This document was too large to scan as a single document. It has been divided into smaller sections.

Section 3 of 4

Document Information			
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APPENDIX F

WORKER DOSE ESTIMATE TO EXCAVATE BC CRIBS AND TRENCHES

NOTE: This appendix contains a worker dose estimate document that was completed during the summer of 2004. The document has been incorporated into DOE/RL-2004-66 in its entirety.

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EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency and the U.S. Department of Energy are considering the actions required to protect people and the environment from the radioactive material buried in the BC Cribs and Trenches. One alternative is to excavate the soil containing the near-surface radioactivity and bury it in an engineered burial ground. Part of the information needed in order to assess the alternative of excavation is the radiation dose to workers that likely would be incurred if the radioactive material were to be excavated, transported, and buried in an engineered burial ground. This document discusses this estimate of radiation dose.

Two collective dose estimates are given: one of the collective dose to excavate the BC Cribs and Trenches with no radiological controls and one of the collective dose with representative radiological controls. Both dose estimates are based on measurements taken in a single trench, 216-B-26, because this is the only site for which several measurements of the concentrations of radioactive materials in the near-surface soil have been taken. Results of gamma logging and soil samples are combined to form an estimate of the concentrations of radioactive material in the soil. The estimates of the collective dose to excavate Trench 216-B-26 with and without radiological controls were based on these concentrations and an assumed excavation process using conventional excavators. As part of these dose estimates, results show that the doses from airborne radioactivity and from direct exposure to beta particles would be very small fractions of the external dose due to photon radiation. Results also show that the photon radiation would be due almost entirely to Cs-137. Thus, the collective dose that would be incurred in excavating the site, transporting the contaminated soil, and burying the contaminated soil is due almost entirely to external gamma dose from Cs-137.

Once the collective dose for the two cases was calculated for Trench 216-B-26, the dose from excavating, transporting, and burying the radioactive material from the other cribs and trenches was estimated using the results of the Soil Inventory Model. This model estimates the radioactive material that originally was disposed of in the various cribs and trenches. Assuming that the collective dose to excavate a site is roughly proportional to the Cs-137 inventory and recognizing that most of the Cs-137 that was disposed of in the cribs and trenches still is in the near-surface soil (except for radioactive decay), the collective doses due to the other cribs and

trenches were estimated by using the collective dose due to Trench 216-B-26 and the ratio of the Cs-137 inventory in the given crib or trench to the Cs-137 inventory in Trench 216-B-26.

Using this method, the collective dose estimate to excavate, transport, and dispose of the contaminated soil without radiological controls is 13.4 person-rem for Trench 216-B-26 and 127 person-rem for all of the BC Cribs and Trenches. The collective dose to excavate, transport, and dispose of the contaminated soil with representative radiological controls is 8.0 person-rem for Trench 216-B-26 and 76 person-rem for all the BC Cribs and Trenches. Seventy-six person-rem is about 27 percent of the Hanford Site collective dose for 2003.

The uncertainty associated with these estimates cannot be accurately assessed, but it can be roughly estimated. It is judged that most of the uncertainty lies in the estimate of the source term (the concentrations of radioactive material in the soil), rather than the process model (assumed means of excavation, transport, and disposal) or the radiation dose calculations (done using tested, commercial software). Assuming that the samples obtained from Trench 216-B-26 are representative of the actual population of radioactive materials in the trench (probably only roughly true), the samples were fitted to a probability density function and potential range of values estimated. Furthermore, the Soil Inventory Model also estimates a probability density function for the total Cs-137 inventory in Trench 216-B-26 from entirely independent means, so the two approaches can be compared to get some idea of the uncertainty in the source term estimate. The dose estimates given above are based on a source term determined by the simple arithmetic mean of the measurements made in Trench 216-B-26. This concentration of Cs-137 results in a total trench inventory of Cs-137 of about 1500 Ci. This value is at about the 80th percentile of the (approximately lognormal) probability density function calculated using the actual field measurements. It is at about the 97th percentile of the probability density function describing the Cs-137 inventory developed by the Soil Inventory Model; it is roughly three times the median value of the total Cs-137 inventory (about 500 Ci), which is considered to be the best estimate of central tendency by the Soil Inventory Model analysts. These values are in reasonably good agreement considering that the two estimates originate from entirely different approaches, both of which have uncertainty in them.

Thus, an estimate of 76 person-rem to excavate the BC Cribs and Trenches is a reasonable estimate upon which to base the assessment of alternatives. Taking into account all of the available information, it is less likely that the collective dose would be larger than this and more likely that it would be smaller.

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TERMS

DOE	U.S. Department of Energy
ERDF	Environmental Restoration Disposal Facility
HPT	health physics technician
ICRP	International Commission on Radiation Protection
RESRAD	RESidual RADioactivity (dose model)
SIM	Soil Inventory Model
STDEV	standard deviation

METRIC CONVERSION CHART

Into Metric Units			Out of Metric Units		
If You Know	*Multiply By*	*To Get*	*If You Know*	*Multiply By*	*To Get*
Length			**Length**		
inches	25.4	millimeters	millimeters	0.039	inches
inches	2.54	centimeters	centimeters	0.394	inches
feet	0.305	Meters	meters	3.281	feet
yards	0.914	Meters	meters	1.094	yards
miles	1.609	kilometers	kilometers	0.621	miles
Area			**Area**		
sq. inches	6.452	sq. centimeters	sq. centimeters	0.155	sq. inches
sq. feet	0.093	sq. meters	sq. meters	10.76	sq. feet
sq. yards	0.0836	sq. meters	sq. meters	1.196	sq. yards
sq. miles	2.6	sq. kilometers	sq. kilometers	0.4	sq. miles
acres	0.405	hectares	hectares	2.47	acres
Mass (weight)			**Mass (weight)**		
ounces	28.35	grams	grams	0.035	ounces
pounds	0.454	kilograms	kilograms	2.205	pounds
ton	0.907	metric ton	metric ton	1.102	ton
Volume			**Volume**		
teaspoons	5	milliliters	milliliters	0.033	fluid ounces
tablespoons	15	milliliters	liters	2.1	pints
fluid ounces	30	milliliters	liters	1.057	quarts
cups	0.24	liters	liters	0.264	gallons
pints	0.47	liters	cubic meters	35.315	cubic feet
quarts	0.95	liters	cubic meters	1.308	cubic yards
gallons	3.8	liters			
cubic feet	0.028	cubic meters			
cubic yards	0.765	cubic meters			
Temperature			**Temperature**		
Fahrenheit	subtract 32, then multiply by 5/9	Celsius	Celsius	multiply by 9/5, then add 32	Fahrenheit
Radioactivity			**Radioactivity**		
picocuries	37	millibecquerel	millibecquerel	0.027	picocuries

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F1.0 BACKGROUND AND DISCUSSION: BC CRIBS AND TRENCHES DOSE ESTIMATE

F1.1 BACKGROUND

The Fluor Hanford, Inc., Groundwater Protection Project is developing options for the remediation and/or protection of the BC Cribs and Trenches in the 200 East Area of the Hanford Site. During the late 1950s and the 1960s, the BC Cribs and Trenches received liquid waste primarily from fuel reprocessing, but also from the 300 Area laboratories and a reactor accident in the 300 Area. The general layout of the site is shown in Figure F1-1. Figure F1-2 shows a closer map of the BC Cribs and Trenches area. Figure F1-3 shows the BC Cribs under construction in June 1955. Figure F1-4 shows the BC Trenches under construction in 1956. The BC Cribs and Trenches area is described in more detail in DOE/RL-2003-64, *Feasibility Study for the 200-GW-1 Scavenged Waste Group, 200-GW-2 Tank Waste Group, and the 200-PW-5 Fission-Product Rich Waste Group Operable Units.*

This document describes the development of an estimate of the total human radiation dose that would be incurred if the near-surface (down to about 20 ft below the ground surface) radioactive material in the BC Cribs and Trenches were to be excavated and the contaminated soil moved to an engineered burial ground for permanent disposal. This information is needed to determine the best overall approach to managing the near-surface radioactive material. The U.S. Environmental Protection Agency and the U.S. Department of Energy may decide not to excavate the site, but instead require a different solution, such as providing a substantial barrier over the site or fixing the radioactive material more permanently in place.

This document does not constitute a full radiological engineering analysis of this excavation that should take place if this option is ultimately chosen. The dose estimates and the means of dose reduction chosen in developing the dose estimates given here are intended to be adequate to support a larger decision where many other factors exist, such as national requirements and cost. As such, the dose reduction methods chosen are meant to be representative of the methods that might ultimately be used.

F1.2 DESCRIPTION OF THE MODELING PROCESS USED

The human dose that would be incurred in excavating the BC Cribs and Trenches would be determined by the radioactive material buried in the ground (the source of the radiation) and the process used to dig it up (the presence of human beings who will be exposed to the radiation). Thus, both parts of the problem must be approximated—simplified, modeled—such that the dose can be calculated with a reasonable amount of effort and the answer is accurate enough to support the decision to be made. Because meager field information is available, especially in describing the radioactive material in the soil, some discussion of the uncertainty of the dose estimate is needed to properly understand the meaning of the estimates.

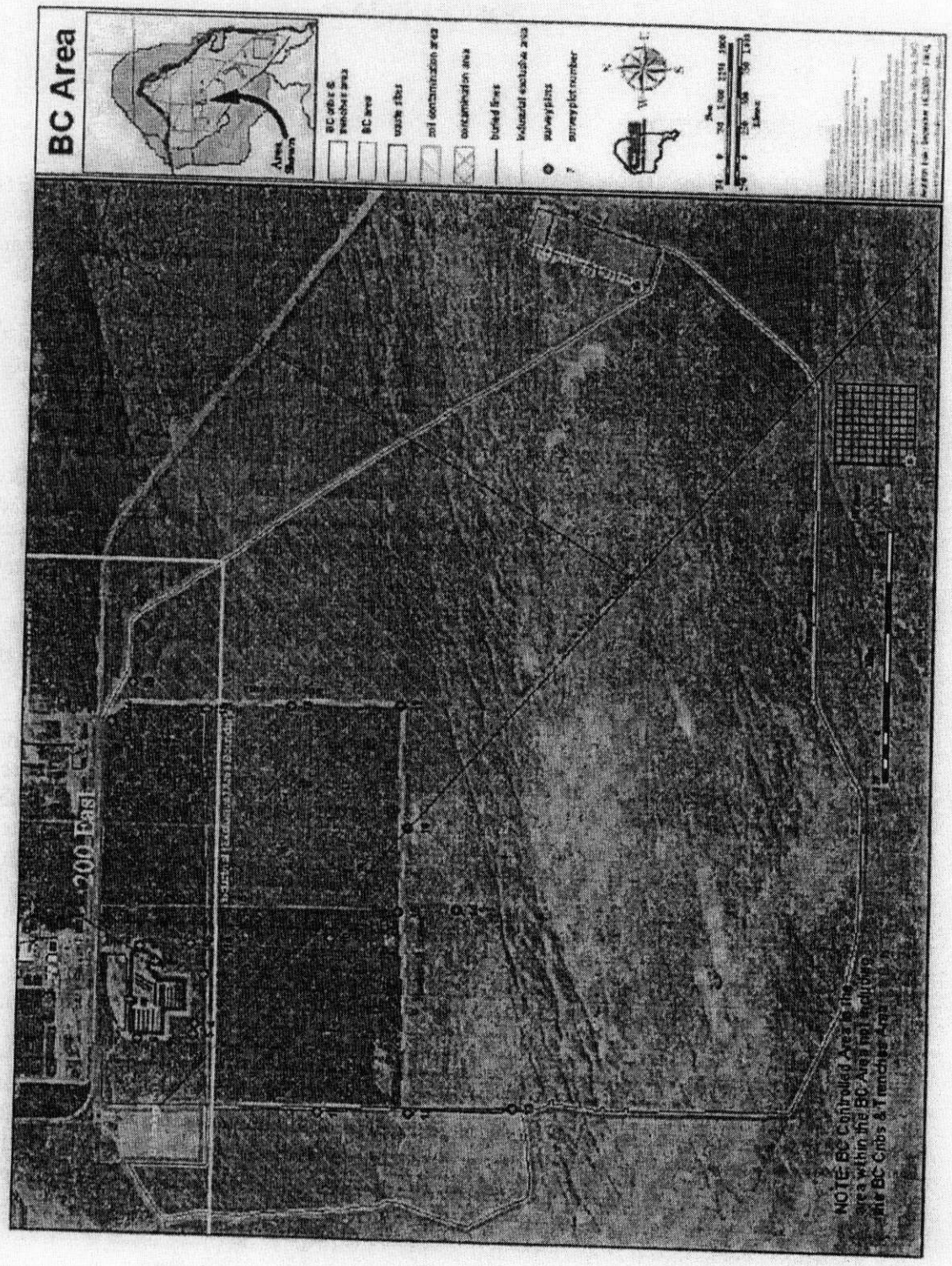

Figure F1-1. BC Controlled Area.

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Figure F1-2. BC Cribs and Trenches.

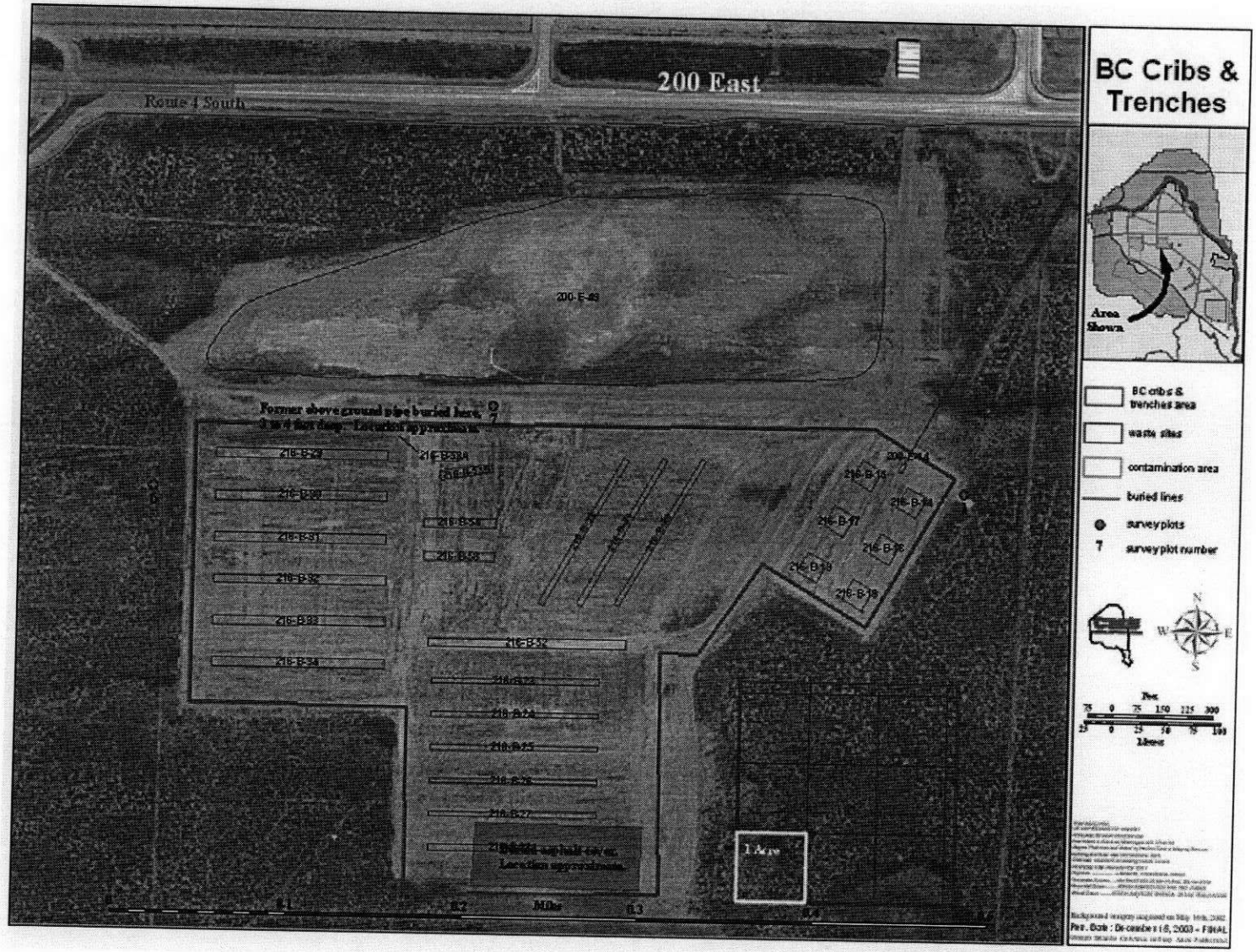

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Figure F1-3. BC Cribs Under Construction, June 1955.

