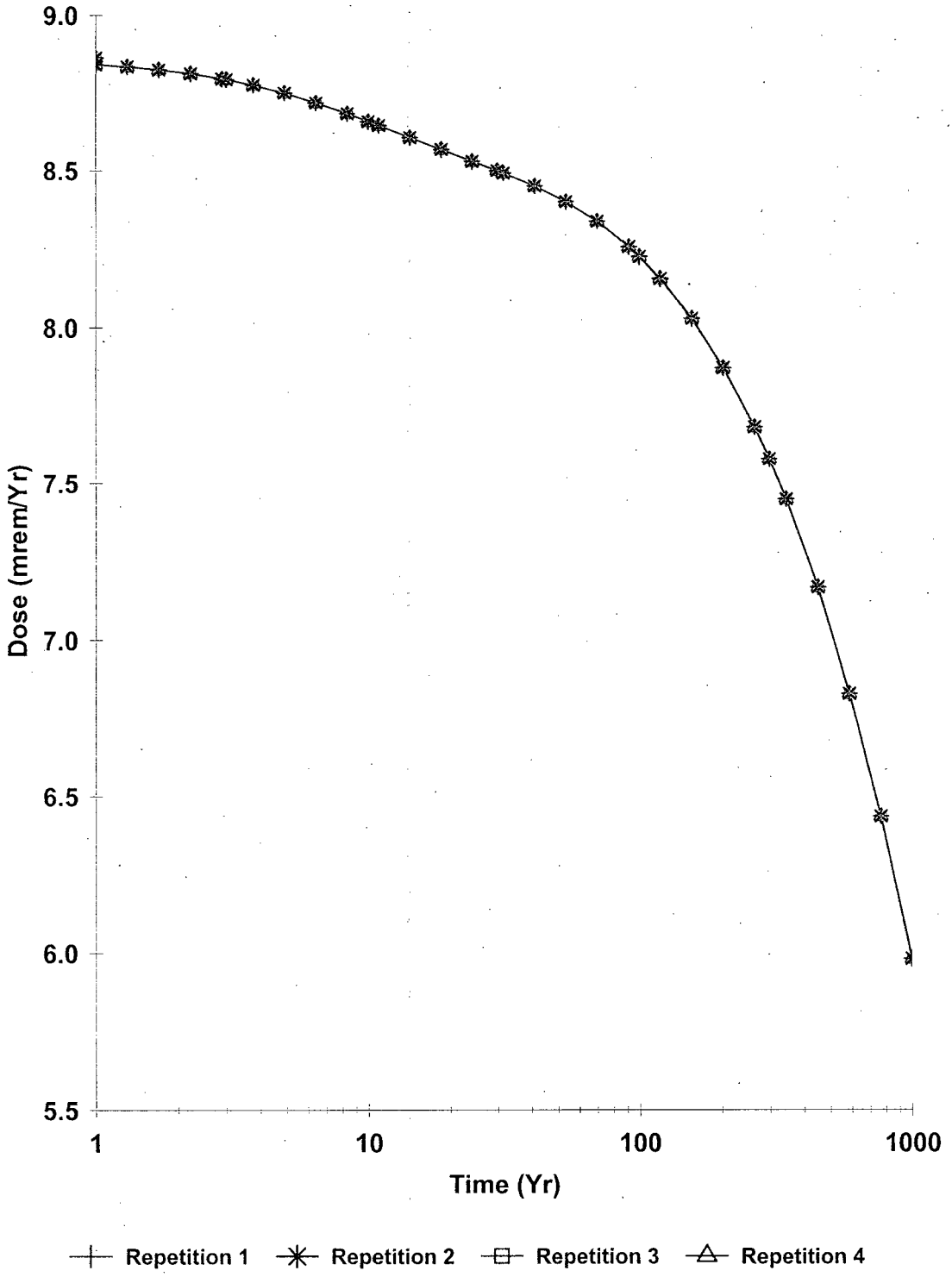
Cumulative	Dose(t), mrem/yr							
Probability	t= 0.00E+00	1.00E+00	3.00E+00	1.00E+01	3.00E+01	1.00E+02	3.00E+02	1.00E+03
0.025	6.23E+00	6.22E+00	6.18E+00	6.09E+00	5.97E+00	5.78E+00	5.33E+00	4.20E+00
0.050	6.24E+00	6.22E+00	6.19E+00	6.09E+00	5.98E+00	5.78E+00	5.33E+00	4.21E+00
0.075	6.24E+00	6.23E+00	6.19E+00	6.10E+00	5.99E+00	5.79E+00	5.33E+00	4.21E+00
0.100	6.52E+00	6.51E+00	6.47E+00	6.37E+00	6.26E+00	6.05E+00	5.58E+00	4.40E+00
0.125	6.53E+00	6.51E+00	6.48E+00	6.38E+00	6.26E+00	6.05E+00	5.58E+00	4.40E+00
0.150	6.53E+00	6.51E+00	6.48E+00	6.38E+00	6.26E+00	6.06E+00	5.58E+00	4.40E+00
0.175	6.53E+00	6.52E+00	6.48E+00	6.38E+00	6.27E+00	6.06E+00	5.58E+00	4.41E+00
0.200	6.54E+00	6.53E+00	6.49E+00	6.39E+00	6.27E+00	6.07E+00	5.59E+00	4.41E+00
0.225	6.97E+00	6.96E+00	6.92E+00	6.81E+00	6.69E+00	6.47E+00	5.96E+00	4.70E+00
0.250	6.98E+00	6.96E+00	6.92E+00	6.82E+00	6.69E+00	6.47E+00	5.96E+00	4.71E+00
0.275	6.98E+00	6.96E+00	6.93E+00	6.82E+00	6.69E+00	6.48E+00	5.97E+00	4.71E+00
0.300	6.98E+00	6.97E+00	6.93E+00	6.82E+00	6.70E+00	6.48E+00	5.97E+00	4.71E+00
0.325	6.99E+00	6.97E+00	6.93E+00	6.82E+00	6.70E+00	6.48E+00	5.97E+00	4.71E+00
0.350	6.99E+00	6.97E+00	6.93E+00	6.82E+00	6.70E+00	6.48E+00	5.97E+00	4.71E+00
0.375	6.99E+00	6.98E+00	6.94E+00	6.83E+00	6.71E+00	6.49E+00	5.98E+00	4.72E+00
0.400	7.72E+00	7.70E+00	7.66E+00	7.54E+00	7.40E+00	7.16E+00	6.60E+00	5.21E+00
0.425	7.72E+00	7.70E+00	7.66E+00	7.54E+00	7.40E+00	7.16E+00	6.60E+00	5.21E+00
0.450	7.72E+00	7.71E+00	7.66E+00	7.54E+00	7.41E+00	7.17E+00	6.60E+00	5.21E+00
0.475	7.73E+00	7.71E+00	7.67E+00	7.55E+00	7.41E+00	7.17E+00	6.60E+00	5.21E+00
0.500	7.73E+00	7.71E+00	7.67E+00	7.55E+00	7.41E+00	7.17E+00	6.61E+00	5.21E+00
0.525	7.73E+00	7.71E+00	7.67E+00	7.55E+00	7.41E+00	7.17E+00	6.61E+00	5.21E+00
0.550	7.73E+00	7.71E+00	7.67E+00	7.55E+00	7.41E+00	7.17E+00	6.61E+00	5.21E+00
0.575	7.73E+00	7.71E+00	7.67E+00	7.55E+00	7.41E+00	7.17E+00	6.61E+00	5.22E+00
0.600	7.74E+00	7.72E+00	7.68E+00	7.56E+00	7.42E+00	7.18E+00	6.61E+00	5.22E+00
0.625	7.75E+00	7.73E+00	7.69E+00	7.57E+00	7.43E+00	7.19E+00	6.62E+00	5.23E+00
0.650	8.90E+00	8.88E+00	8.83E+00	8.69E+00	8.53E+00	8.26E+00	7.61E+00	6.00E+00
0.675	8.90E+00	8.88E+00	8.83E+00	8.69E+00	8.54E+00	8.26E+00	7.61E+00	6.01E+00
0.700	8.90E+00	8.88E+00	8.83E+00	8.70E+00	8.54E+00	8.26E+00	7.61E+00	6.01E+00
0.725	8.90E+00	8.88E+00	8.83E+00	8.70E+00	8.54E+00	8.26E+00	7.61E+00	6.01E+00
0.750	8.91E+00	8.88E+00	8.84E+00	8.70E+00	8.54E+00	8.26E+00	7.61E+00	6.01E+00
0.775	8.91E+00	8.89E+00	8.84E+00	8.70E+00	8.54E+00	8.26E+00	7.61E+00	6.01E+00
0.800	8.91E+00	8.89E+00	8.84E+00	8.70E+00	8.54E+00	8.26E+00	7.62E+00	6.01E+00
0.825	8.91E+00	8.89E+00	8.84E+00	8.70E+00	8.54E+00	8.27E+00	7.62E+00	6.01E+00
0.850	8.91E+00	8.89E+00	8.84E+00	8.71E+00	8.55E+00	8.27E+00	7.62E+00	6.01E+00
0.875	8.92E+00	8.90E+00	8.85E+00	8.72E+00	8.56E+00	8.28E+00	7.63E+00	6.02E+00
0.900	1.09E+01	1.09E+01	1.09E+01	1.07E+01	1.05E+01	1.01E+01	9.35E+00	7.38E+00
0.925	1.09E+01	1.09E+01	1.09E+01	1.07E+01	1.05E+01	1.02E+01	9.36E+00	7.38E+00
0.950	2.83E+01	2.83E+01	2.81E+01	2.77E+01	2.72E+01	2.63E+01	2.42E+01	1.91E+01
0.975	2.84E+01	2.83E+01	2.81E+01	2.77E+01	2.72E+01	2.63E+01	2.43E+01	1.91E+01
1.000	2.84E+01	2.83E+01	2.82E+01	2.77E+01	2.72E+01	2.63E+01	2.43E+01	1.92E+01

Probabilistic results summary : Scabble Ratios, 0.3 cm on pavement, industrial, rad + eat + breathe, 100 sq m File: 466uth100.RAD

Peak of the mean dose (averaged over observations) at graphical times

Repetition	Time of peak mean dose	Peak mean dose
	Years	mrem/yr
1	0.000E+00	8.865E+00
2	0.000E+00	8.865E+00
3	0.000E+00	8.865E+00
4	0.000E+00	8.865E+00

Case 466uth100. Probabilistic Annual Dose from Source on Pavement



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)	3.000E+01	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	3.000E-03	2.000E+00	---	THICK0
R011	Length parallel to aquifer flow (m)	not used	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	2.500E+01	3.000E+01	---	BRDL
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	3.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	3.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	3.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(9)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): Ac-227	1.025E+01	0.000E+00	---	S1(1)
R012	Initial principal radionuclide (pCi/g): Pa-231	1.025E+01	0.000E+00	---	S1(2)
R012	Initial principal radionuclide (pCi/g): Pb-210	3.153E+02	0.000E+00	---	S1(3)
R012	Initial principal radionuclide (pCi/g): Ra-226	3.153E+02	0.000E+00	---	S1(4)
R012	Initial principal radionuclide (pCi/g): Ra-228	7.508E+01	0.000E+00	---	S1(5)
R012	Initial principal radionuclide (pCi/g): Th-228	7.508E+01	0.000E+00	---	S1(6)
R012	Initial principal radionuclide (pCi/g): Th-230	1.757E+02	0.000E+00	---	S1(7)
R012	Initial principal radionuclide (pCi/g): Th-232	7.508E+01	0.000E+00	---	S1(8)
R012	Initial principal radionuclide (pCi/g): U-234	2.252E+02	0.000E+00	---	S1(9)
R012	Initial principal radionuclide (pCi/g): U-235	1.025E+01	0.000E+00	---	S1(10)
R012	Initial principal radionuclide (pCi/g): U-238	2.252E+02	0.000E+00	---	S1(11)
R012	Concentration in groundwater (pCi/L): Ac-227	not used	0.000E+00	---	W1(1)
R012	Concentration in groundwater (pCi/L): Pa-231	not used	0.000E+00	---	W1(2)
R012	Concentration in groundwater (pCi/L): Pb-210	not used	0.000E+00	---	W1(3)
R012	Concentration in groundwater (pCi/L): Ra-226	not used	0.000E+00	---	W1(4)
R012	Concentration in groundwater (pCi/L): Ra-228	not used	0.000E+00	---	W1(5)
R012	Concentration in groundwater (pCi/L): Th-228	not used	0.000E+00	---	W1(6)
R012	Concentration in groundwater (pCi/L): Th-230	not used	0.000E+00	---	W1(7)
R012	Concentration in groundwater (pCi/L): Th-232	not used	0.000E+00	---	W1(8)
R012	Concentration in groundwater (pCi/L): U-234	not used	0.000E+00	---	W1(9)
R012	Concentration in groundwater (pCi/L): U-235	not used	0.000E+00	---	W1(10)
R012	Concentration in groundwater (pCi/L): U-238	not used	0.000E+00	---	W1(11)
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)	1.500E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	0.000E+00	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	4.000E-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)	4.000E+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

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for U-238				
R016	Contaminated zone (cm**3/g)	1.260E+02	5.000E+01	---	DCNUCC(11)
R016	Unsaturated zone 1 (cm**3/g)	not used	5.000E+01	---	DCNUCU(11,1)
R016	Saturated zone (cm**3/g)	not used	5.000E+01	---	DCNUCS(11)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	8.803E-03	ALEACH(11)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(11)
R017	Inhalation rate (m**3/yr)	1.227E+04	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	3.500E-05	1.000E-04	---	MLINH
R017	Exposure duration	3.000E+01	3.000E+01	---	ED
R017	Shielding factor, inhalation	6.000E-01	4.000E-01	---	SHF3
R017	Shielding factor, external gamma	1.700E-01	7.000E-01	---	SHF1
R017	Fraction of time spent indoors	1.825E-01	5.000E-01	---	FIND
R017	Fraction of time spent outdoors (on site)	4.563E-02	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)	not used	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	not used	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	not used	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	not used	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	not used	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	not used	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	3.650E+01	3.650E+01	---	SOIL

Contaminated Zone Dimensions	
Area:	30.00 square meters
Thickness:	0.00 meters
Cover Depth:	0.00 meters

Initial Soil Concentrations, pCi/g	
Ac-227	1.025E+01
Pa-231	1.025E+01
Pb-210	3.153E+02
Ra-226	3.153E+02
Ra-228	7.508E+01
Th-228	7.508E+01
Th-230	1.757E+02
Th-232	7.508E+01
U-234	2.252E+02
U-235	1.025E+01
U-238	2.252E+02

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

t (years):	0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
TDOSE(t):	6.358E+00	6.342E+00	6.308E+00	6.209E+00	6.096E+00	5.898E+00	5.436E+00	4.291E+00
M(t):	2.543E-01	2.537E-01	2.523E-01	2.484E-01	2.438E-01	2.359E-01	2.174E-01	1.716E-01

Maximum TDOSE(t): 6.358E+00 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	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	frac
Ac-227	3.265E-02	0.0051	4.434E-03	0.0007	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.453E-04	0.0C
Pa-231	4.063E-03	0.0006	9.278E-04	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.539E-04	0.0C
Pb-210	1.027E-02	0.0016	4.709E-04	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.128E-02	0.0C
Ra-226	4.654E+00	0.7321	1.845E-04	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.256E-03	0.0C
Ra-228	7.248E-01	0.1140	2.842E-04	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.524E-04	0.0C
Th-228	7.761E-01	0.1221	1.423E-03	0.0002	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.544E-04	0.0C
Th-230	1.469E-03	0.0002	3.746E-03	0.0006	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.813E-04	0.0C
Th-232	4.214E-02	0.0066	8.066E-03	0.0013	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.057E-03	0.0C
U-234	1.078E-03	0.0002	1.936E-03	0.0003	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.170E-04	0.0C
U-235	1.291E-02	0.0020	8.211E-05	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.364E-05	0.0C
U-238	5.693E-02	0.0090	1.731E-03	0.0003	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.010E-04	0.0C
Total	6.317E+00	0.9935	2.328E-02	0.0037	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.782E-02	0.0C

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	frac
Ac-227	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.783E-02	0.0C
Pa-231	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.545E-03	0.0C
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	2.202E-02	0.0C
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.657E+00	0.73
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	7.256E-01	0.11
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	7.778E-01	0.12
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.696E-03	0.0C
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	5.126E-02	0.0C
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.331E-03	0.0C
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.301E-02	0.0C
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	5.896E-02	0.0C
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.358E+00	1.0C

*Sum of all water independent and dependent pathways.