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Figure F1-4. Trenches Under Construction in 1956.

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The radiation source term model is the set of radionuclides in the soil, their concentrations in the soil, and their distribution in the soil that will be used as the basis for determining the human dose when the soil is excavated. The model is a simplification of the actual radiation source term in the soil (the actual set of radionuclides, their concentrations, and their distributions in the soil, to the extent that this is known). This radiation source term must be simplified (modeled); otherwise, the actual calculations become unreasonably complex. In this case, the average concentrations of the radionuclides in a volume of soil—rather than the actual, highly variable concentrations—are used for the calculations. Section F1.3 describes the determination of the source term and the calculation of the source term model.

The process model used in these calculations is a simplified version of the process used to excavate a crib or trench with a large mechanical excavator. This is a practical approach and is representative of the class of approaches that might be used. It also is the approach used by Bechtel Hanford, Inc., to excavate trenches at the N Reactor and other locations. Section F1.4 describes the process model.

F1.3 RADIATION SOURCE TERM MODEL DESCRIPTION

The radiation source term is the set of radionuclides in the soil, their concentrations in the soil, and their distribution in the soil. The source term directly affects not only the ultimate human dose, but also the structure of the model used to estimate the human dose. The radiation source term model, used in the calculations, is derived from what is known of the actual source term.

Of the cribs and trenches of interest, only Trench 216-B-26 has been radiologically characterized by physical measurements to any extent. This trench has been sparsely characterized by seven boreholes in which were used gamma-logging devices to determine the presence of gamma-emitting radionuclides, particularly the dominant Cs-137. These boreholes were approximately evenly spaced down the major axis of the trench. In one of these boreholes, soil samples also were taken and analyzed for radioactive material. This allows the Cs-137 concentrations determined at many locations by gamma logging to be calibrated against actual soil sample results. This also allows the determination of the ratios of the concentrations of other radionuclides known to be present to the concentration of Cs-137. From these data, one can obtain estimates of the average concentrations of radionuclides known to be present over chosen volumes. Thus, this information allows the development of a source term model for Trench 216-B-26. It also allows the estimation of the uncertainty in the source term model introduced by the small number of actual samples.

The Soil Inventory Model (SIM), which estimates from process data the amount of each radionuclide disposed to each crib and trench, allows the estimation of the human exposure likely to be incurred while excavating each crib and trench, based on the human dose calculated for Trench 216-B-26 and the ratio of the Cs-137 activities in the other cribs and trenches to the Cs-137 activity in Trench 216-B-26. This process is supportable, because the total human exposure to be incurred in excavating a crib or trench will be roughly proportional to the Cs-137 inventory in the crib or trench. The details of these considerations are as follows.

F1.3.1 Source Term Model for Trench 216-B-26

1. Gamma Logs in Trench 216-B-26

   The starting point for estimating the source term is a set of seven gamma logs done by S. M. Stoller Corporation along the length of Trench 216-B-26 (DOE-EM/GJ613-2004, *C4191 Log Data Report*; GTO-2003-521-TAC, *C4195 Log Data Report*; GTO-2003-530-TAC, *C4196 Log Data Report*; GTO-2003-531-TAC, *C4192 Log Data Report*; GTO-2003-532-TAC, *C4197 Log Data Report*; GTO-2003-533-TAC, *C4193 Log Data Report*; and GTO-2003-534-TAC, *C4194 Log Data Report*). Figure F1-5 shows the approximate locations of the boreholes for the gamma logs. Stoller personnel provided spreadsheets showing the estimated Cs-137 concentrations (pCi/g) at various depths below the ground surface; the estimations are based on the direct counts at those depths using the gamma-sensitive detectors (personal communication, Stan Sobczyk, April 14, 2004). These data are shown in Table F1-1. Note that the columns in the table are in the order of the boreholes proceeding from west to east.

   Several observations should be noted about this table. First, there is a limited amount of data for a trench that is 500 ft long and 10 ft wide at the disposal surface (10 ft below ground level). Second, the radioactive material is not uniformly distributed beneath the length of trench, but the distribution varies greatly (many orders of magnitude from the available data). Third, the values given for Borehole C4194 are radically different from the values given for all other boreholes and indicate almost no Cs-137 activity in the soil. It seems likely that this hole was bored into one of the soil berms originally built into the trench to aid in uniform spreading of the waste throughout the trench; these berms can be seen in Figure F1-4. These data are not representative of the trench and must be discarded. Fourth, Boreholes C4191 and C4195 are within 3 ft of each other and should not both be used in determining average concentrations within a layer of soil (as discussed later in this chapter). The values for these boreholes will be averaged and treated as a single borehole in the averaging process, so as not to over-represent this area of the trench in the trench-wide average. Thus, the values to be used to obtain the averages for the source term model are shown in Table F1-2.

2. Modeled Soil Layers and Cs-137 Concentrations Based on Gamma Logs

   As shown in Table F1-2, the variation in concentrations of Cs-137 in the various layers is complex and must be simplified in order to use exposure rate models to calculate human dose. To make the dose calculations for excavation practical, the activity in the soil needs to be modeled as a few layers of uniform concentration.

Figure F1-5. Approximate Locations of Boreholes, Berms, and Aboveground Waste Feed Distribution Piping for Trench 216-B-26.

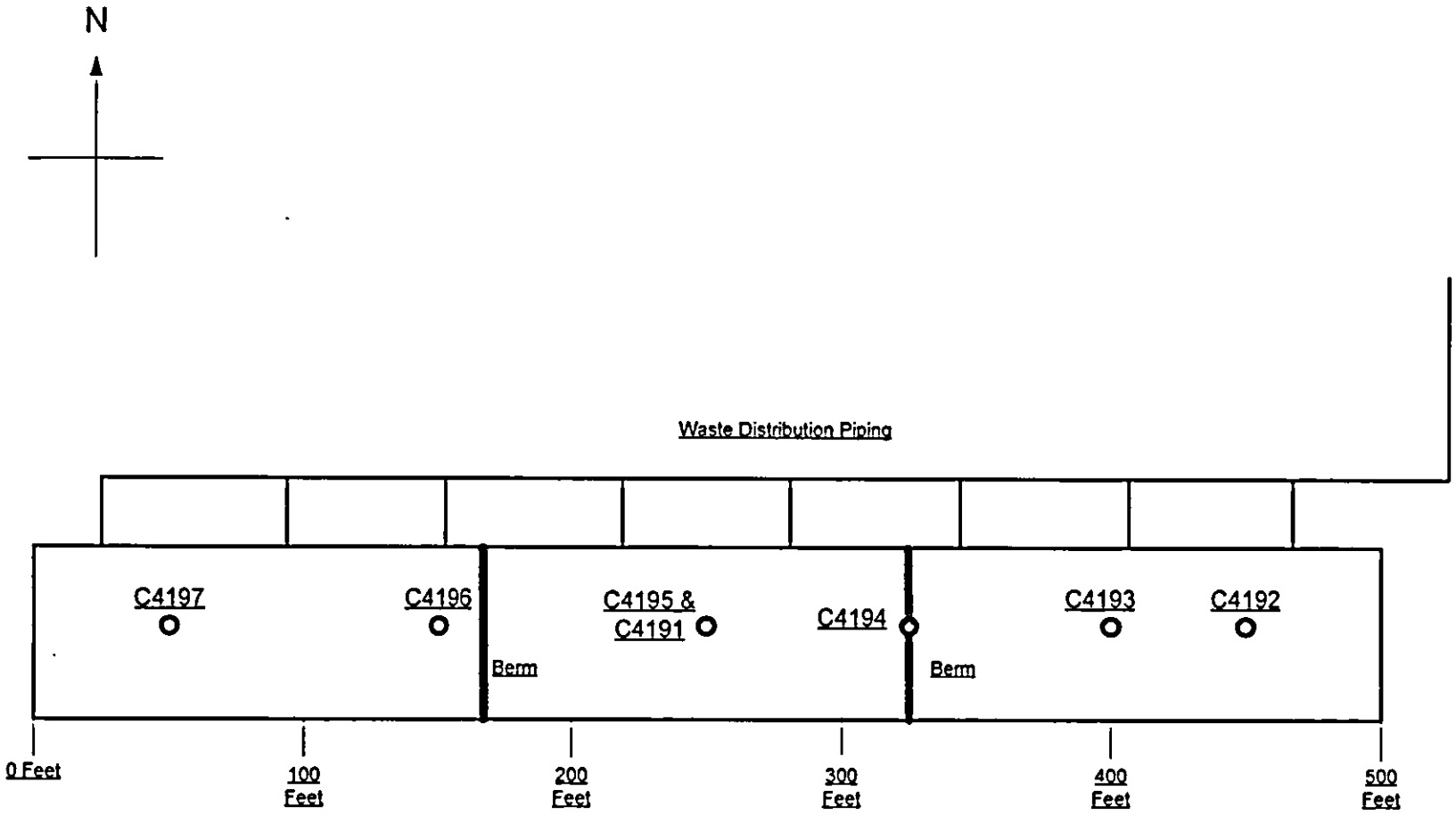

Table F1-1. Cesium-137 Concentration vs. Depth from Gamma Logs for Trench 216-B-26.

Depth (ft)	C4197	C4196	C4195	C4191	C4194	C4193	C4192
	Conc (pCi/g)	Conc (pCi/g)	Conc (pCi/g)	Conc (pCi/g)	Conc (pCi/g)	Conc (pCi/g)	Conc (pCi/g)
1	0	0	0	1	0	0	0
2	0	0	0	1	0	0	0
3	0	1	0	1	0	0	0
4	0	0	0	0	0	1	2
5	0	0	0	0	1	1	4
6	1	0	0	0	0	0	1
7	1	1	0	0	0	0	3
8	0	0	0	4	0	0	4
9	0	0	3	72	1	15	9
10	2	3	195	550	2	711	639
11	99	179	5,568	33,942	7	80,806	25,056
12	7,463	16,093	1,759,522	2,862,422	6	384,650	2,352,526
13	18,428	60,311	1,417,083	3,598,264	1	29,242	1,248,648
14	1,625	13,402	183,716	239,122	0	6,600	666,781
15	380	2,843	26,551	46,252	0	2,386	95,645
16	127	1,385	406	146,113	0	638	7,767
17	43	373	1,625	57,469	0	187	2,820
18	6	124	15,230	7,721	0	11	1,198
19	1	146	2,944	6,410	0	4	581
20	11	168	203	2,112	0	3	433
21	12	19	84	1,026	0	1	258
22	77	5	70	561	0	2	1,201
23	16	5	5,635	227	0	274	142
24	1	2	5,584	378	0	1,280	467
25	0	2	171	942	0	128	2,152
26	0	0	147	538	0	46	813
27	0	1	72	401	0	40	211
28	0	0	566	346	0	274	886
29	1	0	24	584	0	423	55
30	0	0	13	664	0	27	238
31	0	0	67	545	0	2	14
32	0	1	65	449	0	4	189
33	0	3	134	229	0	16	107
34	0	24	63	542	0	35	33
35	1	5	58	271	0	32	307
36	4	4	1,472	81	0	52	41
37	17	5	3,271	75	0	1,250	32
38	11	47	1,806	258	0	961	26
39	0	36	1,594	206	0	951	39

Table F1-2. Adjusted Cesium-137 Concentrations vs. Depth from Gamma Logs for Trench 216-B-26.

Depth (ft)	C4197	C4196	C4191/5	C4193	C4192
	Conc (pCi/g)	Conc (pCi/g)	Conc (pCi/g)	Conc (pCi/g)	Conc (pCi/g)
1	0	0	1	0	0
2	0	0	1	0	0
3	0	1	1	0	0
4	0	0	0	1	2
5	0	0	0	1	4
6	1	0	0	0	1
7	1	1	0	0	3
8	0	0	2	0	4
9	0	0	38	15	9
10	2	3	373	711	639
11	99	179	19,755	80,806	25,056
12	7,463	16,093	2,310,972	384,650	2,352,526
13	18,428	60,311	2,507,674	29,242	1,248,648
14	1,625	13,402	211,419	6,600	666,781
15	380	2,843	36,402	2,386	95,645
16	127	1,385	73,259	638	7,767
17	43	373	29,547	187	2,320
18	6	124	11,476	11	1,198
19	1	146	4,677	4	581
20	11	168	1,066	3	433
21	12	19	555	1	258
22	77	5	316	2	1,201
23	16	5	2,931	274	142
24	1	2	2,981	1,280	467
25	0	2	557	128	2,152
26	0	0	343	46	313
27	0	1	237	40	211
28	0	0	456	274	386
29	1	0	304	423	55
30	0	0	339	27	238
31	0	0	306	2	14
32	0	1	257	4	189
33	0	3	182	16	107
34	0	24	303	35	33
35	1	5	165	32	307
36	4	4	777	52	41
37	17	5	1,673	1,250	32
38	11	47	1,032	961	26
39	0	36	900	951	39

An inspection of the data indicates a large concentration of activity between 11 and 18 ft. This concentration constitutes most of the near-surface activity. Of these, a higher concentration of activity lies in the band of 11 to 14 ft and a more moderate concentration lies in the band of 15 to 18 ft. To simplify the calculation, a single-activity concentration for each radionuclide will be developed for each of the two bands. The activity concentrations to be used in each case are judgmental. After some consideration, it was decided to model the arithmetic mean of the measurements as the best overall estimate of activity concentration to use. In addition, another band of low activity is defined to be in the 18- to 20-ft layer. This band will expose workers to radiation after the soil above it is removed. The activity in this band also will be defined as the average of the measurements taken.

Table F1-3 calculates the activity concentration for Cs-137 as determined by the gamma logs for each of the three layers of soil. This table shows the results of Excel[1] calculations using the AVERAGE and the STDEV functions built into Excel. The values chosen for the model are rounded versions of the calculated values of the averages. In summary, the values of the Cs-137 concentrations in each layer to be used in further developing the source term are shown in Table F1-4.

3. Adjustment of the Modeled Cs-137 Concentration Based on a Soil Sample Result

Several split-spoon soil samples were taken from Borehole C4191 and analyzed by laboratory analysis for a set of radionuclides (DOE/RL-2003-64). The only soil sample in the region of interest that showed significant activity was the one from the 13.0- to 15.5-ft level. These results are shown in Table F1-5.

The value reported as Sr-90 is reported in the soil sample results as "total beta radiostrontium." This is almost entirely Sr-90 (personal communication, S. J. Trent, February 5, 2004).

The reported values are taken from a sample of the mixture of the soil in the bottom half of the 2.5-ft split spoon (personal communication, T. M. Johansen with M. W. Benecke, April 12, 2004); i.e., the 529,000 pCi/g Cs-137 result is the average value of the soil at the depth of 14.25 to 15.5 ft.

[1]Excel is a trademark of the Microsoft Corporation.

Table F1-3. Values for Various Layers of Activity Based on Cesium-137 Concentrations from Gamma Logs.