Probabilistic Input

Number of Sample Runs: 1600

Number	Name	Distribution	Parameters							
1	MLINH	CONTINUOUS LINEAR	8	0	0	.000015	.0151	.000023	.1365	.00
2	SHF1	DISCRETE CUMULATIVE	8	.0084	.01	.022	.09	.035	.21	.05

Probabilistic Total Dose Summary

Nuclide (j)	Peak Time	Peak Dose	DOSE(j,t), mrem/yr t= 0.00E+00	1.00E+00	3.00E+00	1.00E+01	3.00E+01	1.00E+02	3.00E+02	1.00E+03
Ac-227										
Min	0.00E+00	2.18E-02	2.18E-02	2.11E-02	1.97E-02	1.56E-02	8.04E-03	7.88E-04	1.03E-06	8.46E-17
Max	0.00E+00	1.06E-01	1.06E-01	1.03E-01	9.60E-02	7.61E-02	3.92E-02	3.84E-03	5.04E-06	4.12E-16
Avg	0.00E+00	3.49E-02	3.49E-02	3.38E-02	3.16E-02	2.51E-02	1.29E-02	1.26E-03	1.66E-06	1.36E-16
Std	0.00E+00	1.60E-02	1.60E-02	1.55E-02	1.45E-02	1.15E-02	5.91E-03	5.79E-04	7.60E-07	6.21E-17
Pa-231										
Min	7.52E+01	1.91E-02	3.25E-03	3.92E-03	5.19E-03	8.96E-03	1.55E-02	1.87E-02	1.08E-02	1.38E-03
Max	7.62E+01	9.18E-02	1.44E-02	1.76E-02	2.38E-02	4.22E-02	7.41E-02	8.99E-02	5.21E-02	6.64E-03
Avg	7.57E+01	3.05E-02	5.14E-03	6.22E-03	8.26E-03	1.43E-02	2.48E-02	2.99E-02	1.73E-02	2.21E-03
Std	1.56E-01	1.37E-02	2.00E-03	2.49E-03	3.43E-03	6.20E-03	1.10E-02	1.34E-02	7.78E-03	9.92E-04
Pb-210										
Min	0.00E+00	1.77E-02	1.77E-02	1.72E-02	1.61E-02	1.29E-02	6.87E-03	7.55E-04	1.37E-06	3.53E-16
Max	0.00E+00	4.27E-02	4.27E-02	4.14E-02	3.89E-02	3.12E-02	1.66E-02	1.82E-03	3.31E-06	8.51E-16
Avg	0.00E+00	2.12E-02	2.12E-02	2.05E-02	1.93E-02	1.55E-02	8.23E-03	9.04E-04	1.64E-06	4.22E-16
Std	0.00E+00	5.02E-03	5.02E-03	4.86E-03	4.56E-03	3.66E-03	1.95E-03	2.14E-04	3.89E-07	9.99E-17
Ra-226										
Min	0.00E+00	2.87E+00	2.87E+00	2.86E+00	2.86E+00	2.85E+00	2.81E+00	2.68E+00	2.30E+00	1.37E+00
Max	0.00E+00	1.39E+01	1.39E+01	1.38E+01	1.38E+01	1.38E+01	1.36E+01	1.29E+01	1.11E+01	6.58E+00
Avg	0.00E+00	4.30E+00	4.30E+00	4.30E+00	4.30E+00	4.28E+00	4.22E+00	4.01E+00	3.46E+00	2.05E+00
Std	0.00E+00	2.27E+00	2.27E+00	2.27E+00	2.27E+00	2.26E+00	2.23E+00	2.11E+00	1.82E+00	1.08E+00
Ra-228										
Min	2.29E+00	5.53E-01	4.47E-01	5.25E-01	5.47E-01	2.90E-01	2.03E-02	1.45E-06	2.07E-18	0.00E+00
Max	2.30E+00	2.68E+00	2.16E+00	2.54E+00	2.65E+00	1.40E+00	9.80E-02	7.01E-06	1.00E-17	0.00E+00
Avg	2.30E+00	8.31E-01	6.71E-01	7.89E-01	8.22E-01	4.35E-01	3.05E-02	2.18E-06	3.11E-18	0.00E+00
Std	1.21E-03	4.39E-01	3.54E-01	4.16E-01	4.34E-01	2.30E-01	1.61E-02	1.15E-06	1.64E-18	0.00E+00
Th-228										
Min	0.00E+00	4.78E-01	4.78E-01	3.33E-01	1.61E-01	1.28E-02	9.09E-06	8.78E-17	0.00E+00	0.00E+00
Max	0.00E+00	2.31E+00	2.31E+00	1.61E+00	7.80E-01	6.17E-02	4.40E-05	4.25E-16	0.00E+00	0.00E+00
Avg	0.00E+00	7.19E-01	7.19E-01	5.00E-01	2.42E-01	1.92E-02	1.37E-05	1.32E-16	0.00E+00	0.00E+00
Std	0.00E+00	3.79E-01	3.79E-01	2.64E-01	1.28E-01	1.01E-02	7.21E-06	6.96E-17	0.00E+00	0.00E+00
Th-230										
Min	1.00E+03	4.41E-01	1.84E-03	2.75E-03	4.25E-03	9.06E-03	2.27E-02	6.84E-02	1.83E-01	4.41E-01
Max	1.00E+03	2.13E+00	1.20E-02	1.51E-02	2.18E-02	4.50E-02	1.11E-01	3.31E-01	8.85E-01	2.13E+00
Avg	1.00E+03	6.63E-01	5.21E-03	6.25E-03	8.32E-03	1.55E-02	3.60E-02	1.05E-01	2.77E-01	6.63E-01
Std	0.00E+00	3.48E-01	1.30E-03	1.66E-03	2.59E-03	6.26E-03	1.70E-02	5.31E-02	1.44E-01	3.48E-01
Th-232										
Min	6.67E+01	8.45E-01	2.87E-02	8.79E-02	2.20E-01	5.79E-01	8.28E-01	8.45E-01	8.41E-01	8.31E-01
Max	6.73E+01	4.09E+00	1.41E-01	4.27E-01	1.06E+00	2.80E+00	4.00E+00	4.09E+00	4.07E+00	4.02E+00
Avg	6.70E+01	1.27E+00	4.73E-02	1.36E-01	3.34E-01	8.73E-01	1.25E+00	1.27E+00	1.27E+00	1.25E+00
Std	1.12E-01	6.68E-01	2.07E-02	6.75E-02	1.72E-01	4.57E-01	6.54E-01	6.68E-01	6.65E-01	6.57E-01
U-234										
Min	0.00E+00	1.28E-03	1.28E-03	1.27E-03	1.24E-03	1.17E-03	9.86E-04	5.70E-04	2.60E-04	5.37E-04
Max	0.00E+00	7.10E-03	7.10E-03	7.04E-03	6.91E-03	6.50E-03	5.47E-03	3.09E-03	1.28E-03	2.59E-03
Avg	0.00E+00	3.05E-03	3.05E-03	3.03E-03	2.98E-03	2.80E-03	2.35E-03	1.31E-03	4.62E-04	8.07E-04
Std	0.00E+00	7.65E-04	7.65E-04	7.59E-04	7.46E-04	7.01E-04	5.90E-04	3.35E-04	1.69E-04	4.23E-04
U-235										
Min	0.00E+00	7.98E-03	7.98E-03	7.91E-03	7.77E-03	7.30E-03	6.13E-03	3.33E-03	5.99E-04	6.16E-06
Max	0.00E+00	3.86E-02	3.86E-02	3.83E-02	3.76E-02	3.53E-02	2.97E-02	1.61E-02	2.90E-03	2.97E-05
Avg	0.00E+00	1.20E-02	1.20E-02	1.19E-02	1.17E-02	1.10E-02	9.24E-03	5.02E-03	9.06E-04	9.75E-06
Std	0.00E+00	6.31E-03	6.31E-03	6.25E-03	6.14E-03	5.78E-03	4.85E-03	2.63E-03	4.72E-04	4.51E-06

Probabilistic Total Dose Summary(cont.)

Nuclide (j)	Peak Time	Peak Dose	DOSE(j,t), mrem/yr t= 0.00E+00	1.00E+00	3.00E+00	1.00E+01	3.00E+01	1.00E+02	3.00E+02	1.00E+03
U-238										
Min	0.00E+00	3.57E-02	3.57E-02	3.54E-02	3.48E-02	3.27E-02	2.74E-02	1.48E-02	2.54E-03	5.52E-06
Max	0.00E+00	1.73E-01	1.73E-01	1.71E-01	1.68E-01	1.58E-01	1.33E-01	7.17E-02	1.23E-02	2.67E-05
Avg	0.00E+00	5.45E-02	5.45E-02	5.40E-02	5.31E-02	4.99E-02	4.18E-02	2.26E-02	3.88E-03	8.42E-06
Std	0.00E+00	2.78E-02	2.78E-02	2.76E-02	2.71E-02	2.55E-02	2.14E-02	1.15E-02	1.98E-03	4.30E-06
∑ALL										
Min	0.00E+00	3.91E+00	3.91E+00	3.90E+00	3.88E+00	3.82E+00	3.75E+00	3.63E+00	3.34E+00	2.64E+00
Max	0.00E+00	1.89E+01	1.89E+01	1.88E+01	1.87E+01	1.84E+01	1.81E+01	1.75E+01	1.61E+01	1.27E+01
Avg	0.00E+00	5.88E+00	5.88E+00	5.86E+00	5.83E+00	5.74E+00	5.63E+00	5.45E+00	5.02E+00	3.97E+00
Std	0.00E+00	3.09E+00	3.09E+00	3.08E+00	3.06E+00	3.01E+00	2.96E+00	2.86E+00	2.64E+00	2.08E+00

∑ALL is total dose summed for all nuclides.

Probabilistic results summary : Scabble Ratios, 0.3 cm on pavement, industrial,
rad + eat + breathe, 30 sq m File: 465uth30.RAD
Cumulative Probability Summary for: Total Dose Over Pathways

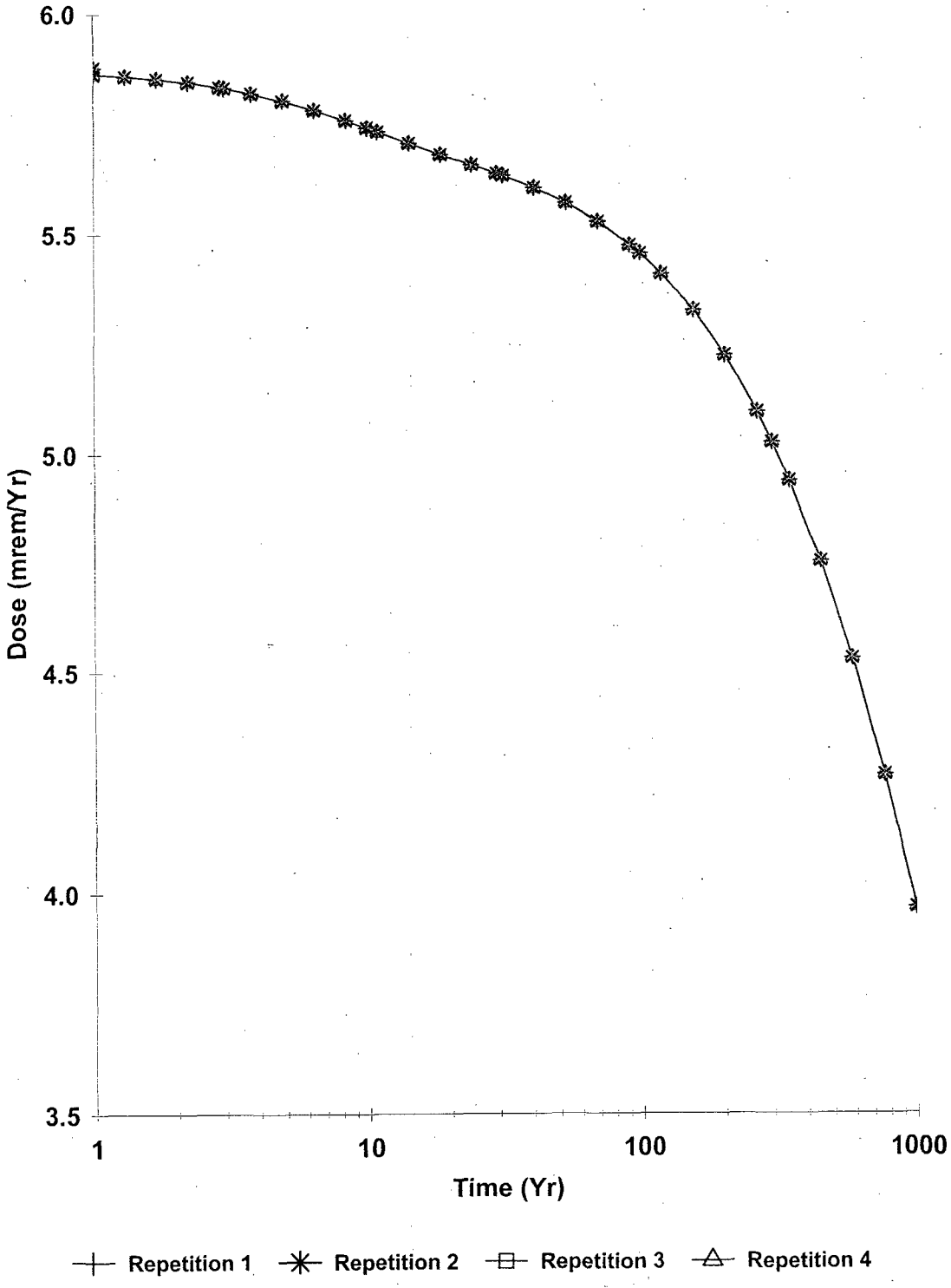
Cumulative Probability	Dose(t), mrem/yr t= 0.00E+00	1.00E+00	3.00E+00	1.00E+01	3.00E+01	1.00E+02	3.00E+02	1.00E+03
0.025	4.12E+00	4.11E+00	4.09E+00	4.03E+00	3.95E+00	3.83E+00	3.53E+00	2.78E+00
0.050	4.13E+00	4.12E+00	4.10E+00	4.03E+00	3.96E+00	3.83E+00	3.53E+00	2.79E+00
0.075	4.13E+00	4.12E+00	4.10E+00	4.04E+00	3.96E+00	3.83E+00	3.53E+00	2.79E+00
0.100	4.32E+00	4.31E+00	4.29E+00	4.22E+00	4.14E+00	4.01E+00	3.69E+00	2.91E+00
0.125	4.32E+00	4.31E+00	4.29E+00	4.22E+00	4.14E+00	4.01E+00	3.69E+00	2.92E+00
0.150	4.32E+00	4.31E+00	4.29E+00	4.22E+00	4.15E+00	4.01E+00	3.70E+00	2.92E+00
0.175	4.33E+00	4.32E+00	4.29E+00	4.23E+00	4.15E+00	4.01E+00	3.70E+00	2.92E+00
0.200	4.33E+00	4.32E+00	4.30E+00	4.23E+00	4.16E+00	4.02E+00	3.70E+00	2.92E+00
0.225	4.62E+00	4.61E+00	4.58E+00	4.51E+00	4.43E+00	4.28E+00	3.95E+00	3.12E+00
0.250	4.62E+00	4.61E+00	4.58E+00	4.51E+00	4.43E+00	4.29E+00	3.95E+00	3.12E+00
0.275	4.62E+00	4.61E+00	4.59E+00	4.52E+00	4.43E+00	4.29E+00	3.95E+00	3.12E+00
0.300	4.63E+00	4.61E+00	4.59E+00	4.52E+00	4.43E+00	4.29E+00	3.95E+00	3.12E+00
0.325	4.63E+00	4.62E+00	4.59E+00	4.52E+00	4.44E+00	4.29E+00	3.96E+00	3.12E+00
0.350	4.63E+00	4.62E+00	4.59E+00	4.52E+00	4.44E+00	4.29E+00	3.96E+00	3.12E+00
0.375	4.64E+00	4.62E+00	4.60E+00	4.53E+00	4.44E+00	4.30E+00	3.96E+00	3.13E+00
0.400	5.11E+00	5.10E+00	5.07E+00	4.99E+00	4.90E+00	4.74E+00	4.37E+00	3.45E+00
0.425	5.12E+00	5.10E+00	5.08E+00	5.00E+00	4.91E+00	4.75E+00	4.37E+00	3.45E+00
0.450	5.12E+00	5.11E+00	5.08E+00	5.00E+00	4.91E+00	4.75E+00	4.38E+00	3.45E+00
0.475	5.12E+00	5.11E+00	5.08E+00	5.00E+00	4.91E+00	4.75E+00	4.38E+00	3.45E+00
0.500	5.12E+00	5.11E+00	5.08E+00	5.00E+00	4.91E+00	4.75E+00	4.38E+00	3.46E+00
0.525	5.12E+00	5.11E+00	5.08E+00	5.00E+00	4.91E+00	4.75E+00	4.38E+00	3.46E+00
0.550	5.12E+00	5.11E+00	5.08E+00	5.00E+00	4.91E+00	4.75E+00	4.38E+00	3.46E+00
0.575	5.12E+00	5.11E+00	5.08E+00	5.01E+00	4.91E+00	4.75E+00	4.38E+00	3.46E+00
0.600	5.13E+00	5.12E+00	5.09E+00	5.01E+00	4.92E+00	4.76E+00	4.38E+00	3.46E+00
0.625	5.14E+00	5.13E+00	5.10E+00	5.02E+00	4.93E+00	4.77E+00	4.39E+00	3.47E+00
0.650	5.90E+00	5.88E+00	5.85E+00	5.76E+00	5.65E+00	5.47E+00	5.04E+00	3.98E+00
0.675	5.90E+00	5.89E+00	5.85E+00	5.76E+00	5.66E+00	5.47E+00	5.04E+00	3.98E+00
0.700	5.90E+00	5.89E+00	5.85E+00	5.76E+00	5.66E+00	5.47E+00	5.05E+00	3.98E+00
0.725	5.90E+00	5.89E+00	5.86E+00	5.76E+00	5.66E+00	5.48E+00	5.05E+00	3.98E+00
0.750	5.90E+00	5.89E+00	5.86E+00	5.77E+00	5.66E+00	5.48E+00	5.05E+00	3.98E+00
0.775	5.90E+00	5.89E+00	5.86E+00	5.77E+00	5.66E+00	5.48E+00	5.05E+00	3.99E+00
0.800	5.91E+00	5.89E+00	5.86E+00	5.77E+00	5.66E+00	5.48E+00	5.05E+00	3.99E+00
0.825	5.91E+00	5.89E+00	5.86E+00	5.77E+00	5.66E+00	5.48E+00	5.05E+00	3.99E+00
0.850	5.91E+00	5.90E+00	5.87E+00	5.77E+00	5.67E+00	5.48E+00	5.05E+00	3.99E+00
0.875	5.92E+00	5.91E+00	5.87E+00	5.78E+00	5.68E+00	5.49E+00	5.06E+00	3.99E+00
0.900	7.25E+00	7.24E+00	7.20E+00	7.08E+00	6.96E+00	6.73E+00	6.20E+00	4.90E+00
0.925	7.26E+00	7.24E+00	7.20E+00	7.09E+00	6.96E+00	6.73E+00	6.21E+00	4.90E+00
0.950	1.88E+01	1.88E+01	1.87E+01	1.84E+01	1.81E+01	1.75E+01	1.61E+01	1.27E+01
0.975	1.88E+01	1.88E+01	1.87E+01	1.84E+01	1.81E+01	1.75E+01	1.61E+01	1.27E+01
1.000	1.89E+01	1.88E+01	1.87E+01	1.84E+01	1.81E+01	1.75E+01	1.61E+01	1.27E+01

Probabilistic results summary : Scabble Ratios, 0.3 cm on pavement, industrial, rad + eat + breathe, 30 sq m File: 465uth30.RAD

Peak of the mean dose (averaged over observations) at graphical times

Repetition	Time of peak mean dose	Peak mean dose
	Years	mrem/yr
1	0.000E+00	5.877E+00
2	0.000E+00	5.877E+00
3	0.000E+00	5.877E+00
4	0.000E+00	5.877E+00

Case 465uth30. Probabilistic Mean Annual Dose from Source on Pavement



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)	2.000E+01	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	3.000E-03	2.000E+00	---	THICK0
R011	Length parallel to aquifer flow (m)	not used	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	2.500E+01	3.000E+01	---	BRDL
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	3.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	3.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	3.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(9)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): Ac-227	1.025E+01	0.000E+00	---	S1(1)
R012	Initial principal radionuclide (pCi/g): Pa-231	1.025E+01	0.000E+00	---	S1(2)
R012	Initial principal radionuclide (pCi/g): Pb-210	3.153E+02	0.000E+00	---	S1(3)
R012	Initial principal radionuclide (pCi/g): Ra-226	3.153E+02	0.000E+00	---	S1(4)
R012	Initial principal radionuclide (pCi/g): Ra-228	7.508E+01	0.000E+00	---	S1(5)
R012	Initial principal radionuclide (pCi/g): Th-228	7.508E+01	0.000E+00	---	S1(6)
R012	Initial principal radionuclide (pCi/g): Th-230	1.757E+02	0.000E+00	---	S1(7)
R012	Initial principal radionuclide (pCi/g): Th-232	7.508E+01	0.000E+00	---	S1(8)
R012	Initial principal radionuclide (pCi/g): U-234	2.252E+02	0.000E+00	---	S1(9)
R012	Initial principal radionuclide (pCi/g): U-235	1.025E+01	0.000E+00	---	S1(10)
R012	Initial principal radionuclide (pCi/g): U-238	2.252E+02	0.000E+00	---	S1(11)
R012	Concentration in groundwater (pCi/L): Ac-227	not used	0.000E+00	---	W1(1)
R012	Concentration in groundwater (pCi/L): Pa-231	not used	0.000E+00	---	W1(2)
R012	Concentration in groundwater (pCi/L): Pb-210	not used	0.000E+00	---	W1(3)
R012	Concentration in groundwater (pCi/L): Ra-226	not used	0.000E+00	---	W1(4)
R012	Concentration in groundwater (pCi/L): Ra-228	not used	0.000E+00	---	W1(5)
R012	Concentration in groundwater (pCi/L): Th-228	not used	0.000E+00	---	W1(6)
R012	Concentration in groundwater (pCi/L): Th-230	not used	0.000E+00	---	W1(7)
R012	Concentration in groundwater (pCi/L): Th-232	not used	0.000E+00	---	W1(8)
R012	Concentration in groundwater (pCi/L): U-234	not used	0.000E+00	---	W1(9)
R012	Concentration in groundwater (pCi/L): U-235	not used	0.000E+00	---	W1(10)
R012	Concentration in groundwater (pCi/L): U-238	not used	0.000E+00	---	W1(11)
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)	1.500E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	0.000E+00	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	4.000E-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)	4.000E+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

Contaminated Zone Dimensions	
Area:	20.00 square meters
Thickness:	0.00 meters
Cover Depth:	0.00 meters

Initial Soil Concentrations, pCi/g	
Ac-227	1.025E+01
Pa-231	1.025E+01
Pb-210	3.153E+02
Ra-226	3.153E+02
Ra-228	7.508E+01
Th-228	7.508E+01
Th-230	1.757E+02
Th-232	7.508E+01
U-234	2.252E+02
U-235	1.025E+01
U-238	2.252E+02

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

t (years):	0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
TDOSE(t):	5.474E+00	5.460E+00	5.431E+00	5.346E+00	5.249E+00	5.078E+00	4.680E+00	3.695E+00
M(t):	2.190E-01	2.184E-01	2.172E-01	2.138E-01	2.099E-01	2.031E-01	1.872E-01	1.478E-01

Maximum TDOSE(t): 5.474E+00 mrem/yr at t = 0.000E+00 years

Probabilistic Input

Number of Sample Runs: 1600

Number	Name	Distribution	Parameters							
1	MLINH	CONTINUOUS LINEAR	8	0	0	.000015	.0151	.000023	.1365	.0C
2	SHF1	DISCRETE CUMULATIVE	8	.0084	.01	.022	.09	.035	.21	.05

Probabilistic Total Dose Summary

Nuclide (j)	Peak Time	Peak Dose	DOSE(j,t), mrem/yr t= 0.00E+00	1.00E+00	3.00E+00	1.00E+01	3.00E+01	1.00E+02	3.00E+02	1.00E+03
Ac-227										
Min	0.00E+00	1.86E-02	1.86E-02	1.80E-02	1.69E-02	1.34E-02	6.88E-03	6.74E-04	8.85E-07	7.23E-17
Max	0.00E+00	9.17E-02	9.17E-02	8.87E-02	8.30E-02	6.58E-02	3.39E-02	3.32E-03	4.36E-06	3.56E-16
Avg	0.00E+00	3.02E-02	3.02E-02	2.92E-02	2.73E-02	2.17E-02	1.12E-02	1.09E-03	1.43E-06	1.17E-16
Std	0.00E+00	1.37E-02	1.37E-02	1.33E-02	1.24E-02	9.85E-03	5.07E-03	4.97E-04	6.52E-07	5.33E-17
Pa-231										
Min	7.52E+01	1.63E-02	2.72E-03	3.29E-03	4.38E-03	7.61E-03	1.32E-02	1.59E-02	9.23E-03	1.18E-03
Max	7.62E+01	7.94E-02	1.25E-02	1.53E-02	2.07E-02	3.66E-02	6.41E-02	7.77E-02	4.51E-02	5.74E-03
Avg	7.57E+01	2.64E-02	4.42E-03	5.35E-03	7.11E-03	1.23E-02	2.14E-02	2.58E-02	1.50E-02	1.91E-03
Std	1.47E-01	1.18E-02	1.73E-03	2.16E-03	2.96E-03	5.34E-03	9.47E-03	1.15E-02	6.69E-03	8.52E-04
Pb-210										
Min	0.00E+00	1.31E-02	1.31E-02	1.27E-02	1.19E-02	9.54E-03	5.07E-03	5.58E-04	1.01E-06	2.60E-16
Max	0.00E+00	3.47E-02	3.47E-02	3.37E-02	3.16E-02	2.53E-02	1.35E-02	1.48E-03	2.70E-06	6.92E-16
Avg	0.00E+00	1.61E-02	1.61E-02	1.56E-02	1.47E-02	1.18E-02	6.26E-03	6.88E-04	1.25E-06	3.21E-16
Std	0.00E+00	4.33E-03	4.33E-03	4.20E-03	3.94E-03	3.16E-03	1.68E-03	1.85E-04	3.36E-07	8.63E-17
Ra-226										
Min	0.00E+00	2.47E+00	2.47E+00	2.47E+00	2.46E+00	2.45E+00	2.42E+00	2.30E+00	1.98E+00	1.17E+00
Max	0.00E+00	1.19E+01	1.19E+01	1.19E+01	1.19E+01	1.19E+01	1.17E+01	1.11E+01	9.56E+00	5.67E+00
Avg	0.00E+00	3.71E+00	3.71E+00	3.70E+00	3.70E+00	3.68E+00	3.63E+00	3.45E+00	2.97E+00	1.76E+00
Std	0.00E+00	1.96E+00	1.96E+00	1.96E+00	1.95E+00	1.94E+00	1.92E+00	1.82E+00	1.57E+00	9.29E-01
Ra-228										
Min	2.29E+00	4.76E-01	3.85E-01	4.52E-01	4.71E-01	2.49E-01	1.74E-02	1.25E-06	1.78E-18	0.00E+00
Max	2.30E+00	2.30E+00	1.86E+00	2.18E+00	2.28E+00	1.21E+00	8.44E-02	6.04E-06	8.62E-18	0.00E+00
Avg	2.29E+00	7.16E-01	5.78E-01	6.79E-01	7.08E-01	3.75E-01	2.62E-02	1.88E-06	2.68E-18	0.00E+00
Std	1.35E-03	3.78E-01	3.05E-01	3.58E-01	3.74E-01	1.98E-01	1.38E-02	9.90E-07	1.41E-18	0.00E+00
Th-228										
Min	0.00E+00	4.11E-01	4.11E-01	2.86E-01	1.39E-01	1.10E-02	7.82E-06	7.55E-17	0.00E+00	0.00E+00
Max	0.00E+00	1.99E+00	1.99E+00	1.39E+00	6.71E-01	5.31E-02	3.78E-05	3.65E-16	0.00E+00	0.00E+00
Avg	0.00E+00	6.19E-01	6.19E-01	4.31E-01	2.09E-01	1.65E-02	1.18E-05	1.14E-16	0.00E+00	0.00E+00
Std	0.00E+00	3.26E-01	3.26E-01	2.27E-01	1.10E-01	8.71E-03	6.20E-06	5.99E-17	0.00E+00	0.00E+00
Th-230										
Min	1.00E+03	3.79E-01	1.52E-03	2.30E-03	3.65E-03	7.79E-03	1.95E-02	5.89E-02	1.58E-01	3.79E-01
Max	1.00E+03	1.83E+00	1.12E-02	1.36E-02	1.94E-02	3.94E-02	9.60E-02	2.86E-01	7.63E-01	1.83E+00
Avg	1.00E+03	5.71E-01	4.73E-03	5.62E-03	7.40E-03	1.36E-02	3.12E-02	9.02E-02	2.39E-01	5.71E-01
Std	0.00E+00	3.00E-01	1.21E-03	1.50E-03	2.28E-03	5.42E-03	1.46E-02	4.58E-02	1.24E-01	3.00E-01
Th-232										
Min	6.67E+01	7.27E-01	2.47E-02	7.56E-02	1.89E-01	4.98E-01	7.12E-01	7.27E-01	7.24E-01	7.15E-01
Max	6.72E+01	3.52E+00	1.23E-01	3.69E-01	9.18E-01	2.41E+00	3.45E+00	3.52E+00	3.51E+00	3.46E+00
Avg	6.70E+01	1.10E+00	4.12E-02	1.18E-01	2.88E-01	7.53E-01	1.07E+00	1.10E+00	1.09E+00	1.08E+00
Std	1.15E-01	5.75E-01	1.79E-02	5.82E-02	1.48E-01	3.93E-01	5.63E-01	5.75E-01	5.73E-01	5.65E-01
U-234										
Min	0.00E+00	1.09E-03	1.09E-03	1.08E-03	1.07E-03	1.00E-03	8.44E-04	4.88E-04	2.25E-04	4.62E-04
Max	0.00E+00	6.56E-03	6.56E-03	6.50E-03	6.39E-03	6.01E-03	5.05E-03	2.85E-03	1.14E-03	2.23E-03
Avg	0.00E+00	2.79E-03	2.79E-03	2.76E-03	2.71E-03	2.55E-03	2.15E-03	1.20E-03	4.09E-04	6.95E-04
Std	0.00E+00	7.17E-04	7.17E-04	7.11E-04	6.98E-04	6.57E-04	5.52E-04	3.12E-04	1.48E-04	3.64E-04
U-235										
Min	0.00E+00	6.83E-03	6.83E-03	6.77E-03	6.66E-03	6.26E-03	5.25E-03	2.85E-03	5.14E-04	5.26E-06
Max	0.00E+00	3.31E-02	3.31E-02	3.28E-02	3.22E-02	3.03E-02	2.54E-02	1.38E-02	2.49E-03	2.56E-05
Avg	0.00E+00	1.03E-02	1.03E-02	1.02E-02	1.00E-02	9.44E-03	7.92E-03	4.31E-03	7.78E-04	8.41E-06
Std	0.00E+00	5.41E-03	5.41E-03	5.36E-03	5.27E-03	4.95E-03	4.15E-03	2.26E-03	4.04E-04	3.88E-06