High-Activity Layer Gamma Log Values for Cs-137 (pCi/g)			Moderate-Activity Layer Gamma Log Values for Cs-137 (pCi/g)			Low-Activity Layer Gamma Log Values for Cs-137 (pCi/g)		
	99			380			1	
	7,463			127			11	
	18,428			43			146	
	1,625			6			168	
	179			2,843			4,677	
	16,093			1,385			1,066	
	60,311			373			4	
	13,402			124			3	
	19,755			36,402			581	
	2,310,972			73,259			433	
	2,507,674			29,547		Average	709	700
	211,419			11,476		Std Dev	1,436	
	80,806			2,386				
	384,650			638				
	29,242			187				
	6,600			11				
	25,056			95,645				
	2,352,526			7,767				
	1,248,648			2,820				
	666,781			1,198				
Average	498,086	500,000	Average	13,331	13,300			
Std Dev	870,901		Std Dev	26,534				

Table F1-4. Rounded Average Cesium-137 Activity Concentrations in Model Soil Levels Based on Gamma Log Results (pCi/g).

Layer in Soil	Rounded Average
High-activity layer (11 to 14 ft)	500,000
Moderate-activity layer (15 to 18 ft)	13,300
Low-activity layer (19 to 20 ft)	700

Table F1-5. Borehole C4191 Soil Sample Concentrations for the 13.0- to 15.5-Foot Level (pCi/g).

Radionuclide	Concentration (pCi/g)
Cs-137	529,000
Ni-63	2,110
Pu-239/240	195
Sr-90	974,000

Now, from Table F1-1, one can see that for Borehole C4191 (the same borehole from which the soil sample was taken) the Cs-137 concentration from the gamma log at the 14-ft level is 239,122 pCi/g and at the 15-ft level it is 46,252 pCi/g. Taking the volume (or mass) weighted average of these two in the proportion of 3:2 (i.e., three ¼-ft units from the 14.25- to 15.0-ft level and two ¼-ft units from the 15.0- to 15.5-ft level) results in a weighted average concentration of 161,974 or 162,00 pCi/g of Cs-137. This value is equivalent to the laboratory soil sample result of 529,000 pCi/g. Therefore, the ratio of the soil sample result for Cs-137 to the gamma log result for Cs-137 is 529,000/162,000 or 3.27 or 3.3.

Using this ratio, one can adjust the gamma log concentrations in each of the three activity layers to concentrations reflecting the presumably more accurate soil sample results simply by multiplying the gamma log concentrations by this ratio (Table F1-6).

Table F1-6. Rounded Adjusted Cesium-137 Concentrations Based on the Ratio of Soil Sample to Gamma Log Cesium-137 Concentrations (pCi/g).

Layer in Soil	Rounded Adjusted Concentration
High-activity layer (11 to 14 ft)	1,600,000
Moderate-activity layer (15 to 18 ft)	44,000
Low-activity layer (19 to 20 ft)	2,300

Note that this adjustment depends on a ratio developed from a single soil sample and that it assumes that this ratio remains constant throughout the soil volume to be excavated.

4. Calculation of Other Radionuclide Concentrations Based on Ratios to Cs-137

The borehole soil sample data given in Table F1-5 allow the calculation of ratios between Cs-137 and the other radionuclides and the subsequent estimation of the concentrations of the other radionuclides in the three modeled layers of soil. These ratios (rounded) are shown in Table F1-7.

Table F1-7. Borehole C4191 Soil Sample Radionuclide Concentration Ratios.

Radionuclide	Ratios
Ni-63/Cs-137	4.0×10^{-3}
Pu-239/240/Cs-137	3.7×10^{-4}
Sr-90/Cs-137	1.8

By applying these ratios to the (rounded) adjusted Cs-137 concentrations for the three layers, as shown in Table F1-6, one gets the results shown in Table F1-8.

Table F1-8. Model Source Term for the Three Soil Layers.

Layer	Radionuclide	Concentration (pCi/g)	Concentration (µCi/cm^3)
High-activity	Cs-137	1,600,000	2.6
	Ba-137m	1,500,000	2.5
	Sr-90	2,900,000	4.6
	Y-90	2,900,000	4.6
	Ni-63	6,400	0.01
	Pu-239	600	0.001
Moderate-activity	Cs-137	44,000	0.07
	Ba-137m	42,000	0.07
	Sr-90	79,000	0.13
	Y-90	79,000	0.13
	Ni-63	180	0.0003
	Pu-239	16	0.00003
Low-activity	Cs-137	2,300	0.004
	Ba-137m	2,200	0.004
	Sr-90	4,100	0.007
	Y-90	4,100	0.007
	Ni-63	9	0.00001
	Pu-239	1	0.000002

In this table, Y-90 is added, because it is not included in the soil sample report for strontium (personal communication, S. J. Trent, February 5, 2004). All the activity for Pu-239/240 is ascribed to Pu-239, because the energy variation is small. The conversions to microcuries per cubic centimeter ($\mu Ci/cm^3$) were made, because these units are convenient to use in the code to be used to calculate dose rate (MicroShield[1]). A soil density of 1.6 g/cm^3 was used to perform the conversions.

F1.3.2 Extension to the Remaining BC Cribs and Trenches: Soil Inventory Model

The *Hanford Soil Inventory Model* (BHI-01496) estimates the inventories of contaminants that were discharged to many cribs, ponds, and specific retention trenches, and contaminants that were released in some unplanned events on the Central Plateau of the Hanford Site. As part of this, the SIM provides an estimate of radioactive material released to each of the BC Cribs and Trenches. The SIM is based on process knowledge of canyon building operations and on waste transfer records. It simulates the annual release to a waste site (in this case, the individual cribs and trenches in the BC Area) based on the volume of specific waste streams that were discharged and the best information on the composition of each waste stream. In addition to detailed plant operation manuals, the SIM relies on summaries of waste releases to the vadose zone. The SIM and the initial results were published in BHI-01496. This work is continuing.

The SIM values for the Cs-137 inventory in each crib and trench provide a way to estimate the collective dose to be expended while excavating the other cribs and trenches, from the dose estimate for excavating Trench 216-B-26. If one assumes that the total dose to be incurred in excavating a crib or trench is roughly proportional to the Cs-137 inventory in the trench,[2] then to obtain the expected dose for excavating a given crib or trench, one only has to multiply the dose calculated to excavate Trench 216-B-26 by the ratio of the Cs-137 SIM inventory for the given crib or trench to the Cs-137 SIM inventory for Trench 216-B-26. Note that this depends on the ratios of the SIM inventories, not on the actual individual values. To perform these calculations, the SIM analyst recommended that the median values be used. Tables F1-9 and F1-10 give estimates of the protected and unprotected dose to excavate the BC Cribs and Trenches. The value for excavating Trench 216-B-26 used in Table F1-9 is derived in Chapter F2.0. The value used in Table F1-10 is derived in Chapter F3.0.

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[1]MicroShield is a trademark of AREVA Radiation Software, FRAMATOME ANP, Inc., Lynchburg, Virginia.

[2]This assumption is more difficult to sustain for the cribs than it is for the remaining trenches, because of the differences in size, shape, and construction. Although some differences would exist in the excavation process, it still will be necessary to excavate (and probably dilute) the soil; even then, almost all of the dose still will come from Cs-137. Furthermore, the shipment and disposal process will be the same. Thus, the approximation for a crib is useful, even though it is rougher than it is for a trench.

Table F1-9. Estimated Collective Dose to Unprotected Workers Excavating the BC Cribs and Trenches.

Name of Crib or Trench	Crib or Trench*	Median SIM Inventory of Cs-137 as of January 1, 2001 (Ci)	Median SIM Cs-137 Inventory ÷ Median SIM B-26 Cs-137 Inventory	Estimated Unprotected Worker Collective Dose (Person-Rem)
216-B-14	Crib	298	0.60	7.98
216-B-15	Crib	217	0.43	5.82
216-B-16	Crib	192	0.38	5.16
216-B-17	Crib	114	0.23	3.07
216-B-18	Crib	286	0.57	7.65
216-B-19	Crib	217	0.43	5.82
216-B-20	Trench (500)	494	0.99	13.24
216-B-21	Trench (500)	158	0.32	4.24
216-B-22	Trench (500)	163	0.33	4.36
216-B-23	Trench (500)	156	0.31	4.17
216-B-24	Trench (500)	165	0.33	4.41
216-B-25	Trench (500)	166	0.33	4.46
216-B-26	Trench (500)	500	1.00	13.40
216-B-27	Trench (500)	150	0.30	4.02
216-B-28	Trench (500)	173	0.35	4.65
216-B-29	Trench (500)	164	0.33	4.40
216-B-30	Trench (500)	163	0.33	4.37
216-B-31	Trench (500)	166	0.33	4.44
216-B-32	Trench (500)	162	0.32	4.33
216-B-33	Trench (500)	160	0.32	4.29
216-B-34	Trench (500)	165	0.33	4.41
216-B-52	Trench (580)	289	0.58	7.76
216-B-53A	Trench (60)	10	0.02	0.27
216-B-53B	Trench (150)	6	0.01	0.16
216-B-54	Trench (200)	6	0.01	0.16
216-B-58	Trench (200)	5	0.01	0.12
				Total collective dose: 127

*Values in parentheses provide trench lengths in feet.

SIM = Soil Inventory Model.

Table F1-10. Estimated Collective Dose to Protected Workers Excavating the BC Cribs and Trenches.

Name of Crib or Trench	Crib or Trench*	Median SIM Inventory of Cs-137 as of January 1, 2001 (Ci)	Median SIM Cs-137 Inventory + Median SIM B-26 Cs-137 Inventory	Estimated Protected Worker Collective Dose (Person-Rem)
216-B-14	Crib	298	0.60	4.76
216-B-15	Crib	217	0.43	3.48
216-B-16	Crib	192	0.38	3.08
216-B-17	Crib	114	0.23	1.83
216-B-18	Crib	286	0.57	4.57
216-B-19	Crib	217	0.43	3.47
216-B-20	Trench (500)	494	0.99	7.90
216-B-21	Trench (500)	158	0.32	2.53
216-B-22	Trench (500)	163	0.33	2.60
216-B-23	Trench (500)	156	0.31	2.49
216-B-24	Trench (500)	165	0.33	2.64
216-B-25	Trench (500)	166	0.33	2.66
216-B-26	Trench (500)	500	1.00	8.00
216-B-27	Trench (500)	150	0.30	2.40
216-B-28	Trench (500)	173	0.35	2.78
216-B-29	Trench (500)	164	0.33	2.63
216-B-30	Trench (500)	163	0.33	2.61
216-B-31	Trench (500)	166	0.33	2.65
216-B-32	Trench (500)	162	0.32	2.59
216-B-33	Trench (500)	160	0.32	2.56
216-B-34	Trench (500)	165	0.33	2.63
216-B-52	Trench (580)	289	0.58	4.63
216-B-53A	Trench (60)	10	0.02	0.16
216-B-53B	Trench (150)	6	0.01	0.09
216-B-54	Trench (200)	6	0.01	0.09
216-B-58	Trench (200)	5	0.01	0.07
				Total collective dose: 76

*Values in parentheses provide trench lengths in feet.

SIM = Soil Inventory Model.

F1.4 EXCAVATION PROCESS MODEL DESCRIPTION

F1.4.1 Basic Excavation Process

A basic process was adopted to guide the dose estimate in both of the dose estimates discussed below: dose to unprotected workers and dose to workers with in-trench soil mixing. The basic process is to excavate the soil using a large excavator, while taking action to suppress dust and therefore airborne radioactive material. The excavated soil is loaded into a shipping container so that it can be transported to the burial ground. If necessary, the contaminated soil is diluted with uncontaminated soil in order to keep the exposure rate from the Environmental Restoration Disposal Facility (ERDF) shipping container within the ERDF specifications (50 mR/h at a 1 ft distance). The shipping container is taken to a tent where the inner soil-containing bag is sealed and a cover is placed over the shipping container. A radiological survey is performed to ensure that the container meets the ERDF specifications and the shipping requirements. The shipping containers then are moved to a queuing area at the excavation site, where they await transport to the ERDF queuing area. A truck transports the container between the two queuing areas. A radiological survey is performed at the ERDF queuing area, after which the container is transported to the dumpsite and the soil is dumped into the ERDF burial ground. Once the soil is dumped, the contaminated soil is spread on the ground by a bulldozer.

The basic steps of the process model and many of the physical parameters used were taken from or influenced by the process used by Bechtel Hanford, Inc., to excavate Trench 116-N-1 at the N Reactor. The primary reference used was BHI-01558, *116-N-1 Trench Level II ALARA Review.*

F1.4.2 Common Physical Parameters

Certain physical parameters used in process modeling are used repeatedly in the calculations. These parameters are summarized here to familiarize the reader with their use.

1. Trench Dimensions

   The model trench, 216-B-26, is 500 ft long and the radioactive material is assumed to have been piped to a 10-ft wide and 500-ft long soil surface that is 10 ft below the present ground surface. In excavation, the slope of the sides of the trench will be such that the horizontal dimension is 1.5 times the vertical dimension. Thus, a trench 12 ft deep would have its sides slope so that the horizontal distance from the edge of the bottom of the trench to the top of the trench would be 18 ft.

2. Excavator Operator

   The excavator is positioned 5 ft from and 5 ft above the edge of the trench and is assumed to be shielded with 2 in. of leaded glass for the case where radiological controls are used. This shielding was made necessary by the long exposure times to the excavator operator.

3. Laborer Spraying for Dust

   The laborer spraying for dust is assumed to be positioned at the edge of the trench for 15 percent of the time.

4. Excavator Bucket

   The excavator bucket is 5 by 5 by 3 ft and is made of 2-in.-thick steel. The bucket is assumed to be filled to three-quarters capacity with each scoop; thus, the volume of soil movement per scoop is 56 ft^3.

5. Excavation Rate

   The excavator operator is assumed to excavate at a rate of 20 buckets per hour. This is 1,120 ft^3/h.

6. Time and Dose Point for Surveying Excavator Bucket

   A health physics technician (HPT) will survey every fifth bucket of soil and is assumed to be 1 ft from the bucket for 15 seconds.

7. ERDF Container

   The ERDF container holds about 320 ft^3 of soil. The size of the soil volume is about 22 ft long by 7.25 ft wide by 2 ft deep. The container wall is made of 0.25 in. steel.

8. Time and Dose Point to Seal and Cover the ERDF Container

   The laborers sealing and covering the ERDF container are assumed to take 15 minutes to perform the job in the unprotected case and 2 minutes in the protected case. The laborers are assumed to be at a point 1 ft from the side of the container and 5 ft above the container; thus, they are not shielded by the container.

9. Time and Dose Point to Survey the ERDF Container

   It is assumed that it will take 5 minutes to survey the ERDF container before shipping. The dose rate is calculated at a point 3 ft from the side of the container.

10. Shuttle Truck

    The shuttle truck driver is assumed to be 3.5 ft from the end of the ERDF container. For the protected case, the driver is assumed to be shielded with 2 in. of steel.

11. Cross-Site Transfer Truck

    The cross-site transfer truck driver is assumed to be 9 ft from the end of the ERDF container. There is no shielding other than the wall of the container.

12. Time and Dose Point to Dump Soil at ERDF

    The laborer assisting with dumping the soil at ERDF is assumed to be at a point 1 ft from the end of the truck and 1 ft from the truck. The laborer will be exposed at this point for 5 minutes for each container.

13. Bulldozer Operator

    A bulldozer is used to spread the soil once it is dumped into ERDF. The operator is assumed to be 6 ft above the level of the soil. It is assumed that it will take the operator 5 minutes to spread each container of soil.

F1.4.3 Soil Dilution Ratios

One of the requirements for soil shipped to ERDF is that the dose rate outside the container at 1 ft from the surface of the container cannot exceed 50 mrem/h. Because much of the soil in the cribs and trenches has sufficient radioactivity to exceed this value if placed undiluted into an ERDF container, the soil has to be diluted with clean (or low-activity) soil before shipment to ERDF.