Probabilistic Total Dose Summary(cont.)

Nuclide (j)	Peak Time	Peak Dose	DOSE(j,t), mrem/yr t= 0.00E+00	1.00E+00	3.00E+00	1.00E+01	3.00E+01	1.00E+02	3.00E+02	1.00E+03
U-238										
Min	0.00E+00	3.06E-02	3.06E-02	3.04E-02	2.98E-02	2.80E-02	2.35E-02	1.27E-02	2.18E-03	4.74E-06
Max	0.00E+00	1.49E-01	1.49E-01	1.47E-01	1.45E-01	1.36E-01	1.14E-01	6.17E-02	1.06E-02	2.30E-05
Avg	0.00E+00	4.69E-02	4.69E-02	4.65E-02	4.56E-02	4.29E-02	3.60E-02	1.94E-02	3.34E-03	7.25E-06
Std	0.00E+00	2.39E-02	2.39E-02	2.37E-02	2.33E-02	2.19E-02	1.83E-02	9.90E-03	1.70E-03	3.69E-06
∑ALL										
Min	0.00E+00	3.36E+00	3.36E+00	3.36E+00	3.34E+00	3.29E+00	3.23E+00	3.12E+00	2.88E+00	2.27E+00
Max	0.00E+00	1.62E+01	1.62E+01	1.62E+01	1.61E+01	1.59E+01	1.56E+01	1.51E+01	1.39E+01	1.10E+01
Avg	0.00E+00	5.06E+00	5.06E+00	5.05E+00	5.02E+00	4.94E+00	4.85E+00	4.69E+00	4.33E+00	3.41E+00
Std	0.00E+00	2.66E+00	2.66E+00	2.65E+00	2.64E+00	2.60E+00	2.55E+00	2.47E+00	2.27E+00	1.80E+00

∑ALL is total dose summed for all nuclides.

Probabilistic results summary : Scabble Ratios, 0.3 cm on pavement, industrial,
rad + eat + breathe, 20 sq m File: 468uth20.RAD

Cumulative Probability Summary for: Total Dose Over Pathways

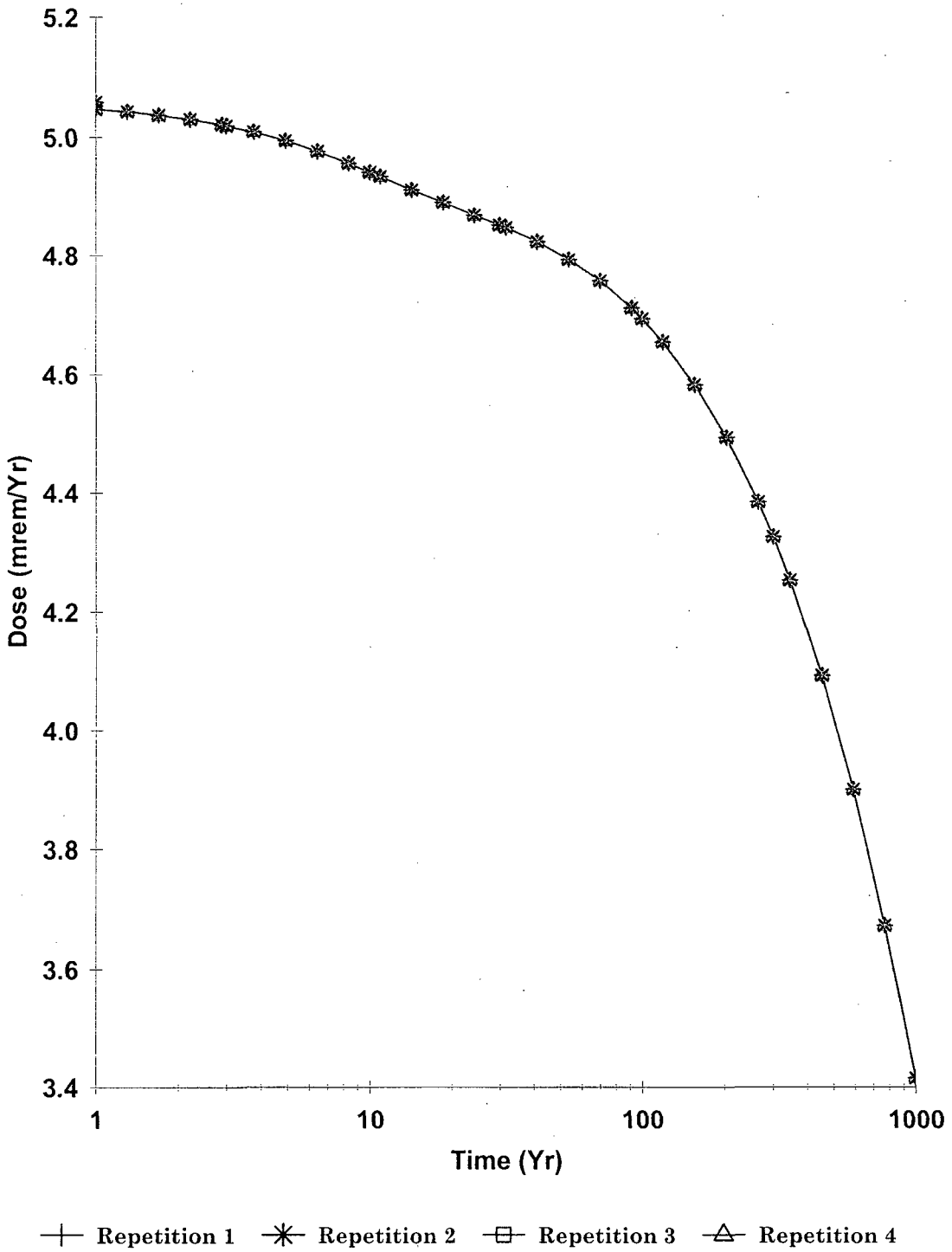
Cumulative Probability	Dose(t), mrem/yr t= 0.00E+00	1.00E+00	3.00E+00	1.00E+01	3.00E+01	1.00E+02	3.00E+02	1.00E+03
0.025	3.55E+00	3.54E+00	3.52E+00	3.47E+00	3.40E+00	3.29E+00	3.03E+00	2.40E+00
0.050	3.55E+00	3.55E+00	3.53E+00	3.47E+00	3.41E+00	3.30E+00	3.04E+00	2.40E+00
0.075	3.56E+00	3.55E+00	3.53E+00	3.48E+00	3.41E+00	3.30E+00	3.04E+00	2.40E+00
0.100	3.72E+00	3.71E+00	3.69E+00	3.63E+00	3.56E+00	3.45E+00	3.18E+00	2.51E+00
0.125	3.72E+00	3.71E+00	3.69E+00	3.63E+00	3.57E+00	3.45E+00	3.18E+00	2.51E+00
0.150	3.72E+00	3.71E+00	3.69E+00	3.64E+00	3.57E+00	3.45E+00	3.18E+00	2.51E+00
0.175	3.73E+00	3.72E+00	3.70E+00	3.64E+00	3.57E+00	3.46E+00	3.18E+00	2.51E+00
0.200	3.73E+00	3.72E+00	3.70E+00	3.65E+00	3.58E+00	3.46E+00	3.19E+00	2.52E+00
0.225	3.97E+00	3.96E+00	3.94E+00	3.88E+00	3.81E+00	3.69E+00	3.40E+00	2.68E+00
0.250	3.98E+00	3.97E+00	3.95E+00	3.89E+00	3.81E+00	3.69E+00	3.40E+00	2.68E+00
0.275	3.98E+00	3.97E+00	3.95E+00	3.89E+00	3.82E+00	3.69E+00	3.40E+00	2.69E+00
0.300	3.98E+00	3.97E+00	3.95E+00	3.89E+00	3.82E+00	3.69E+00	3.40E+00	2.69E+00
0.325	3.98E+00	3.97E+00	3.95E+00	3.89E+00	3.82E+00	3.70E+00	3.40E+00	2.69E+00
0.350	3.99E+00	3.98E+00	3.95E+00	3.89E+00	3.82E+00	3.70E+00	3.41E+00	2.69E+00
0.375	3.99E+00	3.98E+00	3.96E+00	3.90E+00	3.83E+00	3.70E+00	3.41E+00	2.69E+00
0.400	4.40E+00	4.39E+00	4.37E+00	4.30E+00	4.22E+00	4.08E+00	3.76E+00	2.97E+00
0.425	4.40E+00	4.39E+00	4.37E+00	4.30E+00	4.22E+00	4.09E+00	3.77E+00	2.97E+00
0.450	4.41E+00	4.39E+00	4.37E+00	4.30E+00	4.22E+00	4.09E+00	3.77E+00	2.97E+00
0.475	4.41E+00	4.40E+00	4.37E+00	4.30E+00	4.23E+00	4.09E+00	3.77E+00	2.97E+00
0.500	4.41E+00	4.40E+00	4.37E+00	4.31E+00	4.23E+00	4.09E+00	3.77E+00	2.97E+00
0.525	4.41E+00	4.40E+00	4.37E+00	4.31E+00	4.23E+00	4.09E+00	3.77E+00	2.98E+00
0.550	4.41E+00	4.40E+00	4.38E+00	4.31E+00	4.23E+00	4.09E+00	3.77E+00	2.98E+00
0.575	4.41E+00	4.40E+00	4.38E+00	4.31E+00	4.23E+00	4.09E+00	3.77E+00	2.98E+00
0.600	4.41E+00	4.40E+00	4.38E+00	4.31E+00	4.23E+00	4.09E+00	3.77E+00	2.98E+00
0.625	4.43E+00	4.42E+00	4.39E+00	4.32E+00	4.24E+00	4.10E+00	3.78E+00	2.99E+00
0.650	5.08E+00	5.06E+00	5.04E+00	4.96E+00	4.87E+00	4.71E+00	4.34E+00	3.43E+00
0.675	5.08E+00	5.07E+00	5.04E+00	4.96E+00	4.87E+00	4.71E+00	4.34E+00	3.43E+00
0.700	5.08E+00	5.07E+00	5.04E+00	4.96E+00	4.87E+00	4.71E+00	4.34E+00	3.43E+00
0.725	5.08E+00	5.07E+00	5.04E+00	4.96E+00	4.87E+00	4.71E+00	4.34E+00	3.43E+00
0.750	5.08E+00	5.07E+00	5.04E+00	4.96E+00	4.87E+00	4.71E+00	4.35E+00	3.43E+00
0.775	5.08E+00	5.07E+00	5.04E+00	4.97E+00	4.87E+00	4.72E+00	4.35E+00	3.43E+00
0.800	5.09E+00	5.07E+00	5.05E+00	4.97E+00	4.88E+00	4.72E+00	4.35E+00	3.43E+00
0.825	5.09E+00	5.07E+00	5.05E+00	4.97E+00	4.88E+00	4.72E+00	4.35E+00	3.43E+00
0.850	5.09E+00	5.08E+00	5.05E+00	4.97E+00	4.88E+00	4.72E+00	4.35E+00	3.43E+00
0.875	5.10E+00	5.09E+00	5.06E+00	4.98E+00	4.89E+00	4.73E+00	4.36E+00	3.44E+00
0.900	6.24E+00	6.23E+00	6.20E+00	6.10E+00	5.99E+00	5.79E+00	5.34E+00	4.22E+00
0.925	6.25E+00	6.23E+00	6.20E+00	6.10E+00	5.99E+00	5.80E+00	5.34E+00	4.22E+00
0.950	1.62E+01	1.62E+01	1.61E+01	1.58E+01	1.55E+01	1.50E+01	1.39E+01	1.09E+01
0.975	1.62E+01	1.62E+01	1.61E+01	1.58E+01	1.56E+01	1.51E+01	1.39E+01	1.10E+01
1.000	1.62E+01	1.62E+01	1.61E+01	1.59E+01	1.56E+01	1.51E+01	1.39E+01	1.10E+01

Probabilistic results summary : Scabble Ratios, 0.3 cm on pavement, industrial, rad + eat + breathe, 20 sq m File: 468uth20.RAD

Peak of the mean dose (averaged over observations) at graphical times

Repetition	Time of peak mean dose	Peak mean dose
	Years	mrem/yr
1	0.000E+00	5.059E+00
2	0.000E+00	5.059E+00
3	0.000E+00	5.059E+00
4	0.000E+00	5.059E+00

Case 468uth20. Probabilistic Annual Dose from 20 sq m Source on Pavement



Probabilistic Input

Number of Sample Runs: 1600

Number	Name	Distribution	Parameters							
1	MLINH	CONTINUOUS LINEAR	8	0	0	.000015	.0151	.000023	.1365	.00
2	SHF1	DISCRETE CUMULATIVE	8	.0084	.01	.022	.09	.035	.21	.05