Two basic approaches exist for diluting soil that is too active to ship without dilution to ERDF: (1) adding clean soil to the trench and mixing the soil in the trench, and (2) removing the contaminated soil from the trench and mixing it with clean soil using some sort of mechanical mixer located outside the trench. From a radiation control perspective, the best way to do the mixing is probably in the trench, because the radioactive source is shielded and the same method of dust suppression that would be used for excavation (spraying with a mist) can be used. However, there is some dilution factor (mixing ratio) above which in-trench mixing becomes impractical. This is because the required amount of clean soil becomes so thick that it cannot be practically mixed using a bucket. There is no sharp line between the two methods, but in-trench mixing probably becomes impractical above a dilution ratio of about 6 to 8.

In the calculation of the collective dose for Trench 216-B-26, in-trench dilution was used as a representative method, because the *average* concentration in the trench (the source term model uses the average concentration of the measured values) was small enough for in-trench mixing to be used. However, it must be emphasized, that in the case of an actual excavation, one would not likely be dealing with an overall average concentration, but a concentration present in a particular section of the trench. As can be seen by the soil concentration measurements in Trench 216-B-26, the concentrations in the trench are far from uniform. From Table F1-1, one can see that the concentrations of Cs-137 vary by a factor of 10^5 in the band between the depth of 10 ft and the depth of 14 ft. The difficulty of achieving uniform distribution of the waste over the bottom of the trenches and the risk of channeling in the soil was recognized by those who planned the disposal in the 1950s (HW-43101, *TBP Scavenged Waste Trench Disposal Scope Study*). Thus, in some areas of a trench, the concentrations may be low and require no dilution at all, while in other areas large dilutions may be needed.

F1.5 DISCUSSION OF DOSE CALCULATIONS

F1.5.1 General Discussion of Dose Calculations

Dose calculations were performed for Trench 216-B-26 for two cases: with and without representative radiological controls. Three potential sources of exposure were considered: inhalation of airborne radioactive material, external beta exposure, and external gamma exposure. (The doses caused by inhalation and external beta exposure were determined to be negligible.)

The collective dose from the excavation of Trench 216-B-26 without radiological controls was calculated using an excavation process that uses conventional (nonradiological) hazard controls and an excavation process chosen for efficiency. The excavation was modeled as being done by a large conventional excavator that sat directly over the trench on the soil overburden. The excavator started at one end and moved down the trench, excavating as it went. The complete collective dose from the excavation of a 10-ft section of the trench was calculated, and this value was simply multiplied by 50 to get the collective dose for the trench. The dose to each modeled person from the beginning of the excavation to the disposal of the contaminated soil in the burial ground was estimated using MicroShield.

The collective dose from the excavation of Trench 216-B-26 with radiological controls was calculated using an excavation process that uses basic radiological hazard controls and is reasonably efficient. The excavation was modeled as being done by a large conventional excavator that sat beside the trench (as opposed to being directly over the trench on the overburden). The excavator started at one end and moved down the trench, excavating as it went. The complete collective dose from the excavation of a 25-ft section of the trench was calculated, and this value was simply multiplied by 20 to get the collective dose for the trench. The dose to each modeled person from the beginning of the excavation to the disposal of the contaminated soil in the burial ground was estimated using MicroShield. The process model assumed that for unavoidable chronic exposures, shielding would be provided wherever practical and that for high-exposure rates, stay-times would be controlled to the minimum needed to do the job.

The remaining portions of this section discuss the external beta dose and the inhalation dose. Section F1.6 summarizes the results of the dose calculations. Chapters F2.0 and F3.0 provide the details of the dose calculations for Trench 216-B-26.

F1.5.2 Potential External Dose from Strontium-Yttrium-90 in Soil

This section discusses the potential external dose from the beta particles from Sr-90 and Y-90.

The concentrations of Sr-90 and Y-90 are, in this case, about twice the concentrations of Cs-137 present in the soil (Cs-137 provides the bulk of the external gamma dose in this case). The doses to workers from these radioactive materials need to be considered. However, the doses to workers from the Sr-90 and Y-90 in the soil are more difficult to calculate than the doses from

the Cs-137 gamma emissions, because Sr-90 and Y-90 are (essentially) pure beta emitters and beta dosimetry is considerably more complex than gamma dosimetry. For example, the computer code MicroShield, used in this report to calculate the photon doses to workers, will not calculate the beta doses, due to this complexity. Doses from the beta particles can arise from the beta particles themselves and from the bremsstrahlung X-rays emitted by the beta particles as they travel through materials. Detailed calculations of the doses to be received from Sr-90 and Y-90 would be difficult and costly and such calculations are not justified, because the doses are expected to be small compared to the doses from the Cs-137. However, to put the doses into perspective, the resulting beta doses can be compared to the doses expected from Cs-137.

One way to compare the doses from these two sources is to examine the dose coefficients for exposure to contaminated soil as presented in Federal Guidance Report No. 12 (EPA 402-R-93-081), *External Exposure to Radionuclides in Air, Water, and Soil*, Table III.7, "Dose Coefficients for Exposure to Soil Contaminated to an Infinite Depth" (pp. 165-181). The dose coefficient values for Cs-137 (Ba-137m) and Sr-Y-90 are shown in Table F1-11. Note that the dose coefficient given in Table III.7 for Cs-137 does not include the dose coefficient for Ba-137m (the actual source for the 0.662 MeV photon commonly associated with Cs-137, the parent of Ba-137m) and these two dose coefficients will be added to make a coefficient for Cs-137 (Ba-137m). The dose coefficients listed in Table F1-11 are for the effective dose equivalent.

Table F1-11. Dose Coefficients for Exposure to Soil Contaminated to an Infinite Depth.

Radionuclide	Units of Sv/s per Bq/m^3
Sr-90	3.77×10^{-21}
Y-90	1.28×10^{-19}
Cs-137	4.02×10^{-21}
Ba-137m	1.93×10^{-17}
Sr-Y-90	1.32×10^{-19}
Cs-137 (Ba-137m)	1.93×10^{-17}

Source: EPA 402-R-93-081, 1993, *External Exposure to Radionuclides in Air, Water, and Soil*, Federal Guidance Report No. 12, U.S. Environmental Protection Agency, Washington, D.C.

Note that the dose coefficient for Cs-137 (Ba-137m) is approximately 10^{-17} and the coefficient for Sr-Y-90 is approximately 10^{-19}. Thus, under these conditions, the Sr-Y-90 would contribute less than a few percent of the dose to a human that Cs-137 (Ba-137m) would contribute.

Therefore, the Sr-Y-90 is unlikely to contribute significantly to the worker external dose under the conditions modeled in this dose estimate.

F1.5.3 Assessment of Potential Internal Exposures

This section discusses the potential dose from the inhalation of airborne radioactive material.

Radiation doses from airborne exposures resulting from excavation of contaminated soil and its subsequent disposal may be estimated from the following equation:

$$D = \sum_r S\, C_r\, I\, t\, DF_r$$

where

S = the concentration of respirable contaminated soil material in air (g/m^3)
C_r = the activity of radionuclide r in the soil (pCi/g)
I = the inhalation rate of the worker (m^3/h)
t = the length of time the worker is exposed (hours)
DF_r = the inhalation dose coefficient for radionuclide r (rem/pCi).

Several operations are envisaged for the unprotected workers excavating at the BC Cribs and Trenches, and these parameters may vary for each. The types of workers include the following:

- Operator in an excavator cab
- Laborer spraying water for dust suppression beside excavator
- Workers covering waste transport containers
- Laborer guiding container dumping in ERDF
- Bulldozer operator spreading soil within ERDF.

The parameters selected for analysis are described in the following paragraphs.

1. Concentrations of Dust in Air

   The excavator operator and nearby dust-suppression laborer will be exposed to three separate sources of dust in air: resuspension from the exposed trench bottom, suspension caused by operations of the excavator bucket while digging, and releases during dumping of the excavator bucket into the transport container.

   DOE/TIC-27601, *Atmospheric Science and Power Production*, summarizes available information on resuspension of contaminants in surface soils. As discussed in DOE/TIC-27601, resuspension factors are highly uncertain and can vary over several orders of magnitude, depending on soil type, wind speed, moisture content, and other factors. For wind-driven resuspension from relatively large surfaces, the resuspension factors in DOE/TIC-27601's compilation range from about 10^{-10} to 10^{-5} m^{-1}. DOE-HDBK-3010-94, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*, presents a similar summary adapted from NUREG/CR-2651, *Accident Generated Particulate Materials and Their Characteristics -- A Review of Background Information*, and Sehmel 1980, "Particle Resuspension: A Review." DOE-HDBK-3010-94 recommends a resuspension rate of 4×10^{-5}/h for nominal outdoor wind speeds (<2 m/s with gusts up to 20 m/s) over a

quiescent bed, which with several assumptions on availability of surface soil is roughly equivalent to a resuspension factor of about 10^{-9} m^{-1}. This is appropriate for exposures to the exposed waste surface in the trench, and for the wastes in the transport container.

For active mechanical disturbances, the resuspension factor is larger. Resuspension factors for a number of operations similar to excavator operations are presented by DOE/TIC-27601 in Table F1-12.

Table F1-12. Resuspension Factors for Mechanical Operations in Soil.

Operation	Resuspension Factor (m^{-1})
Tractor operations on contaminated field	2.4×10^{-7}
In tractor cab on contaminated field	4×10^{-9} to 2×10^{-7}
Rototilling	5.6×10^{-8}
Planting/disking	1.8×10^{-8} to 7.9×10^{-6}

The upper bound of these operations gives a resuspension factor of about 2×10^{-7} m^{-1}. This value is appropriate for use with the excavator digging operations and bulldozer operations.

When the excavator bucket is filled, it is dumped in free air into a transport container. PNL-5356, *Potential Radiological Impacts of Upper-Bound Operational Accidents During Proposed Disposal Alternatives for Hanford Defense Waste*, uses a release fraction for spills of 0.12 percent (a fraction of 1.2×10^{-3}). For spills of powder in air, DOE-HDBK-3010-94 suggests release fractions of 3×10^{-4} to 2×10^{-3} of the involved material, with respirable fractions of 0.5 and 0.3, respectively. This is for pure powders; the Hanford Site soils to be removed are much coarser. PNL-3498, *Potential Airborne Release from Soil-Working Operations in a Contaminated Area*, measured the size fractions of Hanford Site soils and reported that the respirable fraction is 0.088 percent. Thus, for outdoor operations with soil, dumping from the bucket into a container might release a respirable fraction of the material of around 10^{-6} per dumping event.

Surface soils have a bulk density of approximately 1.6 g/cm^3. If it is assumed that the surface 1 mm is "available" for resuspension, this is about 1600 g/m^2. Thus, for operations represented with a resuspension factor, the product of this value and the resuspension factor yields the approximate air concentration in grams per cubic meter.

The dumping of the 5- by 3- by 5-ft (2.1 m^3) excavator bucket into the container results in a release of 3.4 g of soil dust, using the release fraction of about 10^{-6}. This activity is assumed to occur once every 3 minutes (20 buckets/h), so the effective release rate is 2.8×10^{-3} g/s. Using the conservative screening approach to atmospheric dispersion and dilution in National Council on Radiation Protection and Measurements Report No. 123, *Screening Models for Releases of Radionuclides to Atmosphere, Surface Water, and Ground* (which incorporates an assumption that the wind only blows toward the receptor about 25 percent of the time) with the Hanford Site annual average wind speed of 3.4 m/s (PNNL-14242, *Hanford Site Climatological Data Summary 2002 with Historical Data*),

an atmospheric dispersion factor of about 10^{-3} s/m^3 is appropriate, resulting in an average air concentration of dust of 2.8×10^{-6} g/m^3.

For a laborer assisting the dumping of the transport container into ERDF, the release fraction would be similar to that for emptying the excavator bucket, but the amount of material involved would be larger and the frequency of operation would be less. For a single unloading operation, the air concentration might reach ten times that achieved during the bucket dump operation (i.e., ten times the instantaneous concentration, $10 \times [3.4 \text{ g/s} * 10^{-3} \text{ s/m}^3] = 3.4 \times 10^{-2}$ g/m^3), but only remain at that concentration for a period of about 10 seconds.

These combined assumptions yield concentrations of dust in air for each operation or worker location as shown in Table F1-13.

Table F1-13. Soil Mass Air Concentrations for Excavation and Disposal Activities.

Location/Operation	Pathway Source	Air Concentration (g/m^3)
Excavator operator/laborer	Wind resuspension from bottom of trench	1.6×10^{-6}
	Digging operations	3.2×10^{-4}
	Dumping bucket	2.8×10^{-6}
Covering transport container	Wind resuspension	1.6×10^{-6}
Container dumping assistant	Dumping operations	3.4×10^{-2} g/m^3 for 10 s/load
Bulldozer operator	Waste spreading	3.2×10^{-4}

2. Inhaled Amount Rates

The parameters for the inhalation pathway include a breathing rate. The International Commission on Radiation Protection (ICRP) provides average adult inhalation rates (ICRP Publication 23, *Reference Man: Anatomical, Physiological and Metabolic Characteristics*). The value recommended by the Washington Department of Health (WDOH/320-015, *Hanford Guidance for Radiological Cleanup*) (0.83 m^3/h) is the ICRP annual average. However, the ICRP also indicates that during physical activities, the breathing rate is increased. The ICRP value for the inhalation rate for light activity is 1.2 m^3/h, with a note that this value can increase to nearly 2.6 m^3/h during periods of heavy work. The RESidual RADioactivity (RESRAD) (NUREG/CR-6697, *Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes*) default and the analyses performed for DOE/RL 96-16, *Screening Assessment and Requirements for a Complete Assessment: Columbia River Comprehensive Impact Assessment*, address this increase using values of about 1.3. DOE/RL-91-45, *Hanford Site Risk Assessment Methodology*, uses a value of 2.5, near the ICRP upper bound, which seems unreasonable for the entire working year. Therefore, a value of 1.3 m^3/h is recommended.

The amount inhaled is simply the product of the air concentration, the breathing rate, and the time of exposure. The inhaled amounts are given as rates for each operation; the amount of contaminated soil dust inhaled for a unit operation is shown in Table F1-14. Note that most operations are presented per hour of operation; however, the inhalation to

the laborer assisting with dumping the transport container into ERDF is listed per load dumped. The overall times of exposure are given above. The various sources are listed separately and summed for the excavator operator and the assistant.

Table F1-14. Soil Mass Inhalation Rates for Cleanup and Disposal Activities.

Location/Operation	Pathway Source	Inhalation Rates
Excavator operator/laborer	Wind resuspension from bottom of trench	2.1×10^{-6} g/h
	Digging operations	4.2×10^{-4} g/h
	Dumping bucket	3.6×10^{-6} g/h
	TOTAL	4.3×10^{-4} g/h
Covering transport container	Wind resuspension	2.1×10^{-6} g/h
Container dumping assistant	Dumping operations	1.2×10^{-4} g/*load*
Bulldozer operator	Waste spreading	4.2×10^{-4} g/h

3. Inhalation Doses

The soil concentrations of radionuclides in Trench 216-B-26 are listed in Table F1-8 and summarized here. The soil is considered to consist of three contaminated layers: a high-activity upper, and moderate-activity second and low-activity lower layers. The dominant radionuclides measured are ^{137}Cs, ^{63}Ni, ^{90}Sr, and ^{239}Pu. The decay progenies of the ^{137}Cs and ^{90}Sr, which are ^{137m}Ba and ^{90}Y, respectively, are assumed to be in equilibrium with their parents at all times. The concentrations in the three layers are shown in Table F1-15.

Table F1-15. Radionuclide Concentrations for Modeled Soil Levels.