Probabilistic Total Dose Summary

Nuclide (j)	Peak Time	Peak Dose	DOSE(j,t), mrem/yr t= 0.00E+00	1.00E+00	3.00E+00	1.00E+01	3.00E+01	1.00E+02	3.00E+02	1.00E+03
Ac-227										
Min	0.00E+00	1.34E-02	1.34E-02	1.29E-02	1.21E-02	9.59E-03	4.94E-03	4.84E-04	6.35E-07	5.19E-17
Max	0.00E+00	6.69E-02	6.69E-02	6.48E-02	6.06E-02	4.80E-02	2.47E-02	2.42E-03	3.18E-06	2.60E-16
Avg	0.00E+00	2.22E-02	2.22E-02	2.15E-02	2.01E-02	1.60E-02	8.22E-03	8.06E-04	1.06E-06	8.64E-17
Std	0.00E+00	9.81E-03	9.81E-03	9.49E-03	8.88E-03	7.04E-03	3.63E-03	3.55E-04	4.66E-07	3.81E-17
Pa-231										
Min	7.51E+01	1.17E-02	1.92E-03	2.34E-03	3.12E-03	5.43E-03	9.44E-03	1.14E-02	6.61E-03	8.43E-04
Max	7.62E+01	5.81E-02	9.27E-03	1.13E-02	1.52E-02	2.69E-02	4.70E-02	5.69E-02	3.30E-02	4.20E-03
Avg	7.57E+01	1.95E-02	3.27E-03	3.96E-03	5.26E-03	9.11E-03	1.58E-02	1.90E-02	1.10E-02	1.41E-03
Std	1.49E-01	8.44E-03	1.26E-03	1.56E-03	2.14E-03	3.84E-03	6.79E-03	8.26E-03	4.79E-03	6.10E-04
Pb-210										
Min	0.00E+00	7.76E-03	7.76E-03	7.52E-03	7.06E-03	5.66E-03	3.01E-03	3.31E-04	6.02E-07	1.55E-16
Max	0.00E+00	2.35E-02	2.35E-02	2.27E-02	2.13E-02	1.71E-02	9.10E-03	1.00E-03	1.82E-06	4.67E-16
Avg	0.00E+00	1.00E-02	1.00E-02	9.70E-03	9.11E-03	7.30E-03	3.89E-03	4.27E-04	7.77E-07	1.99E-16
Std	0.00E+00	3.11E-03	3.11E-03	3.01E-03	2.83E-03	2.27E-03	1.21E-03	1.33E-04	2.41E-07	6.19E-17
Ra-226										
Min	0.00E+00	1.77E+00	1.77E+00	1.77E+00	1.77E+00	1.76E+00	1.73E+00	1.65E+00	1.42E+00	8.41E-01
Max	0.00E+00	8.55E+00	8.55E+00	8.54E+00	8.53E+00	8.49E+00	8.37E+00	7.96E+00	6.85E+00	4.06E+00
Avg	0.00E+00	2.66E+00	2.66E+00	2.65E+00	2.65E+00	2.64E+00	2.60E+00	2.47E+00	2.13E+00	1.26E+00
Std	0.00E+00	1.40E+00	1.40E+00	1.40E+00	1.40E+00	1.39E+00	1.37E+00	1.31E+00	1.12E+00	6.66E-01
Ra-228										
Min	2.29E+00	3.41E-01	2.76E-01	3.24E-01	3.38E-01	1.79E-01	1.25E-02	8.94E-07	1.28E-18	0.00E+00
Max	2.30E+00	1.65E+00	1.33E+00	1.57E+00	1.63E+00	8.65E-01	6.05E-02	4.33E-06	6.18E-18	0.00E+00
Avg	2.29E+00	5.13E-01	4.14E-01	4.87E-01	5.08E-01	2.69E-01	1.88E-02	1.34E-06	1.92E-18	0.00E+00
Std	1.66E-03	2.71E-01	2.19E-01	2.57E-01	2.68E-01	1.42E-01	9.92E-03	7.09E-07	1.01E-18	0.00E+00
Th-228										
Min	0.00E+00	2.95E-01	2.95E-01	2.05E-01	9.94E-02	7.87E-03	5.61E-06	5.41E-17	0.00E+00	0.00E+00
Max	0.00E+00	1.43E+00	1.43E+00	9.93E-01	4.81E-01	3.81E-02	2.71E-05	2.62E-16	0.00E+00	0.00E+00
Avg	0.00E+00	4.43E-01	4.43E-01	3.09E-01	1.50E-01	1.18E-02	8.43E-06	8.14E-17	0.00E+00	0.00E+00
Std	0.00E+00	2.34E-01	2.34E-01	1.63E-01	7.88E-02	6.24E-03	4.45E-06	4.29E-17	0.00E+00	0.00E+00
Th-230										
Min	1.00E+03	2.72E-01	1.08E-03	1.64E-03	2.72E-03	5.69E-03	1.41E-02	4.23E-02	1.13E-01	2.72E-01
Max	1.00E+03	1.31E+00	1.01E-02	1.11E-02	1.53E-02	2.96E-02	7.01E-02	2.06E-01	5.48E-01	1.31E+00
Avg	1.00E+03	4.09E-01	4.01E-03	4.65E-03	5.93E-03	1.04E-02	2.30E-02	6.53E-02	1.71E-01	4.09E-01
Std	0.00E+00	2.15E-01	1.06E-03	1.24E-03	1.75E-03	3.94E-03	1.05E-02	3.28E-02	8.89E-02	2.15E-01
Th-232										
Min	6.66E+01	5.22E-01	1.79E-02	5.44E-02	1.36E-01	3.57E-01	5.11E-01	5.21E-01	5.19E-01	5.13E-01
Max	6.73E+01	2.53E+00	9.11E-02	2.68E-01	6.61E-01	1.73E+00	2.48E+00	2.53E+00	2.52E+00	2.48E+00
Avg	6.70E+01	7.88E-01	3.09E-02	8.58E-02	2.08E-01	5.41E-01	7.72E-01	7.88E-01	7.85E-01	7.75E-01
Std	1.18E-01	4.12E-01	1.29E-02	4.17E-02	1.06E-01	2.82E-01	4.04E-01	4.12E-01	4.10E-01	4.05E-01
U-234										
Min	0.00E+00	8.14E-04	8.14E-04	8.06E-04	7.92E-04	7.45E-04	6.28E-04	3.62E-04	1.67E-04	3.31E-04
Max	0.00E+00	5.58E-03	5.58E-03	5.53E-03	5.44E-03	5.11E-03	4.30E-03	2.41E-03	8.81E-04	1.60E-03
Avg	0.00E+00	2.37E-03	2.37E-03	2.34E-03	2.30E-03	2.17E-03	1.82E-03	1.01E-03	3.20E-04	4.98E-04
Std	0.00E+00	6.22E-04	6.22E-04	6.17E-04	6.06E-04	5.70E-04	4.79E-04	2.68E-04	1.11E-04	2.61E-04
U-235										
Min	0.00E+00	4.88E-03	4.88E-03	4.84E-03	4.75E-03	4.47E-03	3.75E-03	2.04E-03	3.67E-04	3.76E-06
Max	0.00E+00	2.36E-02	2.36E-02	2.34E-02	2.30E-02	2.17E-02	1.82E-02	9.88E-03	1.78E-03	1.87E-05
Avg	0.00E+00	7.37E-03	7.37E-03	7.30E-03	7.18E-03	6.75E-03	5.67E-03	3.08E-03	5.57E-04	6.17E-06
Std	0.00E+00	3.86E-03	3.86E-03	3.82E-03	3.76E-03	3.53E-03	2.97E-03	1.61E-03	2.89E-04	2.77E-06

Probabilistic Total Dose Summary(cont.)

Nuclide (j)	Peak Time	Peak Dose	t= 0.00E+00	1.00E+00	3.00E+00	DOSE(j,t), mrem/yr 1.00E+01	3.00E+01	1.00E+02	3.00E+02	1.00E+03
U-238										
Min	0.00E+00	2.20E-02	2.20E-02	2.18E-02	2.14E-02	2.01E-02	1.69E-02	9.10E-03	1.56E-03	3.39E-06
Max	0.00E+00	1.07E-01	1.07E-01	1.06E-01	1.04E-01	9.80E-02	8.22E-02	4.44E-02	7.63E-03	1.66E-05
Avg	0.00E+00	3.38E-02	3.38E-02	3.35E-02	3.29E-02	3.10E-02	2.60E-02	1.40E-02	2.41E-03	5.23E-06
Std	0.00E+00	1.71E-02	1.71E-02	1.69E-02	1.66E-02	1.57E-02	1.31E-02	7.09E-03	1.22E-03	2.64E-06
∑ALL										
Min	0.00E+00	2.41E+00	2.41E+00	2.40E+00	2.39E+00	2.35E+00	2.31E+00	2.24E+00	2.06E+00	1.63E+00
Max	0.00E+00	1.16E+01	1.16E+01	1.16E+01	1.16E+01	1.14E+01	1.12E+01	1.08E+01	9.96E+00	7.86E+00
Avg	0.00E+00	3.63E+00	3.63E+00	3.62E+00	3.60E+00	3.54E+00	3.48E+00	3.36E+00	3.10E+00	2.45E+00
Std	0.00E+00	1.90E+00	1.90E+00	1.90E+00	1.89E+00	1.86E+00	1.83E+00	1.77E+00	1.63E+00	1.29E+00

∑ALL is total dose summed for all nuclides.

Probabilistic results summary : Scabble Ratios, 0.3 cm on pavement, industrial,
rad + eat + breathe, 10 sq m File: 464uth10.RAD

Cumulative Probability Summary for: Total Dose Over Pathways

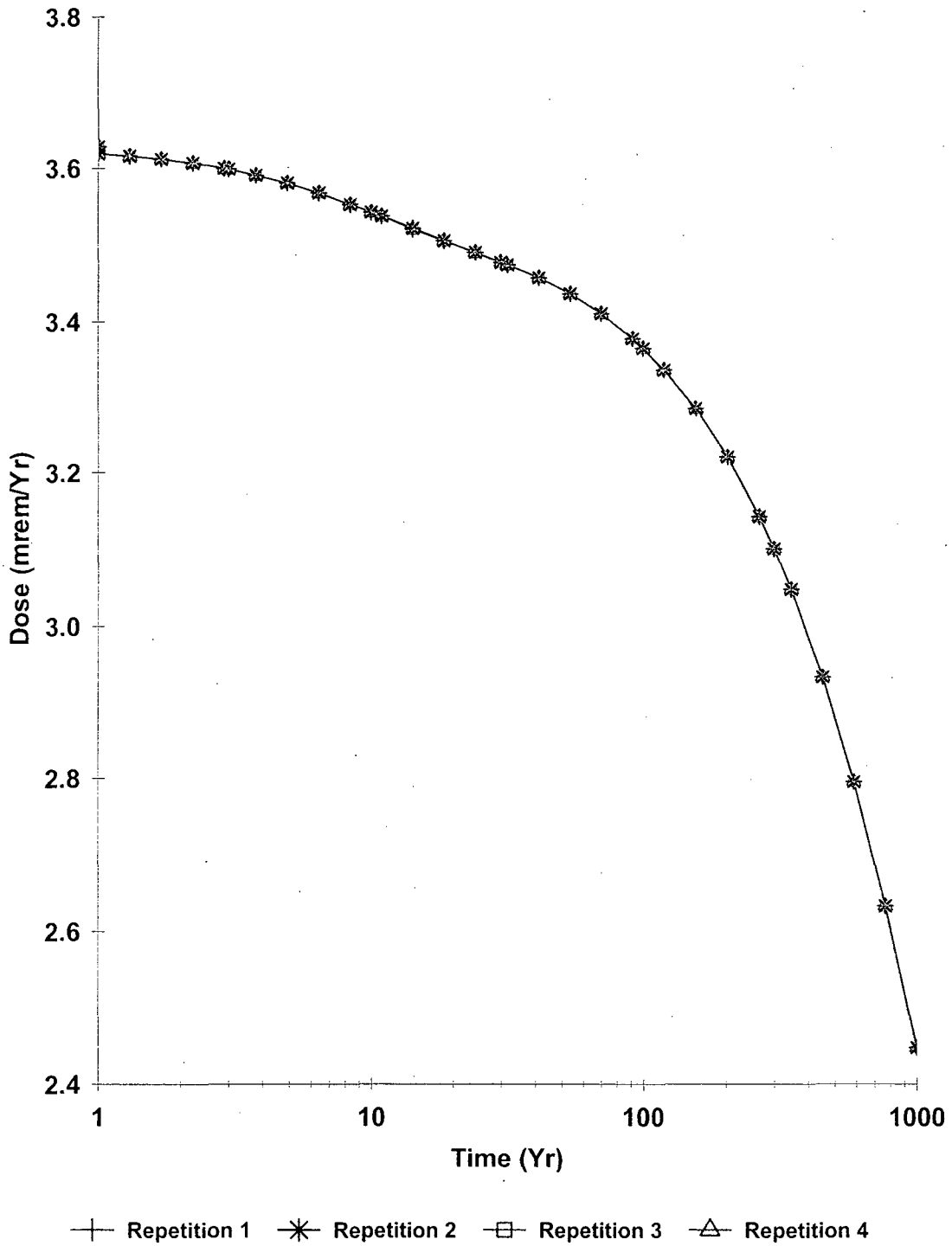
Cumulative Probability	Dose(t), mrem/yr t= 0.00E+00	1.00E+00	3.00E+00	1.00E+01	3.00E+01	1.00E+02	3.00E+02	1.00E+03
0.025	2.54E+00	2.54E+00	2.52E+00	2.49E+00	2.44E+00	2.36E+00	2.17E+00	1.72E+00
0.050	2.55E+00	2.54E+00	2.53E+00	2.49E+00	2.44E+00	2.36E+00	2.18E+00	1.72E+00
0.075	2.55E+00	2.55E+00	2.53E+00	2.49E+00	2.45E+00	2.37E+00	2.18E+00	1.72E+00
0.100	2.66E+00	2.66E+00	2.64E+00	2.60E+00	2.55E+00	2.47E+00	2.28E+00	1.80E+00
0.125	2.67E+00	2.66E+00	2.65E+00	2.61E+00	2.56E+00	2.47E+00	2.28E+00	1.80E+00
0.150	2.67E+00	2.66E+00	2.65E+00	2.61E+00	2.56E+00	2.48E+00	2.28E+00	1.80E+00
0.175	2.67E+00	2.67E+00	2.65E+00	2.61E+00	2.56E+00	2.48E+00	2.28E+00	1.80E+00
0.200	2.68E+00	2.67E+00	2.66E+00	2.62E+00	2.57E+00	2.48E+00	2.29E+00	1.81E+00
0.225	2.85E+00	2.84E+00	2.83E+00	2.78E+00	2.73E+00	2.64E+00	2.44E+00	1.92E+00
0.250	2.85E+00	2.84E+00	2.83E+00	2.79E+00	2.73E+00	2.65E+00	2.44E+00	1.92E+00
0.275	2.85E+00	2.85E+00	2.83E+00	2.79E+00	2.74E+00	2.65E+00	2.44E+00	1.93E+00
0.300	2.86E+00	2.85E+00	2.83E+00	2.79E+00	2.74E+00	2.65E+00	2.44E+00	1.93E+00
0.325	2.86E+00	2.85E+00	2.83E+00	2.79E+00	2.74E+00	2.65E+00	2.44E+00	1.93E+00
0.350	2.86E+00	2.85E+00	2.84E+00	2.79E+00	2.74E+00	2.65E+00	2.44E+00	1.93E+00
0.375	2.86E+00	2.86E+00	2.84E+00	2.80E+00	2.75E+00	2.66E+00	2.45E+00	1.93E+00
0.400	3.15E+00	3.15E+00	3.13E+00	3.08E+00	3.02E+00	2.93E+00	2.70E+00	2.13E+00
0.425	3.16E+00	3.15E+00	3.13E+00	3.08E+00	3.03E+00	2.93E+00	2.70E+00	2.13E+00
0.450	3.16E+00	3.15E+00	3.13E+00	3.08E+00	3.03E+00	2.93E+00	2.70E+00	2.13E+00
0.475	3.16E+00	3.15E+00	3.13E+00	3.09E+00	3.03E+00	2.93E+00	2.70E+00	2.13E+00
0.500	3.16E+00	3.15E+00	3.14E+00	3.09E+00	3.03E+00	2.93E+00	2.70E+00	2.13E+00
0.525	3.16E+00	3.15E+00	3.14E+00	3.09E+00	3.03E+00	2.93E+00	2.70E+00	2.13E+00
0.550	3.16E+00	3.16E+00	3.14E+00	3.09E+00	3.03E+00	2.93E+00	2.70E+00	2.13E+00
0.575	3.16E+00	3.16E+00	3.14E+00	3.09E+00	3.03E+00	2.93E+00	2.70E+00	2.14E+00
0.600	3.17E+00	3.16E+00	3.14E+00	3.09E+00	3.04E+00	2.94E+00	2.71E+00	2.14E+00
0.625	3.18E+00	3.17E+00	3.15E+00	3.10E+00	3.05E+00	2.95E+00	2.71E+00	2.14E+00
0.650	3.64E+00	3.63E+00	3.61E+00	3.55E+00	3.49E+00	3.38E+00	3.11E+00	2.46E+00
0.675	3.64E+00	3.63E+00	3.61E+00	3.56E+00	3.49E+00	3.38E+00	3.11E+00	2.46E+00
0.700	3.64E+00	3.63E+00	3.61E+00	3.56E+00	3.49E+00	3.38E+00	3.11E+00	2.46E+00
0.725	3.64E+00	3.63E+00	3.61E+00	3.56E+00	3.49E+00	3.38E+00	3.11E+00	2.46E+00
0.750	3.64E+00	3.64E+00	3.62E+00	3.56E+00	3.49E+00	3.38E+00	3.12E+00	2.46E+00
0.775	3.65E+00	3.64E+00	3.62E+00	3.56E+00	3.50E+00	3.38E+00	3.12E+00	2.46E+00
0.800	3.65E+00	3.64E+00	3.62E+00	3.56E+00	3.50E+00	3.38E+00	3.12E+00	2.46E+00
0.825	3.65E+00	3.64E+00	3.62E+00	3.56E+00	3.50E+00	3.38E+00	3.12E+00	2.46E+00
0.850	3.65E+00	3.64E+00	3.62E+00	3.57E+00	3.50E+00	3.39E+00	3.12E+00	2.46E+00
0.875	3.66E+00	3.65E+00	3.63E+00	3.57E+00	3.51E+00	3.39E+00	3.13E+00	2.47E+00
0.900	4.48E+00	4.47E+00	4.44E+00	4.37E+00	4.29E+00	4.15E+00	3.83E+00	3.02E+00
0.925	4.48E+00	4.47E+00	4.45E+00	4.38E+00	4.30E+00	4.16E+00	3.83E+00	3.02E+00
0.950	1.16E+01	1.16E+01	1.15E+01	1.13E+01	1.11E+01	1.08E+01	9.94E+00	7.85E+00
0.975	1.16E+01	1.16E+01	1.15E+01	1.14E+01	1.11E+01	1.08E+01	9.95E+00	7.85E+00
1.000	1.16E+01	1.16E+01	1.16E+01	1.14E+01	1.12E+01	1.08E+01	9.96E+00	7.86E+00

Probabilistic results summary : Scabble Ratios, 0.3 cm on pavement, industrial,
rad + eat + breathe, 10 sq m File: 464uth10.RAD

Peak of the mean dose (averaged over observations) at graphical times

Repetition	Time of peak mean dose	Peak mean dose
	Years	mrem/yr
1	0.000E+00	3.628E+00
2	0.000E+00	3.628E+00
3	0.000E+00	3.628E+00
4	0.000E+00	3.628E+00

Case 464uth10. Probabilistic Annual Dose from 10 sq m Source on Pavement



APPENDIX H

TWO SMALL AREAS OF CONTAMINATED SOIL IN PLANT 5

Mallinckrodt Inc.

C-T Phase II Decommissioning Plan

Revision 0

August 1, 2005

NRC Docket: 40-06563
NRC License: STB-401

APPENDIX H
TWO SMALL CONTAMINATED AREAS OF SOIL IN PLANT 5

Two small areas whose radioactive contamination causes their classification to differ from the larger areas surrounding them are identified in CT 2 DP, §14, Figure 14-2. One is southeast of Building 245; the other is east of Building 240. Since these are known small areas subject to alternate treatment in accordance with revised CT 2 DP, §14.4.3.9, and since the NRC staff asks notification and approval of such, John Buckley recommended that these two small areas be identified and justified in response to their queries about the draft CT 2 DP. These two small areas and related characterization survey data are described hereafter.

1.1. SOUTHEAST OF BUILDING 245

A small area of soil contamination has been identified near the southeast corner of Building 245,[1] within a Class 3 area of lesser contamination potential. Three shallow soil samples in one core sampling location, BH 43, contained residual source material as indicated in Table H-1. The topsoil sample contained >DCGLw, attributable to Ra^{226}. Localized, with radioactivity diminishing with depth, suggests a surficial contaminating event. When the local, elevated contamination is removed, the remaining small area will be Class 2[2] or perhaps even Class 3.

After clean-up, the vicinity of the small area would logically qualify as one in which the number of measurements estimated to satisfy a WRS test would be unreasonably large. Consistent with the framework for such contingency described in CT Phase II DP, §14.4.3.9 (previously §14.4.3.8), a final status survey should include at least one measurement per 25 m^2 in the small survey unit, and the release criterion shall be that no measurement may exceed the DCGLw. All the surface of the small survey unit would be subject to a gamma scan as part of the final status survey.

1.2. EAST OF BUILDING 240

A small, Class 1 area[3] has been identified adjacent the east side of Building 240.[4] Five samples, in a line, including one of sediment taken from a sewer manhole, exhibited composite radioactivity concentration ≥ 0.5 DCGLw. The samples containing the most source material were shallow, the deepest being 4.5 feet.

Of 35 soil or sediment samples taken in 15 locations in the vicinity (ref. Table H-2 herein), 30 samples contained < 0.5 DCGLw, suggesting that the contaminated area is

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1 CT Phase II Decommissioning Plan, §14 Facility Radiation Surveys, Figure 14-2.

2 Class 2 indicates an area is impacted by residual radioactivity, has low potential for containing residual radioactivity concentration > DCGLw, and has little or no potential for a small area of radioactivity > DCGLEMC.

3 Class 1 indicates reasonable expectation that soil in the unit may contain radioactivity concentration greater than the DCGLw.

4 CT Phase II Decommissioning Plan, §14 Facility Radiation Surveys, Figure 14-2.

confined as CT 2 DP, §14, Figure 14-2 indicates. Since the contamination is apparently in a shallow, narrow zone, it might be justifiable to treat it as a discrete remediation and survey unit.

After clean-up, the vicinity of the small area would logically qualify as one in which the number of measurements estimated to satisfy a WRS test would be unreasonably large. Consistent with the framework for such contingency described in CT Phase II DP, §14.4.3.9 (previously §14.4.3.8), a final status survey should include at least one measurement per 25 m^2 in the small survey unit, and the release criterion shall be that no measurement may exceed the DCGLw. All the surface of the small survey unit would be subject to a gamma scan as part of the final status survey.

Table H-1. Source Material Concentration in Soil Core Samples Near the Southeast of Building 245

Location I.D.	CT 2 DP Figure	CT 2 DP Table	Sample Depth		Fraction of DCGLw	Radioactivity Concentration			
			Top (ft)	Bottom (ft)		Uranium (pCi/g)	Th^{230} (pCi/g)	Ra^{226} (pCi/g)	Thorium (pCi/g)
BH 34	4-7	4-7	3	4	0.2	5.6 [e]	6.3	6.9	1.3 [c]
BH 34	4-7	4-7	9	10	0.1	4.3 [e]	5.8	4.6	2.4 [c]
BH 34	4-7	4-7	15	16	0.0	2.5 [e]	2.1	1.3	1.4 [c]
BH 43	4-7	4-7	0.5	1	1.6	3.9 e	3.0	50.5	1.9 [c]
BH 43	4-7	4-7	2	3	0.8	10.2 a	-	24.8	1.8 [c]
BH 43	4-7	4-7	3	4	0.0	4.1 a	-	2.2	1.8 [c]
BH 43	4-7	4-7	4	5	0.3	4.3	2.9	11.8	1.3 [c]
BH 43	4-7	4-7	10	11	0.0	5.2	7.7	0.9	1.3 [c]
BH 120	4-8	4-8	8	9.	0.0	2.3 [e]	4.2	3.0	1.1 [c]
BH-Z-9	4-13	4-13	0	1	0.0	11.6 [e]	4.6	0.3	0.6 [c]
BH-Z-9	4-13	4-13	1	3	0.0	6.8 [e]	4.0	0.3	0.9 [c]
BH-Z-9	4-13	4-13	3	6	0.0	4.5 [e]	3.1	0.3	0.9 [c]
BH-Z-9	4-13	4-13	6	9	0.0	4.2 [e]	2.9	0.5	0.6 [c]
BH-Z-9	4-13	4-13	9	12	0.0	4.0 [e]	3.3	0.3	0.9 [c]
JA 21	4-16	4-16	3	4	0.1	3.9	3.3	4.0	1.2 [c]
JA 22	4-16	4-16	3	4	0.0	4.9	3.1	1.9	1.1 [c]
JA 23	4-16	4-16	3	4	0.0	2.7	2.4	2.3	1.3 [c]
JA 30	4-16	4-16	9	10	0.0	4.2	3.3	2.5	0.6 [c]

a U^{238}
b Th^{232}
c Average of Th^{232}, Ra^{228}, and Th^{228}
d Ra^{228}
e Average of U^{234} and U^{238}

Table H-2. Source Material Concentration in Soil Core Samples Near the East Side of Building 240

Location I.D.	CT 2 DP Figure	CT 2 DP Table	Sample Depth		Fraction of DCGLw	Radioactivity Concentration			
			Top (ft)	Bottom (ft)		Uranium (pCi/g)	Th^{230} (pCi/g)	Ra^{226} (pCi/g)	Thorium (pCi/g)
JA 02	4-16	4-16	0	1.	0.5	90 [a]	60.7	13.4	2.2 [b]
JA 03	4-16	4-16	0	1,	1.0	28 [a]	41	28	3.1 [b]
JA 04	4-16	4-16	0	1.	4.8	33 [a]	80	133	8.2 [b]
JA 05	4-16	4-16	0	1.	0.2	27 [a]	50	4.8	2.0 [b]
JA 06	4-16	4-16	0	1.	8.3	36 [a]	54	243	5.9 [b]
JA 07	4-16	4-16	0	1.	0.2	52 [a]	61	2.5	2.5 [b]
JA 09	4-16	4-16	0	1.	0.1	70 [a]	50	2.7	1.9 [b]
JA 10	4-16	4-16	0	1.	0.2	71 [a]	81	2.6	2.3 [b]
BH 25	4-7	4-7	2.5	3.5	0.4	82	8.9	4.1	0.9
BH 25	4-7	4-7	4	5	0.1	65	-	2.3	0.6
BH 25	4-7	4-7	8	9	0.1	76	1.9	1.6	1.0
BH 26	4-7	4-7	2.5	3.5	0.4	8.2	-	13.7	1.1 [d]
BH 26	4-7	4-7	4	5	0.7	18.	25.	22.	0.6 [c]
BH 26	4-7	4-7	5	6	0.0	13.	-	1.3	2.6 [d]
BH 26	4-7	4-7	7	8	0.0	11.	-	< 0.6	2.5 [d]
BH 26	4-7	4-7	9	10	0.0	2.2	-	1.2	2.9 [d]
BH 26	4-7	4-7	12	13	0.2	8.0 [e]	6.8	8.5	1.1 [c]
BH 26	4-7	4-7	15	16	0.0	1.1	1.5	1.2	1.3 [c]
BH 83	4-15	4-15	0.5	1.5	0.0	23.9 [e]	24.4	2.0	0.6 [c]
BH 83	4-15	4-15	3.	4.5	0.2	98 [e]	8.4	2.7	1.6 [c]
BH 83	4-15	4-15	6	7.5	0.1	30.3 [e]	2.3	2.9	1.1 [c]
BH 83	4-15	4-15	10.5	12	0.0	1.4 [e]	0.9	1.5	0.9 [c]
BH 83	4-15	4-15	13.5	15	0.0	1.9 [e]	0.9	0.9	0.8 [c]
BH 83	4-15	4-15	16.5	18	0.0	0.8 [e]	1.2	1.0	1.1 [c]
BH 84	4-15	4-15	0.5	1.5	0.0	2.9 [e]	2.7	2.1	0.9 [c]
BH 84	4-15	4-15	3	4.5	0.0	2.5 [e]	2.3	1.1	0.9 [c]
BH 84	4-15	4-15	6	7.5	0.0	0.7 [e]	1.5	1.4	1.0 [c]
BH 85	4-15	4-15	1	1.5	0.0	2.0 [e]	1.4	1.5	0.7
BH 85	4-15	4-15	3	4.5	0.0	2.9 [e]	2.6	1.6	1.0
BH 85	4-15	4-15	6	7.5	0.0	0.6 [e]	0.6	0.5	0.6
BH 85	4-15	4-15	7.5	9	0.0	0.9 [e]	1.0	0.6	1.0
BH 111	4-11	4-11	0	2	0.0	7.7 [a]	1.9	0.8	1.1 [b]
BH 111	4-11	4-11	2	4	0.1	10.5	3.5	1.4	1.7 [b]
BH 111	4-11	4-11	4	6	0.0	3.1 [e]	0.8	0.4	0.9 [b]
MH 09 [f]	4-1	4-1	-	2.3	5.6		2.7	147	14.8 [c]

[a] U^{238}
[b] Th^{232}
[c] Average of Th^{232}, Ra^{228}, and Th^{228}
[d] Ra^{228}
[e] Average of U^{234} and U^{238}
[f] Sample MH 09 was sediment collected in a sewer manhole.

APPENDIX I

MAXIMUM RADIOACTIVE CONTAMINATION ON ITEMS TO BE RELEASED FROM PLANT 5 WITHOUT RESTRICTION

Mallinckrodt Inc.

C-T Phase II Decommissioning Plan

July 23, 2008

NRC Docket: 40-06563
NRC License: STB-401

APPENDIX I

MAXIMUM RADIOACTIVE CONTAMINATION ON ITEMS TO BE RELEASED FROM PLANT 5 WITHOUT RESTRICTION

Maximum acceptable radioactive contamination on items that may be released from a radiologically restricted area in Plant 5 during C-T Phase II decommissioning without restriction on use will be in accordance with NRC *Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material*[1] as specified in Materials License STB-401, Condition 16.[2] A single value for implementation that would represent the mixture of uranium series and thorium series comprising the potential contaminant and that is stated in practically measurable units would be useful.