Layer	Radionuclide	Concentration (pCi/g)
High-activity	^{137}Cs	1,600,000
	^{63}Ni	6,400
	^{90}Sr	2,900,000
	^{239}Pu	600
Moderate-activity	^{137}Cs	44,000
	^{63}Ni	180
	^{90}Sr	79,000
	^{239}Pu	16
Low-activity	^{137}Cs	2,300
	^{63}Ni	9
	^{90}Sr	4,100
	^{239}Pu	1

The radionuclides are assumed to be in the chemical form with the greatest impact, consistent with chemical behavior; thus, ^{137}Cs, ^{63}Ni, and ^{90}Sr are assumed to be soluble, and ^{239}Pu is assumed to be moderately soluble. These classifications also are compatible with the waste streams that generated the wastes. The inhalation dose coefficients are taken from Federal Guidance Report No. 11 (EPA 520/1-88-020), *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion*. Table F1-16 shows radionuclide inhalation classes and dose coefficients.

Table F1-16. Radionuclide Inhalation Classes and Dose Coefficients.

Radionuclide	Inhalation Class	Dose Coefficient (rem/pCi)
^{137}Cs	D	3.2×10^{-8}
^{63}Ni	D	3.1×10^{-9}
^{90}Sr	D	2.4×10^{-7}
^{239}Pu	W	4.2×10^{-4}

The doses per unit operation resulting from inhalation are the sums of the products of the quantity of contaminated soil inhaled, the concentration of the radionuclide, and the dose coefficient. The excavation activities cease at the top of the low-activity soil; the low-activity soil does not contribute to doses from excavation, covering the container, dumping, or bulldozing. However, a small component from wind-driven resuspension from the top of the layer is included for the workers near the trenches. These are summarized for Trench 216-B-26 in Table F1-17.

Table F1-17. Committed Dose Rates per Unit of Airborne Exposure for Excavation and Disposal Activities.

Worker Type	High-Activity Soil	Moderate-Activity Soil	Low-Activity Soil	Units
Excavator operator/laborer	4.3×10^{-4}	1.2×10^{-5}	3.1×10^{-9}	rem/hour
Covering transport container	2.1×10^{-6}	5.7×10^{-8}	3.1×10^{-9}	rem/hour
Container dumping assistant	1.2×10^{-4}	3.2×10^{-6}	--	rem/load
Bulldozer operator	4.2×10^{-4}	1.1×10^{-5}	--	rem/hour

-- = Indicates that this waste form is not transported to this location.

As can be seen in Table F1-18 in Section F1.6, even for the case of the unprotected worker (no effort to control airborne radiological exposure) the internal dose—primarily from Sr-Y-90—is quite small. The total calculated internal dose for the unprotected worker scenario is 0.23 person-rem for the entire trench or approximately 0.5 percent of the total dose. This is easily within the uncertainty of the external dose estimate.

In the case of the protected workers, every reasonable effort will be made to avoid internal exposure. A direct effort to prevent visible dust in the air will be made; this will reduce internal exposures. Care will be taken to avoid ingestion, because the soil will be treated as radioactive material and handled accordingly. Airborne activity will be monitored with air sampling, and respiratory equipment will be used if needed. Thus, there is good reason to expect that the internal exposure for the protected case will be somewhat less than that of the unprotected case. Furthermore, it seems likely that the fraction of the total dose that is internal for the protected case will be as low as (or nearly as low as) that for the unprotected case (0.5 percent). Because this will be a small fraction of the total external dose, there is no reason to spend the resources to estimate it for the protected case. Thus, it will not be estimated and included in the overall estimate.

F1.6 RESULTS OF DOSE CALCULATIONS

This section summarizes the results of the calculations to estimate the dose to excavate the BC Cribs and Trenches. A discussion of the uncertainty in these calculations is given below.

Tables F1-18 and F1-19 combine results from many calculations and deserve some explanation. The tables summarize the dose calculations made for Trench 216-B-26 for the unprotected and the protected cases. In the case of Table F1-18 (for the unprotected case), external and internal dose assessments are included. The internal dose is not included in the protected case summarized in Table F1-19, because the calculations on the protected case had shown that it is negligible. In addition, there is no contribution from the low-activity soil reflected in Table F1-19 for the protected case, because it also had been shown to be negligible in the unprotected case.

Table F1-18 reflects a complicating factor in the assessment of internal contaminations. The internal doses from all of the sources except one are due to chronic exposure and thus are given in dose per unit time (rem/hour). However, one of them, the dose to the dump assistant, was given in dose per load, because the internal exposure to the dump assistant is due to a puff of airborne radioactive material. This is shown in Table F1-17. Thus, in Table F1-18, in the case of the internal exposure of the dump assistant, the number of containers and dose per container are used, rather than the exposure time and dose rate.

The external dose rates used are derived in Chapter F2.0 for the unprotected worker and in Chapter F3.0 for the protected worker.

Table F1-18. Unprotected Worker Dose Summary for Excavating Trench 216-B-26. (2 Pages)

Worker Type	Dose Type	Exp. Source	Number of Workers	Exposure Time (h) or Number of Containers[2,3]	Dose Rate (mR/h) or Dose per Container	Dose for Type (mR) or (mrem)	Total Dose Worker[1] (mrem)	Total Dose Work Area (mrem)	Total Dose (mrem)
Excavation Site Activities and Dose for a 10-ft Section of Trench									
Excavator operator	External	High-activity soil	1	1.64	12.69	20.81	--	--	--
		Moderate-activity soil	1	2.07	0.25	0.52	--	--	--
		Low-activity soil	1	6	0.03	0.18	21.51	--	--
	Internal	High-activity soil	1	1.64	0.43	0.71	--	--	--
		Moderate-activity soil	1	2.07	0.012	0.02	--	--	--
		Low-activity soil	1	6	0	0.00	0.73	--	--
Dust sprayer	External	High-activity soil	1	1.64	20.7	33.95	--	--	--
		Moderate-activity soil	1	2.07	0.36	0.75	--	--	--
		Low-activity soil	1	6	0.03	0.18	34.87	--	--
	Internal	High-activity soil	1	1.64	0.43	0.71	--	--	--
		Moderate-activity soil	1	2.07	0.012	0.02	--	--	--
		Low-activity soil	1	6	0	0.00	0.73	--	--
Cover installer	External	High-activity soil	2	0.21	204	85.68	--	--	--
		Moderate-activity soil	2	0.21	6.71	2.82	88.50	--	--
	Internal	High-activity soil	2	0.21	0.002	0.00	--	--	--
		Moderate-activity soil	2	0.21	0.00006	0.00	--	--	--
		Low-activity soil	2	6	0	0.00	0.00	--	--
Shuttle driver	External	High-activity soil	1	0.21	100	21.00	--	--	--
		Moderate-activity soil	1	0.21	2.79	0.59	21.59	167.93	--

Table F1-18. Unprotected Worker Dose Summary for Excavating Trench 216-B-26. (2 Pages)

Worker Type	Dose Type	Exp. Source	Number of Workers	Exposure Time (h) or Number of Containers[2,3]	Dose Rate (mR/h) or Dose per Container	Dose for Type (mR) or (mrem)	Total Dose Worker[1] (mrem)	Total Dose Work Area (mrem)	Total Dose (mrem)
Cross-Site Transfer Activities for a 10-ft Section of Trench									
Cross-site driver	External	High-activity soil	1	0.63	21.9	13.80	--	--	--
		Moderate-activity soil	1	0.63	0.61	0.38	14.18	14.18	--
ERDF Site Activities for a 10-ft Section of Trench									
Shuttle driver	External	High-activity soil	1	0.31	100	31.00	--	--	--
		Moderate-activity soil	1	0.31	2.79	0.86	31.86	--	--
Dump assistant	External	High-activity soil	1	0.1	278	27.80	--	--	--
		Moderate-activity soil	1	0.1	7.8	0.78	28.58	--	--
	Internal	High-activity soil[2,3]	1	1.25[2,3]	0.12	0.15	--	--	--
		Moderate-activity soil[2,3]	1	1.25[2,3]	0.003	0.00	0.15	--	--
Bulldozer operator	External	Average-activity soil	1	0.1	248	24.80	24.80	--	--
	Internal	Average-activity soil	1	0.1	0.22	0.02	0.02	85.42	268

[1]It is assumed that a worker present where the air receives an exposure of 1 roentgen will receive an effective dose equivalent of 1 rem. This is a conservative assumption.

[2]Number of containers dumped.

[3]Committed effective dose equivalent per container dumped.

ERDF = Environmental Restoration Disposal Facility.

Table F1-19. Dose Summary for Excavating Trench 216-B-26 with In-Trench Mixing. (2 Pages)

Worker Type	Dose Type	Exp. Source	Number of Workers	Exposure Time (h)	Dose Rate (mR/h)	Dose for Type (mrem)	Total Dose Worker (mrem)	Total Dose Work Area (mrem)	Total Dose (mrem)
Excavation Site Activities and Dose for a 25-ft Section of Trench									
Excavator operator	External	High-activity soil	1	4	3.5	14.00	--	--	--
		Mixed high-activity soil	1	18.8	1.15	21.62	--	--	--
		Mixed high- and high-activity soil	1	6.4	4.65	29.76	--	--	--
		Moderate-activity soil	1	5.2	0.086	0.45	65.83	--	--
Dust sprayer	External	High-activity soil	1	0.6	16.7	10.02	--	--	--
		Mixed high-activity soil	1	2.8	7.92	22.18	--	--	--
		Mixed high- and high-activity soil	1	1	24.62	24.62	--	--	--
		Moderate-activity soil	1	0.78	0.53	0.41	57.23	--	--
HPT: bucket	External	Mixed high-activity soil	1	0.12	6.81	0.82	--	--	--
		Moderate-activity soil	1	0.02	1.36	0.03	0.84	--	--
Cover installer	External	Mixed high-activity soil	2	0.73	33.53	48.95	--	--	--
		Moderate-activity soil	2	0.1	6.71	1.34	50.30	--	--
HPT: ERDF canister	External	Mixed high-activity soil	1	1.83	20.86	38.17	--	--	--
		Moderate-activity soil	1	0.25	4.17	1.04	39.22	--	--
Shuttle driver	External	Mixed high-activity soil	1	3.7	1.8	6.66	--	--	--
		Moderate-activity soil	1	0.5	0.36	0.18	6.84	220.25	--

Table F1-19. Dose Summary for Excavating Trench 216-B-26 with In-Trench Mixing. (2 Pages)

Worker Type	Dose Type	Exp. Source	Number of Workers	Exposure Time (h)	Dose Rate (mR/h)	Dose for Type (mrem)	Total Dose Worker (mrem)	Total Dose Work Area (mrem)	Total Dose (mrem)
Cross-Site Transfer Activities for a 25-ft Section of Trench									
Cross-site driver	External	Mixed high-activity soil	1	11	3.06	33.66	--	--	--
		Moderate-activity soil	1	1.5	0.61	0.92	34.58	34.58	--
ERDF Site Activities for a 25-ft Section of Trench									
HPT: ERDF canister	External	Mixed high-activity soil	1	0.92	20.86	19.1912	--	--	--
		Moderate-activity soil	1	0.13	4.17	0.5421	19.73	--	--
Shuttle driver	External	Mixed high-activity soil	1	5.5	1.8	9.90	--	--	--
		Moderate-activity soil	1	0.75	0.36	0.27	10.17	--	--
Dump assistant	External	Mixed high-activity soil	1	1.8	38.34	69.01	--	--	--
		Moderate-activity soil	1	0.24	7.67	1.84	70.85	--	--
Bulldozer operator	External	Average-activity soil	1	2	22.85	45.70	45.70	146.46	401.28
Total dose for 500-ft Trench 216-B-26: 8.0 person-rem									

HPT = health physics technician.
ERDF = Environmental Restoration Disposal Facility.

F1.6.1 Dose Estimate for Excavating without Radiological Protection

The best estimate of the collective dose to excavate Trench 216-B-26 without radiological controls is 13.4 person-rem. For this, the best estimate to excavate the BC Cribs and Trenches without radiological controls is 127 person-rem. This collective dose to excavate the cribs and trenches is 46 percent of the Hanford Site collective dose for 2003. It is believed that these estimates are somewhat conservative, but not extremely so.

1. Collective Dose Estimate for the Unprotected Excavation of Trench 216-B-26

   Table F1-18 summarizes the overall collective dose estimate for a 10-ft section of the trench. The total expected collective dose for the excavation of the 10-ft section of the trench is about 0.268 person-rem. The collective dose estimate for the entire 500-ft trench is about 13.4 person-rem.

   The estimated internal exposure is about 0.082 person-rem, or less than 1 percent of the total collective dose.

   The greatest part, about 63 percent, of the collective dose takes place during the excavation phase of the work. About 32 percent of the dose is received at ERDF and about 5 percent of the dose is received during the transportation of containers from the excavation site to ERDF.

2. Collective Dose Estimate for the Unprotected Excavation of the BC Cribs and Trenches

   An examination of the MicroShield calculations shows that almost the entire external dose from photons is due to Cs-137 (Ba-137m). As discussed in Section F2.5, the external beta exposure from Sr-Y-90 is very small. As discussed in Section F2.6 and summarized in Table F1-9, the internal dose is a tiny fraction of the external dose, which is, as discussed, due almost entirely to Cs-137 (Ba-137m). If the excavation techniques and problems at each trench and crib are about the same, then the total dose for each crib and trench is roughly proportional to the total Cs-137 inventory in that crib or trench.

   The SIM provides internally consistent Cs-137 inventories for each crib and trench (see Table F1-9). Given that the dose for Trench 216-B-26 has been independently estimated, the total dose for a given trench or crib can be estimated by multiplying the total dose for Trench 216-B-26 by the ratio of the Cs-137 inventory in the crib or trench in question to the Cs-137 inventory in Trench 216-B-26 (from the SIM). This is shown in Table F1-9. By this method and under these assumptions, the total estimated collective dose for excavating the BC Cribs and Trenches is about 127 person-rem. This dose is about 46 percent of the total Hanford Site collective dose for 2003 (approximately 279 person-rem) (personal communication, P. S. Barajas, May 13, 2004).

F1.6.2 Dose Estimate for Excavating with Radiological Protection

1. Collective Dose Estimate for the Protected Excavation of Trench 216-B-26

   The estimated total collective dose to protected workers excavating Trench 216-B-26 is 8.0 person-rem (Table F1-19). Approximately 55 percent of the collective dose is received at the excavation site, 9 percent in the cross-site transfer activities, and 36 percent at ERDF. The estimated 8.0 person-rem for protected workers is about 60 percent of the dose estimated for unprotected workers. In this calculation, no account is taken of the low-activity layer, because its contribution would be negligible.

2. Collective Dose Estimate for the Protected Excavation of the BC Cribs and Trenches

   Using the value calculated for collective dose and the SIM Cs-137 inventories per site, and assuming that the collective dose to workers is roughly proportional to the Cs-137 inventory of the site being excavated, the total collective dose to excavate the BC Cribs and Trenches with radiological protection is 76 person-rem (see Table F1-10).

F1.7 DISCUSSION OF UNCERTAINTIES

The sources of uncertainty in this assessment can be conveniently divided into those associated with the source term and those associated with the process. It is likely that the dominant uncertainty is that due to the uncertainty in the source term and the resultant source term model.

F1.7.1 Uncertainties in the Source Term Model and the Soil Inventory Model

It is believed that the main uncertainty in the calculations discussed here is due to the uncertainties in the source term, which are reflected in the source term model used. There are also uncertainties in the SIM, which is used here as a check on the estimated source term.