Phase 2 of C-T decommissioning involves cinder fill soil, sewerage, pavement, and building slabs. The most extensive characterization survey included measurement of key, long-lived radionuclides in cinder fill soil samples. Five hundred and thirty-five samples collected above the subsoil clay layer were analyzed to evaluate the characteristics of the uranium series and thorium series mixture and to interpret a representative uranium series-to-thorium series ratio. This representative U-to-Th ratio provides a basis for deriving a maximum acceptable areal contamination on items in numerical, measureable units.

Cinder soil and sewer sediment samples were analyzed for key, long-lived uranium series and thorium series radionuclide concentration. Representative uranium and thorium concentrations were derived from the analytical results in C-T Phase II Decommissioning Plan Tables 4-1, 4-7, 4-8, 4-9, 4-10, 4-11, 4-12, 4-13, 4-14, 4-15, and 4-16, excluding clay samples in subsoil beneath the cinder soil fill. Uranium-238, Th^{230}, and Ra^{226} concentrations in each sample were arithmetically averaged to represent uranium concentration in the sample and to relate to a category in NRC FC 83-23. Thorium-232, Ra^{228}, and Th^{228} were arithmetically averaged to represent uranium concentration in the sample. The uranium-to-thorium ratio representative of each sample was derived.

The cumulative distribution of the 535 uranium-to-thorium ratios was plotted graphically with cumulative probability on the abscissa and uranium-to-thorium ratio on a logarithmically scaled ordinate. Ideally, if data produce a straight line, the data are distributed lognormally. Most of the data in the accompanying graphical plot indicate the uranium-to-thorium ratio is lognormally distributed. At the 50th cumulative percentile, the lognormal, or geometric mean uranium-to-thorium ratio is observed to be approximately 3.

Maximum acceptable contamination on an item considered for release without

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1 NRC. Policy and Guidance Directive FC 83-23. "Termination of Byproduct, Source, and Special Nuclear Material Licenses. Nov. 4, 1983.

2 Mallinckrodt. *C-T Phase II Decommissioning Plan.* §10.1.6.2 Radiation Surveys. April 14, 2003.

restriction on its use diminishes as the U-to-Th ratio diminishes. Thus, one should consider the likelihood of whether the U-to-Th ratio in contamination on an item might be substantially lower than 3. When the U-to-Th ratio ≤ 3, only 0.06 of samples contain > 10 pCi U+Th per gram soil, *i.e.*, are substantially above background. Consequently, the areal density of soil on an item considered for release is unlikely to produce more than maximum acceptable areal radioactivity when that limit is derived on the basis of U-to-Th ratio = 3. These observations suggest the geometric, or lognormal mean U-to-Th ratio = 3 is a representative ratio on which to derive the maximum acceptable contamination limit on surface of an item considered for release from a restricted area during C-T Phase II decommissioning. The likelihood of it being applied non-conservatively is low; that is, the probability that soil having U-to-Th ratio < 3 would also contain U series + Th series in concentration enough to cause the derived limit to be exceeded is low.

The maximum acceptable average surface contamination on an item to be released from premises for unrestricted use is specified in NRC guidance[3] as:

Table 1. Maximum Acceptable Surface Contamination Level

Nuclides	Average [B]
U_{nat}, U-235, U-238, and associated decay products	5000 dpm α/100 cm²
Th_{nat}, Th-232 [A]	1000 dpm/100 cm²

[A] Traditional practice assumes associated decay products

[B] Traditional practice interprets Th series units to be same as U series, in dpm α/100 cm²

The combined limit for a U-to-Th ratio = 3 is derived as:

$$Avg\ Limit = \frac{C_U \times \alpha_U + C_{th} \times \alpha_{th}}{\frac{C_U \times \alpha_U}{Lim_U} + \frac{C_{th} \times \alpha_{th}}{Lim_{Th}}}$$

Where:

Avg Limit = maximum acceptable average alpha emission by U + Th contamination on a surface of an item to be considered for release without restriction on use. (α/min 100 cm²)

C_U = relative concentration of natural uranium with associated decay products (pCi/g)

C_{Th} = relative concentration of natural thorium with associated decay products (pCi/g)

α_U = number of alpha rays emitted by U series per parent U^{238} disintegration = 8

α_{Th} = number of alpha rays emitted by Th series per parent U^{238} disintegration = 6

Lim_U = maximum acceptable average alpha emission by U series contamination on a surface of an item to be considered for release without restriction on use. = 5000 α/min 100 cm²

[3] NRC. Policy and Guidance Directive FC 83-23.

Lim_{Th} = maximum acceptable average alpha emission by Th series contamination on a surface of an item to be considered for release without restriction on use. = 1000 α/min 100 cm²

The derived maximum acceptable average contamination on the surface of an item is:

$$Avg\ Limit = \frac{3x8+1x6}{\frac{3x8}{2000}+\frac{1x6}{1000}} = 2800\ \frac{\alpha}{min \cdot 100\ cm^2}$$

The derived maximum acceptable contamination on the surface of an item to be released for removal from a radiologically restricted area in Plant 5 during C-T Phase II decommissioning without restriction on future use is specified in this Table 2.

Table 2. Maximum Acceptable Surface Radioactivity on Items to be Released for Removal from a Restricted Area Without Restriction on Use

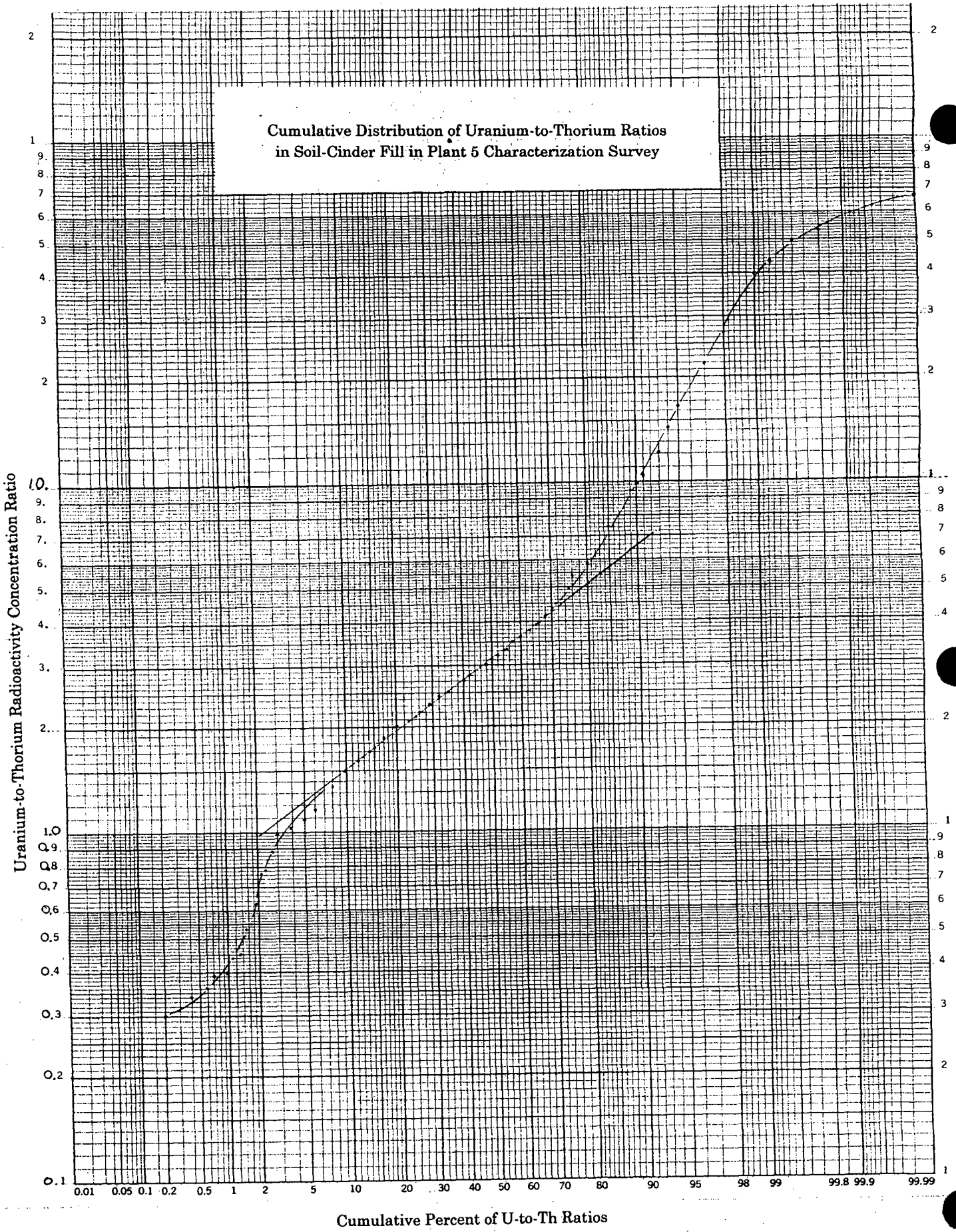
Nuclides	Average (α/min ·100 cm²)	Maximum (α/min ·100 cm²)	Removable (α/min ·100 cm²)
U + Th mix in Plant 5	2800	8400	600

A As used in this table, dpm α means the rate of emission of alpha rays determined by correcting instrument counts per minute for background, efficiency, and geometric factors

B Measurements of average contaminant should not be averaged over more than 1 square meter. For an object of lesser surface area, the average should be derived for each such object.

C The maximum contamination level applies to an area of not more than 100 cm².

D The amount of removable radioactive material per 100 cm² of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of less surface is determined, the pertinent levels should be reduced proportionally and the entire surface should be wiped.


Cumulative Distribution of Uranium-to-Thorium Ratios
in Soil-Cinder Fill in Plant 5 Characterization Survey
Uranium-to-Thorium Radioactivity Concentration Ratio
Cumulative Percent of U-to-Th Ratios
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9 99.99
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 2 3 4 5 6 7 8 9 10

ATTACHMENT 1

OCCUPATIONAL DOSE EVALUATION

Mallinckrodt Inc.

C-T Phase II Decommissioning Plan

May 15, 2003

NRC Docket: 40-06563
NRC License: STB-401

Occupational Dose Evaluation

Introduction

This attachment describes an estimate and evaluation of the occupational radiation dose to a worker participating in the CT Phase 2 decommissioning. The estimate of dose considers a hypothetical situation, likely a bounding scenario, which could occur during the decommissioning. The evaluation provides justification that the activities to be performed during the CT Phase 2 decommissioning will maintain occupational exposure to source material as low as reasonably achievable (ALARA).

Hypothetical Occupational Exposure Scenario

The scope of the decommissioning process for Phase 2 of the C-T decommissioning includes only contaminated surface soils (pavement and slabs) and contaminated subsurface soils (cinder/fill) in Plant 5. The surface soils are of such physical makeup that they would not lend themselves to dispersion. Also, the contamination levels of the surface soils are not significant, in the context of worker exposure, to warrant further consideration. The dominant exposure scenario is the construction workers interaction with subsurface soils. Then the exposure pathways of concern are those associated with the chronic (occupational) exposure scenario of construction activities during the C-T Phase 2 decommissioning; external irradiation from contaminated soil, inhalation of suspended contaminated soil, and inadvertent ingestion of contaminated soil from hands and clothing, all while out-of-doors.

A construction worker may be exposed to subsurface soils during the entire period of excavation activities at Plant 5. This is a bounding scenario because it is believed to pose the maximum integral exposure to a worker. The occupational exposure scenario assumptions below are conservative and will result in a dose to the worker that is bounding.

Scenario Assumptions

The scenario is modeled with the RESRAD computer code. Default values of parameters have been developed and described.[1] Unless described herein, default parameters in RESRAD have been retained in the assessment of occupational dose. The influence of parameters most pertinent to the scenario has been considered for appropriateness of value.

1. (Soil) Nuclide concentration – A soil concentration was estimated for each of the six key radionuclides. The estimate was derived as an average of the sample results for

[1] Biwer, B.M., *et. al.*, "Parameter Distributions for Use in RESRAD and RESRAD-BUILD Computer Codes."C in *Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes.* NUREG/CR-6697. Dec. 2000.

which the sum-of-fractions value is greater than one. The input soil concentrations are:

U-238 - 27 pCi/g,

U-235 – 1 pCi/g,

U-234 – 27 pCi/g

Th-230 - 47 pCi/g,

Ra-226 - 228 pCi/g,

Th-232 - 12 pCi/g,

Ra-228 – 42 pCi/g, and

Th-228 - 17 pCi/g.

2. Basic Radiation Dose Limit – The radiation dose limit for a radiation worker is 5000 mrem/y. [2]

3. Area of contaminated zone – The active working area of an individual construction worker was assumed to be 1000 m^2.

4. Wind speed – The average wind speed reported for St. Louis is 4.3 m/s (9.5 mph). [3]

5. Inhalation rate – An estimate of the volume of air inhaled by a worker while in an area on-site that is contaminated is needed to estimate potential radiological dose to the construction worker during decommissioning activities. That volume is the product of occupancy time and inhalation rate.

   Construction worker activity would seem to be most nearly similar to gardening, for which the recommended default inhalation rate is 1.7 m^3/h. [4] This would correspond to an outdoor worker whose activity is 0.8 moderate exertion at 1.5 m^3/h breathing rate and 0.2 heavy exertion at 2.5 m^3/h breathing rate. [5] Since construction workers are assumed to work out-of-doors entirely, the inhalation rate of this critical group is estimated to be 1.7 m^3/h without adjustment for any time indoors.

6. Mass loading for inhalation – Estimation of intake by inhalation depends on the airborne concentration of contaminated airborne particulate matter. Airborne dust in the vicinity of the excavation may be reasonably assumed maintained less than the OSHA limit[6] for fugitive dust of 1 mg/m^3.

7. Exposure duration – The exposure duration must be entered in the RESRAD code at a minimum value of one year or 8766 hours.

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[2] 10 CFR 20.1201
[3] C-T Phase 2 Decommissioning Plan, Section 3.4, Table 3-2.
[4] Biwer, B.M., et. al., p. 5-4, Table 5.1-3.
[5] Biwer, B.M., et. al., p. 5-4, Table 5.1-2.
[6] 29 CFR 1926.

8. Indoor time fraction – The construction worker is assumed to be indoors during work breaks. The indoor area is assumed to not be in the contaminated areas. The fraction of time the construction worker spends indoors in the contaminated area is assumed to be zero.

9. Outdoor time fraction –The outdoor time fraction is the fraction of the exposure duration spent outdoors in the contaminated area.

   The estimated volume of contaminated soil is 42000 ft^3. It is also estimated that about 1000 ft^3 of soil can be excavated per workday. Then the contaminated soil could be excavated in about 42 workdays. The outdoor time in the contaminated area is assumed comprised of 6 hours per workday, 5 days per workweek, for 12.5 workweeks, or 375 workhours. The fraction of time per year that the construction worker spends outside in the contaminated area is 375 work hours / 8766 total hours = 0.043.

10. Soil ingestion rate – The quantity of contaminated soil ingested incidentally from outdoor activities annually is estimated to range from 0 to 36.5 g/yr.[7] As an account for the aggressive nature of excavation activities, the inadvertent soil ingestion rate will be assumed to increase to 73 g/yr.

11. Number of construction workers – This parameter is not a RESRAD input. This parameter will be used to complete an ALARA evaluation for the occupational dose scenario. This parameter describes the number of construction workers that will be subject to the occupational dose scenario evaluated here. The number of construction workers estimated for the C-T Phase 2 decommissioning is 11.