1. Uncertainties in the Source Term

   To get some understanding of the uncertainty of the estimates made, the estimates of the Cs-137 concentrations from the gamma logs (not adjusted for the soil sample data) for the high and moderate activity layers were fit to the best probability distribution using Crystal Ball[1] (an add-on to Excel) and the *Crystal Ball 2000 User Manual*. Crystal Ball compares the data to its complete library of continuous distributions and using the goodness-of-fit criterion specified, determines the distribution that best fits the data. Crystal Ball compares the data to 11 continuous distributions: normal, triangular, lognormal, uniform, exponential, Weibull, beta, gamma, logistic, Pareto, and extreme value. Three goodness-of-fit criteria can be specified: chi-square, Kolmogorov-Smirnov,

[1]Crystal Ball is a trademark of Decisioneering, Inc., Denver, Colorado.

and Anderson Darling. For both cases and for each goodness-of-fit criterion, Crystal Ball consistently picked the lognormal distribution as the best fit. It also reported that the fits were not particularly good. Thus, the best available (but not really good) estimate for the probability distribution of the soil sample concentrations is the lognormal.

The lognormal distribution is not an unexpected fit, because it is often found to represent environmental pollutants. This distribution usually is strongly skewed to the right, indicating the presence of very high concentrations (as it is in this case). (The presence of high concentrations in some locations is known also from field measurements [see Table F1-1.]) For the lognormal distribution, the best estimate of central tendency is accepted to be the geometric mean (which also is the median or 50 percent percentile value). At this point, one would expect as many values below the median as above the median. The arithmetic mean of the distribution is higher than the geometric mean, because it is biased high by the large values on the tail of the distribution. In this case, the arithmetic mean of the measured samples (not of the predicted distribution) is used as the value for calculating the exposures. The arithmetic mean of the samples was chosen because it is the best estimate of the control tendency taken from the actual measured field data. It is somewhat higher than the geometric mean of the distribution and thus somewhat, but not radically, conservative and, therefore, takes some account for the uncertainty in the calculations. Although the dose will be calculated for the arithmetic mean of the measured values, it will be estimated for the geometric mean and some other percentiles estimated from the distribution fit. See Table F1-20 for the Cs-137 concentrations corresponding to the geometric mean of the distribution and the arithmetic mean of the samples.

Table F1-20. Geometric Means of the Lognormal Distributions and Arithmetic Means of the Samples for Cesium-137 Concentration for the High- and Moderate-Activity Layers.*

Layer of Soil	Concentration	Cs-137 Concentration (pCi/g)
High-activity	Geometric mean, 50% of Distribution	42,485
High-activity	Arithmetic mean of samples, about 80% of Distribution	498,086
Medium-activity	Geometric mean, 50% of distribution	1,149
Medium-activity	Arithmetic mean of samples, about 80% of distribution	13,331

*These values have not been adjusted upward by the soil sample results.

Table F1-21 gives the actual percentiles for the lognormal fit for both soil layers. These percentiles—assuming a lognormal distribution—were independently verified (personal communication, Christopher Murray, June 24, 2004).

Table F1-21. Percentiles for the Fitted Lognormal Distribution for the Measured Values of Cesium-137 Concentration for the High- and Moderate-Activity Layers.*

Percentile	High-Activity Cs-137 Concentrations (pCi/g)	Moderate-Activity Cs-137 Concentrations (pCi/g)
10th	990	33
20th	3,599	111
30th	9,125	268
40th	20,207	569
50th	42,485	1,149
60th	89,324	2,322
70th	197,813	4,927
80th	501,592	11,885
90th	1,822,903	40,304
95th	5,291,286	110,491
99th	39,056,463	732,669

*These values have not been adjusted upward by the soil sample results.

2. Uncertainties in the SIM

As mentioned above, the SIM uses the available production process information, such as reactor production calculations, chemical process records, and disposal records, to estimate the quantity of various analytes sent to the various disposal sites around the Hanford Site. The uncertainty in the factors in the calculation was represented as probability distributions and the individual probability distributions were combined using Monte Carlo calculations using Crystal Ball. Because the probability distributions used generally were non-normal, the median was used as the best estimate of central tendency. Thus, the SIM produced a probability distribution for the quantity of each analyte discharged to the BC Cribs and Trenches.

For Trench 216-B-26 for Cs-137, the percentiles are given in Table F1-22. The median value is the 50 percent percentile value.

3. Discussion of Uncertainty

It is useful to compare the predictions of the SIM for Cs-137 in Trench 216-B-26 to that predicted from the measured values. One check is to see if the total activity predicted by the arithmetic mean for the two layers falls within the range of total activities predicted by the SIM. (The two layers together do not hold 100 percent of the measured activity, but it is most of it.) Using the volumes of the layers (4 by 10 by 500 ft), the average measured activities given above and a soil density of 1.6 g/cc, the high-activity layer has a total activity of about 451 Ci and the moderate activity layer has a total activity of about 12 Ci, for a total activity of about 463 Ci. Multiplying this value by 3.3 to adjust for the soil sample measurements, one gets 1528 Ci. This falls in the upper range of the SIM prediction, between the 95 and 99.5 percentile.

Table F1-22. Trench 217-B-26 Cesium-137 Inventory Percentiles from the Source Inventory Model.

Percentile	Cs-137 Inventory (Ci)
0.5	109
5	191
10	237
15	273
20	305
25	336
30	367
35	399
40	431
45	462
50	500
55	538
60	581
65	630
70	685
75	750
80	827
85	923
90	1,058
95	1,281
99.5	1,941

The best estimate of central tendency of the SIM distribution of Cs-137 inventory in Trench 216-B-26 is considered by the SIM analyst to be the median (50 percent percentile) of 500 Ci. This is one-third the activity estimated by assuming that the average of the measured values is distributed throughout the modeled volume. Part of this discrepancy might be explained by recognizing that the activity is not uniformly distributed throughout the modeled volume but is highly irregular. The measured values, taken in the middle of the trench, could have overestimated the overall average. If this is the case, this would have the effect of lowering the estimated Cs-137 inventory to a value closer to the SIM estimate.

F1.7.2 Uncertainties in the Excavation Process Modeling

The calculation of the dose due to excavating Trench 216-B-26 involves estimates of a large number of physical parameters that go into the time and dose rate calculations. These estimates introduce an (unquantified) degree of uncertainty into the dose calculations. For instance, the

time of exposure to radiation from the trench for the excavator operator and the laborer spraying for dust suppression is determined by how long it takes to do the mixing and excavation, which, in turn, are determined by such quantities as the amount of soil in each excavator bucket and the number of excavator buckets per hour excavated. These basic values are estimates, but they are reasonable estimates, because such activities are reasonably simple to understand. Thus, the uncertainty introduced by process modeling is believed to be small compared to the uncertainty in the source term model and the SIM.

F1.8 SUMMARY OF INSIGHTS GAINED FROM THE MODELING

The primary purpose for modeling radiological exposure in decision-making processes is to gain insights into the nature of the problem, not to generate numbers. The following insights were gained from the modeling process.

- The human dose from digging up the cribs and trenches without radiological controls is unacceptably high.
- Most of the human dose is from external exposure to Cs-137 (Ba-137m) gamma rays. The internal dose from inhaled or ingested radionuclides is expected to be very small. In addition, the external dose from beta particles also is expected to be small compared to the external dose due to photons, almost exclusively from Cs-137.
- Airborne radioactivity during excavation likely will be readily controllable.
- Most of the near-surface radioactivity is in the first few feet below the effluent discharge level.
- Radiological controls can readily be applied to the excavation process to limit the expected human dose.
- The concentration of radioactivity in the ground beneath the cribs and trenches varies widely; e.g., over as much as 5 orders-of-magnitude in Trench 216-B-26. This has implications for radiological controls and the need for a means to dilute soil concentrations to keep the radiation levels from the ERDF containers from exceeding the acceptable radiation level. That is, although the average concentration of Cs-137 across the trench would imply one level of dose rate and one type of mixing (e.g., in-trench mixing) or even no mixing, the presence of reasonably large local areas of high concentrations may force additional radiological control, as well as other forms of mixing that can result in larger mixing ratios, such as using an external mixer.

F2.0 UNPROTECTED WORKER DOSE ESTIMATE FOR EXCAVATING A 500-FOOT TRENCH

F2.1 INTRODUCTION

This chapter describes the method used to develop the dose estimates for excavating a 500-ft trench with uranium recovery waste under the assumption that no actions are taken to protect workers from radiation and to minimize their exposure. In this case, simple excavation efficiency is the overriding consideration.

F2.2 SOURCE TERM

For the convenience of the reader, the model source term, given in Table F1-8, is repeated in Table F2-1.

Table F2-1. Model Source Term for the Three Soil Layers.

Layer	Radionuclide	Concentration (pCi/g)	Concentration (μCi/cm^3)
High-activity	Cs-137	1,600,000	2.6
	Ba-137m	1,500,000	2.5
	Sr-90	2,900,000	4.6
	Y-90	2,900,000	4.6
	Ni-63	6,400	0.01
	Pu-239	600	0.001
Moderate-activity	Cs-137	44,000	0.07
	Ba-137m	42,000	0.07
	Sr-90	79,000	0.13
	Y-90	79,000	0.13
	Ni-63	180	0.0003
	Pu-239	16	0.00003
Low-activity	Cs-137	2,300	0.004
	Ba-137m	2,200	0.004
	Sr-90	4,100	0.007
	Y-90	4,100	0.007
	Ni-63	9	0.00001
	Pu-239	1	0.000002

F2.3 SCENARIO FOR PHYSICAL EXCAVATION

The physical scenario is a description of those activities that are necessary to excavate the trench and that would cause human exposure to radiation. It is not an exhaustive description of all

activities and costs, but only those activities that would be expected to bring an individual doing a required task close enough to the radiation source to result in human exposure.

1. General Description of the Excavation Scenario

   This scenario was chosen because of simple efficiency. An excavator with a 42-ft boom, on which a bucket is mounted, will carry out trench excavation. The excavator will be positioned on top of the trench (i.e., the overburden at ground level) and will move down the trench, excavating as it goes. The trench will be excavated to a depth of 18 ft; a width of 10 ft will be excavated at the maximum depth. This depth will ensure that all high and moderate concentration soils are removed. This assumes no lateral spreading of the waste in the soil. The surface slope on both sides and in front of the excavator will be 1.5:1 (horizontal:vertical). A laborer will spray the soil, in accordance with normal industrial practice, to suppress dust. The excavator operator and the laborer will be exposed to radiation and airborne radioactivity during this process.

   The excavator will place the excavated soil in a container that is loaded onto a shuttle truck, which is parked alongside the trench. Once a container is full, a driver will drive the shuttle truck a short distance to an area where two laborers will install a fabric cover to prevent dust from blowing as the container is moved across-site. The driver then will drive the shuttle truck to a surge queue located near the excavation site and place the container at that site. The excavation site shuttle truck drivers and the laborers installing the cover will be exposed to radiation as the trucks are moved from the trench to the queue.

   Another truck will pick up the container, drive it to the ERDF site, and drop it in the ERDF queue. The driver will be exposed to radiation while transporting the containers from queue to queue.

   An ERDF shuttle truck will load and move the containers to the ERDF dump site, where the soil is dumped. A laborer will open the truck and spray water to settle the dust. Once the soil is dumped, a bulldozer will be used to spread the soil. The shuttle truck driver, the laborer, and the bulldozer operator will be exposed to radiation during this process. The laborer and the bulldozer operator will be exposed to airborne radioactivity.

   The total radiation dose for this process will be calculated for one 10-ft section of the trench. This value will be multiplied by 50 to obtain the total exposure for the trench. A 10-ft section was chosen because that is about the maximum distance that 42-ft boom operators can work and still maintain a 1.5:1 bank slope in front of them.

   This process is illustrated in Figures F2-1 and F2-2.

2. Detailed Description of the Scenario

   This section describes the details of the activities required to remove 10 ft of the trench. Note that the activities are not in exact excavation order, but similar activities for the two layers are grouped together.

Figure F2-1. Sketch of Unprotected Worker Excavation and Transport Process.

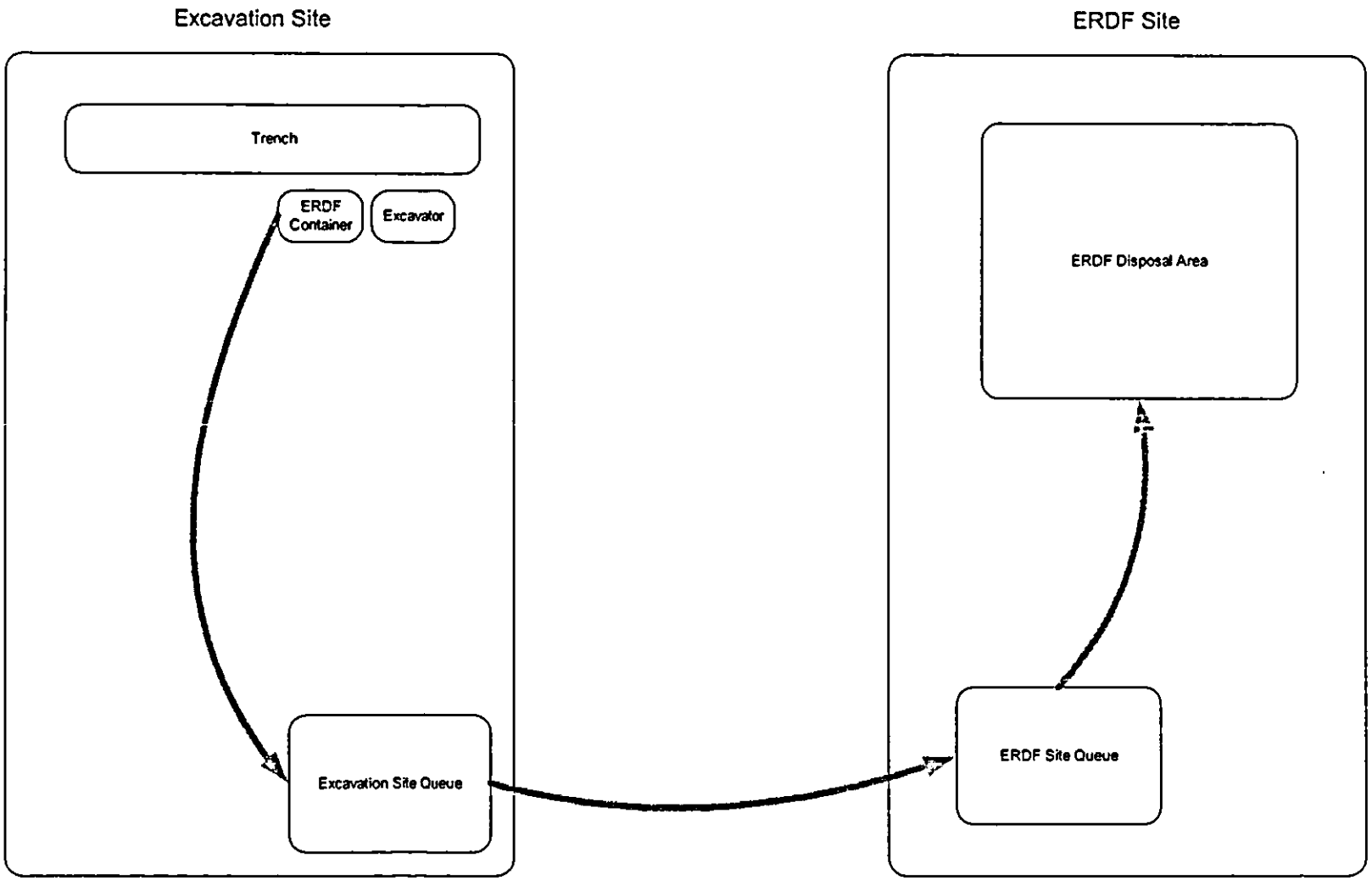
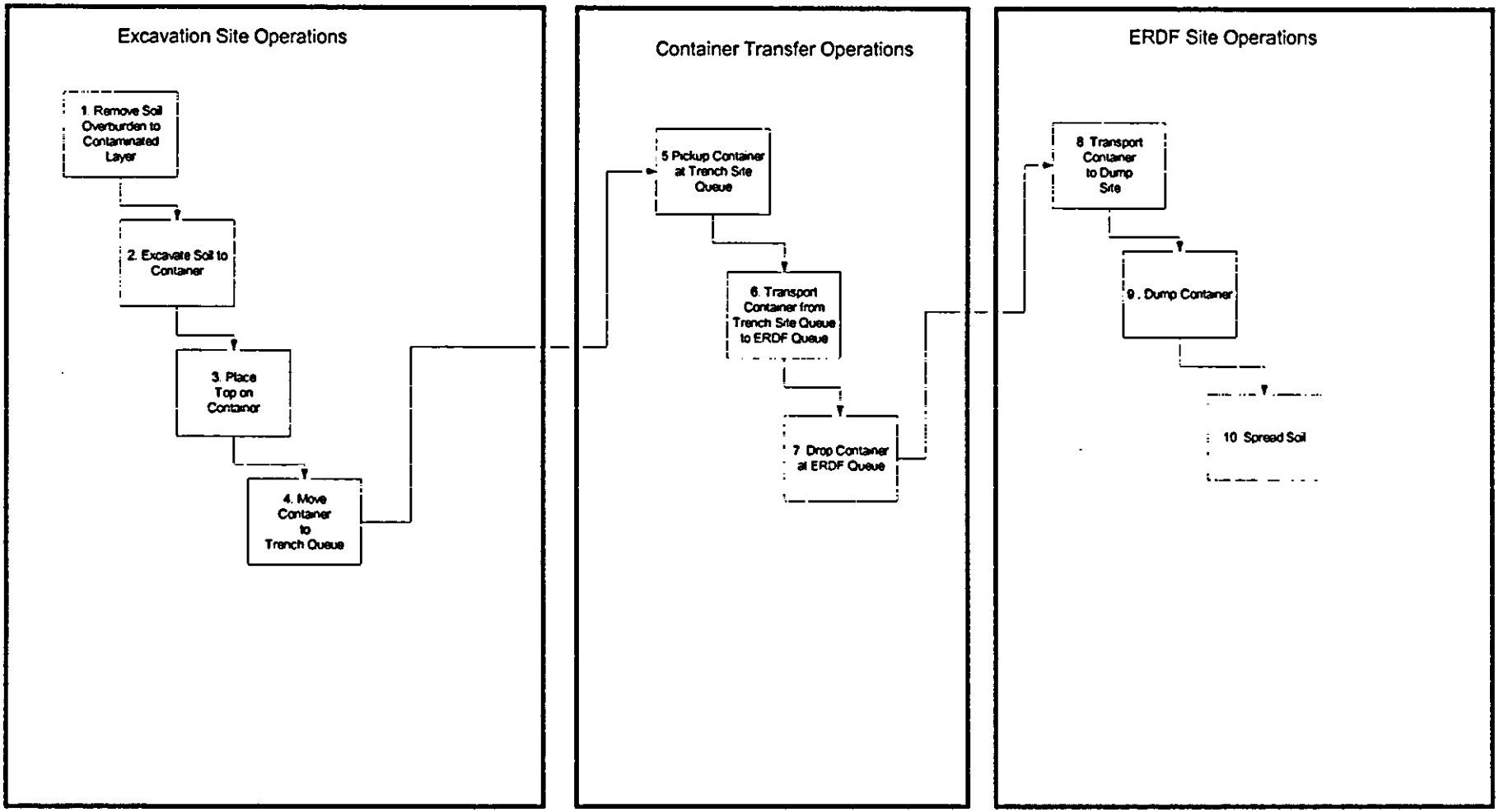