Calculations

Results of the RESRAD modeling are provided in worksheets included with this attachment. In summary, the results reflect the dominant exposure pathway to be external gamma and Ra-226 to be the primary contributor of this pathway. The annual dose to the construction worker, estimated from the aforementioned conservative input parameters, is 120 mrem per year.

Comparison with the Basic Radiation Dose Limit

The basic radiation dose limit is the maximum radiation dose allowed in a year to a radiation worker. The estimated annual dose to the construction worker is less than 10% of the basic radiation dose limit.

ALARA Evaluation

NUREG/BR-0058, Revision 2 (November, 1995) recommends a value of $2,000 per person-rem averted as a criterion for determining whether additional funds should be

[7] Biwer, *et.al.* atch C, pp. c5-19 thru c5-25 in NUREG/CR-6697.

expended to reduce risk. Applying this criterion to the C-T Phase 2 decommissioning, the expenditure that would be justifiable if all radiological dose to C-T decommissioning workers could be averted would be about:

Occupational Dose = 120 mrem per construction worker.
Collective dose = 0.120 rem/worker x 11 workers = 1.3 person-rem.
Justifiable expenditure = $2,000/person-rem x 1.3 person-rem = $2640.

The funds spent to avert dose for the C-T Decommissioning Project already far exceed $2640. Therefore, the project meets the definition of ALARA and should not require measures beyond good health practices to avert dose. Mallinckrodt has incorporated ALARA practices into its radiation protection program through the use of plans, procedures, training, safety work permits, and oversight. Therefore, the intent of the regulations has been met with respect to ALARA.

Conclusions

An occupational dose evaluation was performed for decommissioning work associated with the Mallinckrodt C-T Project. Modeling performed using the RESRAD computer code and site-specific information or estimates yielded an estimate of 120 mrem per year for a representative construction worker. Based upon an estimate of 11 workers on the project, the collective dose was estimated as 1.3 person-rem.

An ALARA evaluation was performed to assess defensible cost-benefit balance for averting dose. Based upon the evaluation, routine health physics measures already planned for the project should be acceptable to maintain doses ALARA during the C-T Decommissioning Project. Additional measures such as a formal ALARA program, or ALARA Committee, are not warranted.

ATTACHMENT 2

ACCIDENT ANALYSIS

Mallinckrodt Inc.

C-T Phase II Decommissioning Plan

May 15, 2003

NRC Docket: 40-06563
NRC License: STB-401

Accident Analysis

Introduction

This attachment describes a credible accident, estimates the resulting quantity of radioactive material (as a contaminant in soils), which could potentially be released, and evaluates a dose to a worker due to the accident. Analysis of the accident considers a worst-case hypothetical situation, likely a bounding scenario, which could occur during the decommissioning process.

Hypothetical Accident Scenario

The scope of the decommissioning process for Phase 2 of the C-T decommissioning includes only contaminated pavement and slabs and contaminated soils (cinder/fill) in Plant 5. The surfaces are of such physical makeup that they would not lend themselves to dispersion. The most readily dispersible contamination occurs in the subsurface soils. Dispersion by water is unlikely considering the soils will be excavated below grade. Intuitively, the exposure pathway of concern for an acute (accident) exposure scenario is identified as inhalation.

Contaminated subsurface soil spilling and generating a dust cloud, which might then be breathed by a worker on-site, is believed to pose the maximum integral exposure to a worker, and thus was chosen as the bounding scenario. . The accident scenario assumptions below are conservative and will result in a calculated release and dose to the worker that is a bounding maximum

Scenario Assumptions

Notable assumptions in the accident scenario are:

1. Comparison of the Allowable Limit on Intake[1] for the six key radionuclides reveals Th-230 and Th-232 to be the most restrictive.
2. Spilled, contaminated soils are assumed to come from beneath Building 238. The subsurface soils in Plant 5 with maximal concentrations of radioactive material are surrounding and beneath Building 238. The most contaminated subsurface soil is characterized by the sample of bottom depth 9.5 feet at BH-15. This sample has the highest concentration of Th-230 and Th-232 with also the greatest combination of the other key radionuclides.
3. Short-lived transformation products are in secular equilibrium with their parents.
4. One cubic meter of soil is spilled; approximately one excavation bucket.
5. The spilled soil generates a puff of dust that is contained within a volume of 10000 cubic meters. (A work area 31.6 m long, 31.6 m wide, and 10 m high.)
6. The estimated instantaneous mass loading of dust in air is 1.3 g/m^3.[2]

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[1] 10 CFR 20, Appendix B, Table 1, Column 2.

[2] Yu, C., *et.al.,* Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil. ANL/EAIS/8. p. 111. April 1993.

7. There is no atmospheric dispersion.
8. The wind is blowing at an average speed of 4.3 meters per second.
9. A worker is at the scene of the accident and is exposed to the dust as it passes around him.
10. The worker's breathing rate is 1.2 m^3/h.

Calculations

The concentration of radioactive material in air due to the spilled soil is:

$$C_{U238} = 72\,\frac{\text{pCi}}{\text{g}} \times 1.3\,\frac{\text{g dust}}{\text{m}^3\text{ air}} \times \frac{1\,\mu\text{Ci}}{10^6\text{ pCi}} \times \frac{1\text{ m}^3}{10^6\text{ cm}^3} = 9.4x10^{-11}\,\frac{\mu\text{Ci}}{\text{cm}^3\text{ air}}$$

$$C_{Th230} = 262\,\frac{\text{pCi}}{\text{g}} \times 1.3\,\frac{\text{g dust}}{\text{m}^3\text{ air}} \times \frac{1\,\mu\text{Ci}}{10^6\text{ pCi}} \times \frac{1\text{ m}^3}{10^6\text{ cm}^3} = 3.4x10^{-10}\,\frac{\mu\text{Ci}}{\text{cm}^3\text{ air}}$$

$$C_{Ra226} = 745\,\frac{\text{pCi}}{\text{g}} \times 1.3\,\frac{\text{g dust}}{\text{m}^3\text{ air}} \times \frac{1\,\mu\text{Ci}}{10^6\text{ pCi}} \times \frac{1\text{ m}^3}{10^6\text{ cm}^3} = 9.7x10^{-10}\,\frac{\mu\text{Ci}}{\text{cm}^3\text{ air}}$$

$$C_{Th232} = 48\,\frac{\text{pCi}}{\text{g}} \times 1.3\,\frac{\text{g dust}}{\text{m}^3\text{ air}} \times \frac{1\,\mu\text{Ci}}{10^6\text{ pCi}} \times \frac{1\text{ m}^3}{10^6\text{ cm}^3} = 6.2x10^{-11}\,\frac{\mu\text{Ci}}{\text{cm}^3\text{ air}}$$

$$C_{Ra228} = 193\,\frac{\text{pCi}}{\text{g}} \times 1.3\,\frac{\text{g dust}}{\text{m}^3\text{ air}} \times \frac{1\,\mu\text{Ci}}{10^6\text{ pCi}} \times \frac{1\text{ m}^3}{10^6\text{ cm}^3} = 2.5x10^{-10}\,\frac{\mu\text{Ci}}{\text{cm}^3\text{ air}}$$

$$C_{Th228} = 61\,\frac{\text{pCi}}{\text{g}} \times 1.3\,\frac{\text{g dust}}{\text{m}^3\text{ air}} \times \frac{1\,\mu\text{Ci}}{10^6\text{ pCi}} \times \frac{1\text{ m}^3}{10^6\text{ cm}^3} = 7.9x10^{-11}\,\frac{\mu\text{Ci}}{\text{cm}^3\text{ air}}$$

The largest dimension of the plume at the breathing zone is diagonal of the work area or 45 m. Assuming that the wind blows such that the worker is exposed for the longest possible time, the time of exposure is then 45 m ÷4.3m/s, or 10 seconds.

Based on the above assumptions and calculations, the intake is:

$$I_{U238} = 9.4\,x10^{-11}\,\frac{\mu Ci}{cm^3\ air} \times 1.2\frac{m^3}{hour} \times \frac{10^6\ cm^3}{m^3} \times \frac{1\ hour}{3600s} \times 10s = 3.2x10^{-07}\,\mu Ci$$

$$I_{Th230} = 3.4\,x10^{-10}\,\frac{\mu Ci}{cm^3\ air} \times 1.2\frac{m^3}{hour} \times \frac{10^6\ cm^3}{m^3} \times \frac{1\ hour}{3600s} \times 10s = 1.2x10^{-06}\,\mu Ci$$

$$I_{Ra226} = 9.7\,x10^{-10}\,\frac{\mu Ci}{cm^3\ air} \times 1.2\frac{m^3}{hour} \times \frac{10^6\ cm^3}{m^3} \times \frac{1\ hour}{3600s} \times 10s = 3.4x10^{-06}\,\mu Ci$$

$$I_{Th232} = 6.2\,x10^{-11}\,\frac{\mu Ci}{cm^3\ air} \times 1.2\frac{m^3}{hour} \times \frac{10^6\ cm^3}{m^3} \times \frac{1\ hour}{3600s} \times 10s = 2.2x10^{-07}\,\mu Ci$$

$$I_{Ra228} = 2.5\,x10^{-10}\,\frac{\mu Ci}{cm^3\ air} \times 1.2\frac{m^3}{hour} \times \frac{10^6\ cm^3}{m^3} \times \frac{1\ hour}{3600s} \times 10s = 8.7x10^{-06}\,\mu Ci$$

$$I_{Th228} = 7.9\,x10^{-11}\,\frac{\mu Ci}{cm^3\ air} \times 1.2\frac{m^3}{hour} \times \frac{10^6\ cm^3}{m^3} \times \frac{1\ hour}{3600s} \times 10s = 2.7x10^{-07}\,\mu Ci$$

Comparison with the Allowable Limit on Intake (ALI)

The ALI is the quantity, in microcuries, of a radionuclide that can be taken into the body in one year by the reference man while still meeting the occupational dose limits. The following table lists the most restrictive lung solubility class ALIs from 10 CFR 20 for radionuclides in the U-238 and Th-232 series up to radon, and calculates the fractional ALI intake by the hypothetical worker exposed to the dust cloud from the spilled soil.

Nuclide	ALI[3] (μCi)	Intake (μCi)	Fraction of ALI
U-238	5 E-02	3.2 E-07	6.5 E-06
Th-234	2 E+02	3.2 E-07	1.6 E-09
Pa-234m	7 E+03	3.2 E-07	4.6 E-11
U-234	7 E-01	3.2 E-07	4.6 E-07
Th-230	6 E-03	1.2 E-06	2.0 E-04
Ra-226	6 E-01	3.4 E-06	5.6 E-06
Th-232	1 E-03	2.2 E-07	2.2 E-04
Ra-228	1 E+00	8.7 E-06	8.7 E-07
Ac-228	9 E+00	8.7 E-06	9.7 E-08
Th-228	1 E-02	2.7 E-07	2.7 E-05
Ra-224	2 E+00	2.7 E-07	1.4 E-07
		Sum of fractions:	4.5 E-04

Thus, the total fractional ALI attributable to the hypothetical accident is so small as to be considered negligible.

As the onsite intake of radioactive material from this accident scenario is insignificant, the offsite intake will also be insignificant. Therefore, no special evaluations were performed for offsite intake or dose.

Conclusions

An accident evaluation was performed to determine the significance of releases and dose to workers. The evaluation was performed for a spill of contaminated soil that released a cloud of dust. The assumptions utilized in the calculations were conservative and it is expected that the results are upper bounds of the actual quantities and doses. Even under these conservative assumptions, the total source term was very small, with a projected intake to the maximum exposed individual onsite of an extremely small fraction of the ALI. The intake, and hence dose, to an offsite individual would be even lower than for the onsite individual. Since the onsite intake calculated under this scenario was negligible, no offsite calculations were performed.

[3] 10 CFR 20, Appendix B, Table 1, Column 2.

ATTACHMENT 3

ANALYSIS OF POTENTIAL FOR AIRBORNE RADIOACTIVE PARTICULATE

Mallinckrodt Inc.

C-T Phase II Decommissioning Plan
August 12, 2008

NRC Docket: 40-06563
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ATTACHMENT 3

ANALYSIS OF POTENTIAL FOR AIRBORNE RADIOACTIVE PARTICULATE

The source of regulated radioactive material in air or water in the environment of Plant 5 during C-T decommissioning is mostly in soil that is to be removed by excavation. In this circumstance, uranium series and thorium series radionuclides have been measured in the cinder fill soil during characterization surveys. Complete survey data are reported in CT Phase II Decommissioning Plan, §4 Radiological Status of the Facility.

For the purpose of estimating potential airborne source material, soil core characterization data were filtered to eliminate all samples in which concentration was ≤ Ra^{226} mean concentration + 1.28 std dev (= 5.44 pCi/g soil) **and** remaining data were filtered to eliminate all samples in which concentration was ≤ Th series average concentration + 1.28 std dev (= 2.16 pCi/g soil). That would admit about 10% of data likely to include background radioactivity, which would be a reasonable overlap with background for the purpose of analyzing air samples.

The geometric mean ratios of key U series radionuclides to Th series, as a basis, observed in these data are:

Relationship	Geometric Mean of Ratios
U series -to- Th series	3.0
U^{238} -to- Th series	1.4
Th^{230} -to- Th series	1.7
Ra^{226} -to- Th series	4.0

The DAC for this mixture of U series and Th series radionuclides = 9.4×10^{-12} μCi/cm^3 air. The portions of this DAC attributable to the parents, U^{238} and Th^{232}, also the lowest specific radioactivity and presenting the dominant mass among U series and Th series radionuclides potentially becoming airborne are:

U^{238} DAC = 8.8×10^{-13} μCi/cm^3 air
Th^{232} DAC = 6.3×10^{-13} μCi/cm^3 air
$U^{238} + Th^{232}$ DAC = 1.5×10^{-12} μCi/cm^3 air

Oztunali[1] estimated the mass loading of dust in air during construction activity to be about 600 μg/m^3 air. For the purpose of estimating potential airborne concentration of $U^{238} + Th^{232}$ and their progeny in air during Phase II decommissioning, soil would be assumed to be the source of airborne dust. What $U^{238} + Th^{232}$ concentration in soil, if suspended in air at 600 μg/m^3, would produce 1.5×10^{-12} μCi/cm^3 air, the portion of DAC attributable to $U^{238} + Th^{232}$, thereby corresponding to 9.4×10^{-12} μCi/cm^3 air, the DAC for the composite of U series and Th series radionuclides?

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[1] Ostunali, O.I., *et.al.*, Data Base for Radioactive Waste Management, Impacts Analyses Methodology Report., NUREG/CR-1759, 3, also reported in Yu, C. *et.al.*, Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil, ANL/EAIS-8, p. 110.

$$C_{U238+Th232}\frac{pCi}{g\ soil}\times\frac{1\ g}{10^6\ \mu g}\times 600\frac{\mu g\ soil}{m^3 air}\times\frac{1\ \mu Ci}{10^6\ pCi}\times\frac{1\ m^3}{10^6\ cm^3}=1.5x10^{-12}=DAC_{U238+Th232}$$

$$C_{U238+Th232}=2.5\times 10^3\ \frac{pCi\ U^{238}+Th^{232}}{g\ soil}$$

This would be greater than any measurement of U^{238} + Th^{232} observed in a soil sample during CT characterization surveys. Therefore, it would be unlikely that source material concentration in occupational air would be as much as one DAC, and unlikely that respiratory protection equipment will be needed.