Figure F2-2. Overview of Unprotected Worker Excavation Scenario – Trench 216-B-26.



Step 1: Removal of High-Activity Layer

After the initial soil is removed down to the high-activity layer (which is assumed to result in no radiation exposure), the soil in the layer that includes the high-activity layer will be removed. The time to remove the layer is the total volume of soil necessary to remove the actual high-activity soil divided by the excavation rate. The average exposure rate to the excavator operator and the sprayer will be the exposure rate from a high-activity slab that is 10 by 10 by 2 ft, or half the thickness of the actual slab. Half the thickness is used, because this would be the average thickness over the entire removal period.

The volume of soil is 1,840 ft^3 (see Figure F2-3[1]) and the excavation rate is 1,120 ft^3/h, so the total exposure time for this step is 1.64 hours. The dimensions of the bucket are assumed to be 5 ft deep by 3 ft wide by 5 ft high (approximately the same as that discussed in BHI-01558) with a total volume of 75 ft^3. Assuming an average 75 percent fill, the amount removed per bucket is 56 ft^3. Assuming 20 buckets per hour, the excavation rate is 1,120 ft^3/h. Figure F2-3 shows the volume of soil to be removed. The actual volume of high-activity soil removed is 400 ft^3 (10 ft length by 10 ft width by 4 ft height). The volume of soil held by one ERDF container filled to 2 ft is 320 ft^3 (see the following discussion). Thus, one 10-ft section of trench will yield 1.25 ERDF containers of high-activity soil.

The excavator operator and sprayer will be exposed to airborne radioactive material during this period.

Step 2: Removal of Moderate-Activity Layer

After the high-activity soil is removed down to the moderate-activity layer, the soil in the layer that includes the moderate-activity layer will be removed. The time to remove the layer is the total volume of soil necessary to remove the actual moderate-activity soil divided by the excavation rate. The average exposure rate to the excavator operator and the sprayer will be the exposure rate from a moderate-activity slab that is 10 by 10 by 2 ft, or half the thickness of the actual slab. Half the thickness is used because this would be the average thickness over the entire removal period.

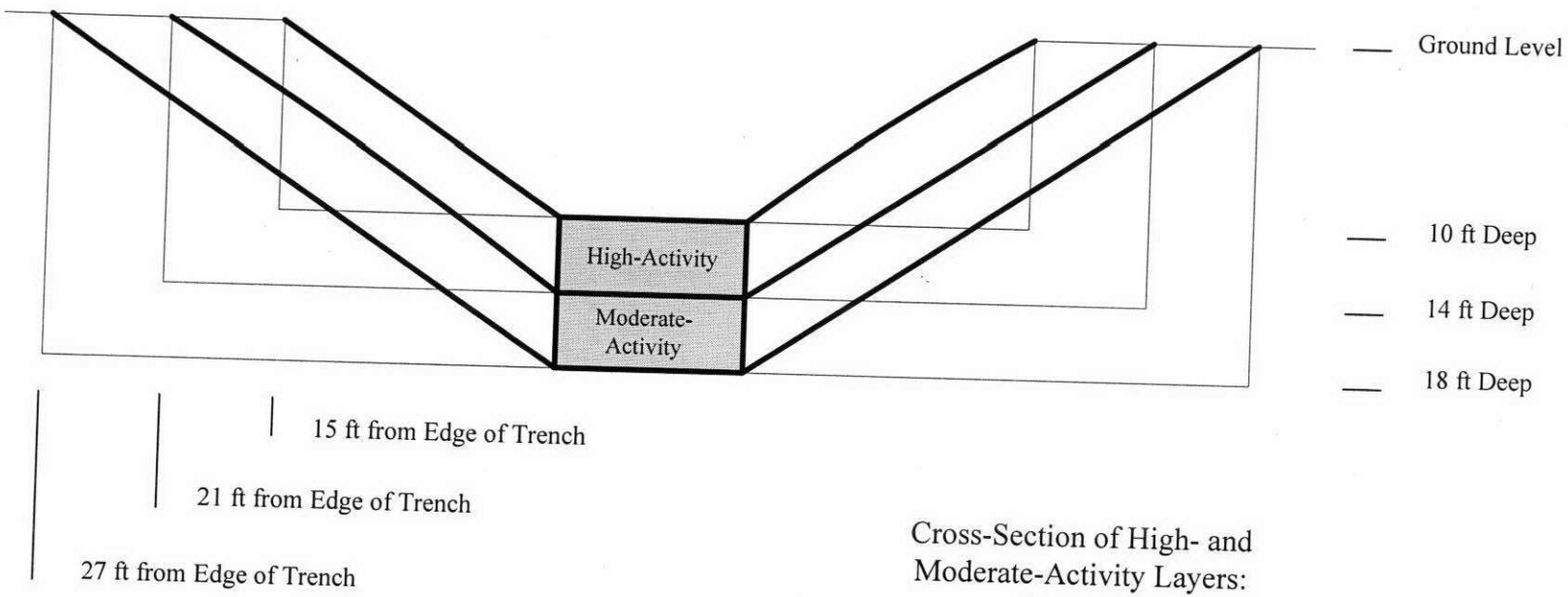
The excavator operator and sprayer will be exposed to airborne radioactive material during this period.

[1]This figure shows the cross-section as vertical with a thickness of 10 ft. The actual surface of the excavated area is not vertical, but is a somewhat complex three-dimensional surface. However, in this case, the excavation thickness also is 10 ft. Because both cases model a 10-ft segment and both excavate the trench in 50 segments (ignoring some minor end effects), the simpler geometry has about the same volume as the complex one. For this reason, the simpler geometry was chosen as the model geometry.

Figure F2-3. View of Excavation Area Down the Center Axis of the Trench.

Slope of the trench walls are in the ratio of 1 (height): 1.5 (width).

This view shows the depth and width of the trench at three depths: (1) top of high-activity layer; (2) interface between high- and moderate-activity layers; and (3) bottom of the moderate-activity layers. The sloping thick lines represent the walls of the trench at various excavation depths.



Cross-Section of High- and Moderate-Activity Layers: 10 by 4 ft

The volume of soil is 2,320 ft^3 and the excavation rate is 1,120 ft^3/h, so the total exposure time for this step is 2.07 hours. Figure F2-3 shows the volume of soil to be removed. The actual volume of moderate-activity soil removed is 400 ft^3 (10 ft length by 10 ft width by 4 ft height). The volume of soil held by one ERDF container filled to 2 ft is 320 ft^3 (see the following discussion). Thus, one 10-ft section of trench will yield 1.25 ERDF containers of moderate-activity soil.

Step 3: Exposure of the Excavator Operator and Sprayer to the Low-Activity Layer

The excavator operator and the sprayer will be exposed to radiation from the low-activity layer once it is exposed. The average exposure rate to these workers will be reached when the trench is half exposed (250 ft). Thus, the exposure rate will be taken to be this value and the exposure time will be the time to excavate a 10-ft length of trench or 6 hours. The total volume of soil excavated for a 10-ft length of trench is 6,660 ft^3 (see Figure F2-3). At an excavation rate of 1,120 ft^3/h, this process will take 5.95 or 6 hours.

Step 4: Installation of the Fabric Cover Over the High-Activity Container

Two workers will install the fabric dust cover over the high-activity container while standing on a scaffold beside the container. As such, they will be directly exposed to the high-activity soil in the container without any shielding from the container wall. The estimated time to install one cover is 0.17 hour. (It is assumed that the cover will be installed at some distance from the trench such that the laborers will not be exposed from the trench.) The volume of soil to which they are exposed is that of one ERDF container, approximately 22 ft long by 7.25 ft wide by 2 ft deep, filled to 2 ft (see BHI-01558). The total volume of soil held by one ERDF container filled to 2 ft is about 320 ft^3. Thus, for each 10 ft of trench, 1.25 covers will be installed over high-activity soil. Thus, the total installation time for the 1.25 covers is 0.21 hour.

Step 5: Installation of the Fabric Cover over the Moderate-Activity Container

Two workers will install the fabric dust cover over the moderate-activity container while standing on a scaffold beside the container. As such, they will be directly exposed to the moderate-activity soil in the container without any shielding from the container wall. The estimated time to install one cover is 0.17 hour (10 minutes). (It is assumed that the cover will be installed at some distance from the trench such that the laborers will not be exposed from the trench.) Thus, for each 10 ft of trench, 1.25 covers will be installed over moderate-activity soil in an ERDF container. Therefore, the total installation time for the 1.25 covers is 0.21 hour.

Step 6: Transport of the High-Activity Container from the Trench to the Excavation Site Queue Area

The shuttle truck driver will be exposed to radiation while driving the shuttle truck with the high-activity container from the trench to the queue area. It is estimated that this trip will take 0.17 hour per container (10 minutes). The shuttle truck driver is assumed to be situated 3.5 ft (see BHI-01558) from the front surface of the ERDF container. The ERDF

container is assumed to be fabricated of ¼-in. (6 mm) steel (see BHI-01558). Thus, the total time for 1.25 containers is 0.21 hour.

Step 7: Transport of the Moderate-Activity Container from the Trench to the Excavation Site Queue Area

The shuttle truck driver will be exposed to radiation while driving the shuttle truck with the moderate-activity container from the trench to the queue area. It is estimated that this trip will take 0.17 hour/container (10 minutes). The shuttle truck driver is assumed to be situated 3.5 ft (see BHI-01558) from the front surface of the ERDF container. The ERDF container is assumed to be fabricated of ¼-in. (6 mm) steel (see BHI-01558). Thus, the total time for 1.25 containers is 0.21 hour.

Step 8: Transport of the High-Activity Container from the Excavation Site Queue to the ERDF Queue

The cross-site truck driver will be exposed to radiation from the high-activity container while driving the container from the excavation site queue to the ERDF queue. The transport time is taken to be 0.5 hours/container (30 minutes). Thus, the total time for a 10-ft section of trench is 0.63 hours. The cross-site truck driver is assumed to be situated 9.0 ft (see BHI-01558) from the front surface of the ERDF container. The ERDF container is assumed to be fabricated of ¼-in. (6 mm) steel (see BHI-01558).

Step 9: Transport of the Moderate-Activity Container from the Excavation Site Queue to the ERDF Queue

The cross-site truck driver will be exposed to radiation from the moderate-activity container while driving the container from the excavation site queue to the ERDF queue. The transport time is taken to be 0.5 hours/container (30 minutes). Thus, the total time for a 10-ft section of trench is 0.63 hours. The cross-site truck driver is assumed to be situated 9.0 ft (see BHI-01558) from the front surface of the ERDF container. The ERDF container is assumed to be fabricated of ¼-in. (6 mm) steel (see BHI-01558).

Step 10: Transport of the High-Activity Container from the ERDF Queue to the Dump Site

The shuttle truck driver will be exposed to radiation while driving the shuttle truck with the high-activity container from the ERDF queue to the dump site. It is estimated that this trip will take 0.25 hours/container (15 minutes). Thus, the total time for a 10-ft section of trench is 0.31 hours. The shuttle truck driver is assumed to be situated 3.5 ft (see BHI-01558) from the front surface of the ERDF container. The ERDF container is assumed to be fabricated of ¼-in. (6 mm) steel (see BHI-01558).

Step 11: Transport of the Moderate-Activity Container from the ERDF Queue to the Dump Site

The shuttle truck driver will be exposed to radiation while driving the shuttle truck with the moderate-activity container from the ERDF queue to the dump site. It is estimated

that this trip will take 0.25 hour/container (15 minutes). Thus, the total time for a 10-ft section of trench is 0.31 hour. The shuttle truck driver is assumed to be situated 3.5 ft (see BHI-01558) from the front surface of the ERDF container. The ERDF container is assumed to be fabricated of ¼-in. (6 mm) steel (see BHI-01558).

Step 12: Dumping of the High-Activity Container at the ERDF Disposal Site

The laborer assisting with the dumping of the high-activity container will be exposed to radiation at the ERDF disposal site. The laborer opens the back of the truck and sprays for dust suppression. It is estimated that this activity will take 0.08 hour/container (5 minutes). Thus, the total time for a 10-ft section of trench is 0.10 hour.

The laborer will be exposed to airborne radioactive material during this period.

Step 13: Dumping of the Moderate-Activity Container at the ERDF Disposal Site

The laborer assisting with the dumping of the moderate-activity container will be exposed to radiation at the ERDF disposal site. It is estimated that this activity will take 0.08 hour/container (5 minutes). Thus, the total time for a 10-ft section of trench is 0.10 hour.

The laborer will be exposed to airborne radioactive material during this period.

Step 14: Spreading of the High- and Moderate-Activity Soil by the ERDF Bulldozer Operator

The bulldozer operator will be exposed to radiation from the spreading of the high- and moderate-activity soil at the ERDF disposal site. The average exposure rate to the bulldozer operator will be determined by calculating the exposure rate to the operator's location from a 0.25 ft (3 in.) high cylinder whose diameter is determined by half the volume of the highly and moderately contaminated soil excavated from the trench and whose concentrations are the average of the concentrations of the high- and moderate-activity soils for each radionuclide. The bulldozer operator will be effectively shielded from a certain area of soil by the mass of the machine; the dose component from a 12-ft diameter disc under the operator will be subtracted to account for this. The exposure time is taken to be 0.08 hour/container (5 minutes). Thus, the exposure time for a 10-ft section of trench is 0.10 hour.

Half the total volume of high- and moderate-activity soil excavated from the trench is 10 ft wide by 8 ft deep by 250 ft long or 20,000 ft^3. The radius of a cylinder with this volume and 0.25 ft deep is 160 ft.

Thus, the dose rate to the bulldozer operator will be calculated by first determining the dose rate at a distance of 6 ft above the center point of a 160-ft radius, 0.25 ft high cylinder with average activity in the soil. The dose rate from a 6-ft radius cylinder directly under the dozed operator will be subtracted. The dose per container then will be calculated using the exposure time per container (0.08 hour). The total direct dose for this activity is the dose rate per container times the total number of containers.

Because the volumes of the high- and moderate-activity soils are the same, the average activity concentration is just a simple average of these two:

- Cs-137: 820,00 pCi/g or 1.3 μCi/cc
- Ba-137m: 780,000 pCi/g or 1.2 μCi/cc
- Sr-90: 1,500,000 pCi/g or 2.4 μCi/cc
- Y-90: 1,500,000 pCi/g or 2.4 μCi/cc
- Ni-63: 3,300 pCi/g or 0.005 μCi/cc
- Pu-239: 300 pCi/g or 0.0005 μC/cc.

The bulldozer operator will be exposed to airborne radioactive material during this period.

F2.4 INDIVIDUAL (DETAILED) CALCULATIONS OF EXTERNAL DOSE

All of the calculations reviewed in this section were performed using MicroShield v6.02. Table F2-1 gives the source term used in these calculations. The source dimensions used are given in the appendices under the section "Source Dimensions" at the top of the first page of each appendix.

1. Excavator and Sprayer Exposure to High-Dose Slab

   It is assumed that the average locations of the sprayer and the excavator operator are the same locations above and behind the center of the high-dose slab. These dose points will be different because of the height and depth of the excavator. (It is assumed that the excavator will be 5 ft behind and 5 ft above the sprayer.) The sprayer will be located 15 ft behind and 10 ft above the high-activity slab. The bulldozer operator will be located 20 ft behind and 15 ft above the slab.

   The exposure rate at the sprayer's location is 20.70 mR/h and for the excavator operator, 12.69 mR/h. See Appendix A.

2. Excavator and Sprayer Exposure to Moderate Dose Slab

   It is assumed that the average locations of the sprayer and the excavator operator are the same locations above and behind the center of the moderate dose slab. Their dose points will be different because of the height and depth of the excavator. The sprayer will be located 21 ft behind and 14 ft above the high-activity slab. The bulldozer operator will be located 26 ft behind and 19 ft above the slab.

   The exposure rate at the sprayer's location is 0.36 mR/h and for the excavator operator, 0.25 mR/h. See Appendix B.

3. Excavator and Sprayer's Exposure to Low Dose Slab

   It is assumed that the excavator and the sprayer will be exposed to the 250-ft long low-dose slab while located above the centerline of the slab and atop the dig face. The sprayer and the excavator operator will be assumed to be at the same location for this calculation, because their actual difference in location is insignificant in this particular calculation. The exposure rate to the excavator operator's and the sprayer's location is 0.03 mR/h. See Appendix C.

4. Container Sealers' Exposure to High-Dose Container

   The container sealers will be exposed to the exposed top of the high-dose container while standing immediately beside the container in the middle. The dose point for this calculation will be 1 ft from the side of the container and 5 ft above the soil in the container.

   The exposure rate at the container sealer's location is 240 mR/h. See Appendix D.

5. Container Sealers' Exposure to Moderate-Dose Container

   The container sealers will be exposed to the exposed top of the moderate-dose container while standing immediately beside the container in the middle. The dose point for this calculation will be 1 ft from the side of the container and 5 ft above the soil in the container.

   The exposure rate at the container sealer's location is 6.71 mR/h. See Appendix E.

6. Excavation Site and ERDF Shuttle Drivers and Cross-Site Driver Exposure to High-Dose Container

   The shuttle drivers and cross-site driver will be exposed to the high-dose container at different dose points. The shuttle driver will be 3.5 ft from the container and the cross-site driver will be 9 ft from the container because of the different types of trailers customarily used for these purposes. No credit will be taken for shielding from the truck cab. One-quarter inch of steel shielding from the container will be used. The doses to the drivers are calculated slightly off the center line, because the drivers are not located in the center of the cab.

   The exposure rate at the location of the shuttle driver is 100 mR/h and at the cross-site driver's location, 21.9 mR/h. See Appendix F.

7. Excavation Site and ERDF Shuttle Drivers and Cross-Site Driver Exposure to Moderate-Dose Container

   The shuttle drivers and cross-site driver will be exposed to the moderate dose container at different dose points. The shuttle driver will be 3.5 ft from the container and the cross-site driver will be 9 ft from the container because of the different types of trailers

customarily used for these purposes. No credit will be taken for shielding from the truck cab. One-quarter inch of steel shielding from the container will be used.

The exposure rate at the shuttle driver's location is 2.79 mR/h and at the cross-site driver's location, 0.61 mR/h. See Appendix G.

8. Dump Assistant's (Laborer) Exposure to High-Dose Container

The dump assistant (laborer at ERDF who assists the driver in dumping the soil from the container) will be exposed to the high-dose container when it is dumped. The worker is assumed to be 1 ft back from the rear corner of the container and 1 ft from the container.

The exposure rate at the dump assistant's location is 278 mR/h. See Appendix H.

9. Dump Assistant's Exposure to Moderate-Dose Container

The dump assistant will be exposed to the moderate-dose container when it is dumped. The worker is assumed to be 1 ft back from the rear corner of the container and 1 ft from the container.

The exposure rate at the dump assistant's location is 7.8 mR/h. See Appendix I.

10. Bulldozer Driver's Exposure to Average (High and Moderate) Activity Soil

The bulldozer driver's direct exposure will be estimated by calculating the exposure rate from a large, flat cylinder and subtracting the exposure from a small, flat cylinder that represents the shielding from the bulldozer. The large cylinder is assumed to be 160 ft in radius and 0.25 ft thick. The small cylinder is assumed to be 6 ft in radius and 0.25 ft thick. The large cylinder represents the soil from high- and moderate-activity layers for half the length of the trench. The activity from half the trench is used in order to represent the average exposure rate to the bulldozer operator. The small cylinder represents the footprint of the bulldozer, which effectively shields the driver from the activity beneath it.

The exposure rate at the bulldozer driver's location is 307 mR/h minus 59 mR/h or 248 mR/h. See Appendices J and K.

F3.0 PROTECTED WORKER DOSE ESTIMATE FOR EXCAVATING A 500-FOOT TRENCH

F3.1 INTRODUCTION

This task is to estimate the human radiation exposure that would be expected to be incurred during the excavation of one of the liquid waste disposal trenches in the BC Cribs and Trenches area.

To give the calculation specificity, Trench 216-B-26 was chosen as the model case, because it is the 500-ft trench with the best characterized radionuclide concentrations. No generality is lost here, because the exposure for excavation of these trenches is estimated to be roughly proportional to the Cs-137 inventory.

The estimate will proceed as follows:

1. A general description of trench retrieval will be described in order to give the reader an understanding of the process to be modeled in the dose estimate (Section F3.3, paragraph 1.).

2. The locations where workers likely would be exposed will be described, and the amount of time that they would be expected to spend at those locations will be estimated (Section F3.3, paragraph 2.).

3. The primary dose-contributing nuclides with photon emissions will be determined and their soil depth distributions will be estimated (Section F3.2).

4. The estimated doses from photon emissions to workers at the various locations described will be estimated using MicroShield v6.02 (Section F3.4).

5. The collective dose from photon exposure then will be estimated (Section F3.6).

F3.2 SOURCE TERM

The source term for this trench (216-B-26) is the same one given for Trench 216-B-26 (discussed in Section F2.2). The source term is reproduced in Table F3-1.

The high-activity soil will be mixed 6:1 with clean soil (total dilution of 7) before it is removed from the trench. The exposure at 1 ft from the side of an ERDF container with high-activity soil from Trench 216-B-26 is 341 mR/h (see Appendix L). Thus, to get the exposure rate to less than 50 mR/h, the criteria in BHI-00139, *Environmental Restoration Disposal Facility Waste Acceptance Criteria)*, one must mix this soil with clean soil in a ratio of 6:1 (actually, the total dilution required is 6.8). The concentration of mixed high-activity soil is given in Table F3-2.

Table F3-1. Model Source Term for the Three Soil Layers.

Layer	Radionuclide	Concentration (pCi/g)	Concentration (μCi/cm^3)
High-activity	Cs-137	1,600,000	2.6
	Ba-137m	1,500,000	2.5
	Sr-90	2,900,000	4.6
	Y-90	2,900,000	4.6
	Ni-63	6,400	0.01
	Pu-239	600	0.001
Moderate-activity	Cs-137	44,000	0.07
	Ba-137m	42,000	0.07
	Sr-90	79,000	0.13
	Y-90	79,000	0.13
	Ni-63	180	0.0003
	Pu-239	16	0.00003
Low-activity	Cs-137	2,300	0.004
	Ba-137m	2,200	0.004
	Sr-90	4,100	0.007
	Y-90	4,100	0.007
	Ni-63	9	0.00001
	Pu-239	1	0.000002

Table F3-2. Concentrations of Radionuclides in Mixed High-Activity Soil.

Radionuclide	Concentration (μCi/cc)
Cs-137	0.37
Ba-137m	0.35
Sr-90	0.66
Y-90	0.66
Pu-239	0.0001
Ni-63	0.001

F3.3 SCENARIO FOR PHYSICAL EXCAVATION

This section discusses the locations of workers with respect to the radioactive material and the amount of time the workers are exposed to the radioactive materials. Note that every possible configuration of radioactive material and worker that likely would occur during the excavation of

a trench cannot practically be modeled. In this estimate, only the primary exposure paths are modeled in order to gain a reasonable estimate of the total expected dose.

All of the following activities refer to a 25-ft section of a trench. A 25-ft section is a practical length to excavate at a time, and the dose for a 500-ft trench can be determined simply by multiplying the results for a 25-ft section by 20.

1. General Description of the Excavation Scenario

   In this scenario, chosen to protect the workers from external exposure and to keep the exposure rate on the side of the ERDF soil container to no more than 50 mR/h at a foot, the excavation of the trench will be carried out by an excavator with a long boom on which is mounted a bucket. The excavator will be positioned beside the trench and will excavate a 25-ft section of the trench at a time. The trench will be excavated to a depth of 18 ft; a width of 10 ft will be excavated at the maximum depth. This will ensure that all high concentration and moderate concentration soils are removed. This assumes no lateral spreading of the waste in the soil. The surface slope on both sides and in front of the excavator will be 1.5:1 (horizontal:vertical). A laborer will spray the soil to suppress any visible dust. An HPT will measure the exposure rate from one out of every fifth bucket of soil as a check on the concentration of radioactive material in the soil. The excavator operator, the laborer, and the HPT will be exposed to radiation and airborne radioactivity during this process.

   The clean excavated soil is placed beside the trench for use in mixing as required. Once the excavator reaches the high-activity soil, the high-activity soil and clean soil will be mixed until the concentration of radioactive material, primarily Cs-137, in the soil is reduced to the point where a 2-ft layer of soil can be loaded into an ERDF container without exceeding the dose constraint of 50 mR/h at 1 ft on the side of the container.

   After the high-activity layer is excavated using dilution, the moderate-activity layer is excavated without dilution, because the moderate-activity soil will not cause the ERDF container to reach 50 mR/h along the side.

   Once a container is full, a driver will drive the shuttle truck a short distance to where two laborers will seal the inner liner and install a fabric cover to prevent dust from blowing as the container is moved across site. An HPT will survey the transport container and ensure that it meets the requirements for shipping and the exposure rate acceptance criterion for ERDF. The driver then will drive the shuttle truck to a surge queue located near the excavation site and place the container at that site. The excavation site shuttle truck drivers, the laborers installing the cover, and the HPT performing the survey will be exposed to radiation as the trucks are moved from the trench to the queue.

   Another truck will pick up the container, drive it to the ERDF site, and drop it in the ERDF queue. The driver will be exposed to radiation while transporting the containers from queue to queue.

   An HPT will perform a survey on the container at the ERDF queue and will be exposed to radiation while doing the survey.

An ERDF shuttle truck will load and move the containers to the ERDF dump site, where the soil is dumped. This process is assisted by a laborer who opens the truck and sprays water to settle the dust. Once the soil is dumped, a bulldozer will be used to spread the soil. The shuttle truck driver, the laborer, and the bulldozer operator will be exposed to radiation during this process.

The total radiation dose for this process will be calculated for one 25-ft section of the trench. This value will be multiplied by 20 to get the total exposure for the trench. A 25-ft section was chosen because it is a practical working distance for the excavator, and it keeps too much of the trench from being exposed at once.

This process is illustrated in Figures F3-1 and F3-2.

2. Detailed Description of the Scenario

All of the following activities refer to a 25-ft section of a trench.

Step 1: Removal of Top 6 Ft of Soil Overburden

This step involves an excavator operator, a laborer watering for dust suppression, and an HPT to occasionally check activity levels in the soil as the top 6 ft of the soil overburden is excavated. The location will be beside the trench. Assuming a trench slope of 1.5 horizontal to 1.0 vertical, the total volume of soil to be excavated would be about 2,850 ft^3. Assuming an average 75 percent fill of a 75 ft^3 bucket (5 by 5 by 3 ft) or 56 ft^3 per bucket will require about 51 buckets per 25-ft section. Assuming 20 buckets per hour, this will take about 2.5 hours to excavate. The laborer is assumed to be exposed 15 percent of the time, because watering to suppress dust is intermittent; this is assumed for this function for all trench retrieval tasks. Because the exposure rate will be approximately a few microroentgen per hour (see Section F3.4), this dose will not be included in the model.

Steps 2, 3, and 4 describe the modeling approach used to estimate the dose from excavating the high-activity layer. The total dose is modeled as four times that necessary to excavate the second (middle) 1 ft of soil in the high-activity layer. (Except for the addition of dilution soil for the first foot on high-activity soil, which already is in place.)

Step 2: Addition of 1,500 ft^3 of Low-Activity Soil (Clean) to the Trench with High-Activity Soil

This activity involves adding 1,500 ft^3 of low-activity soil to the trench on top of the second foot of high-activity soil. A excavator operator and a laborer watering for dust suppression will be needed. The excavator operator will be shielded with a 2-in. leaded glass shield. The dose to the excavator operator and laborer will be modeled as the total time with 12.5 ft of the high-activity layer exposed. At 1,120 ft^3/h (56 ft^3 per bucket at 20 buckets per hour), 1,500 ft^3 will take about 1.34 hours. This activity will be done three times.

Figure F3-1. Sketch of Protected Worker Excavation and Transport Process for In-Trench Mixing.

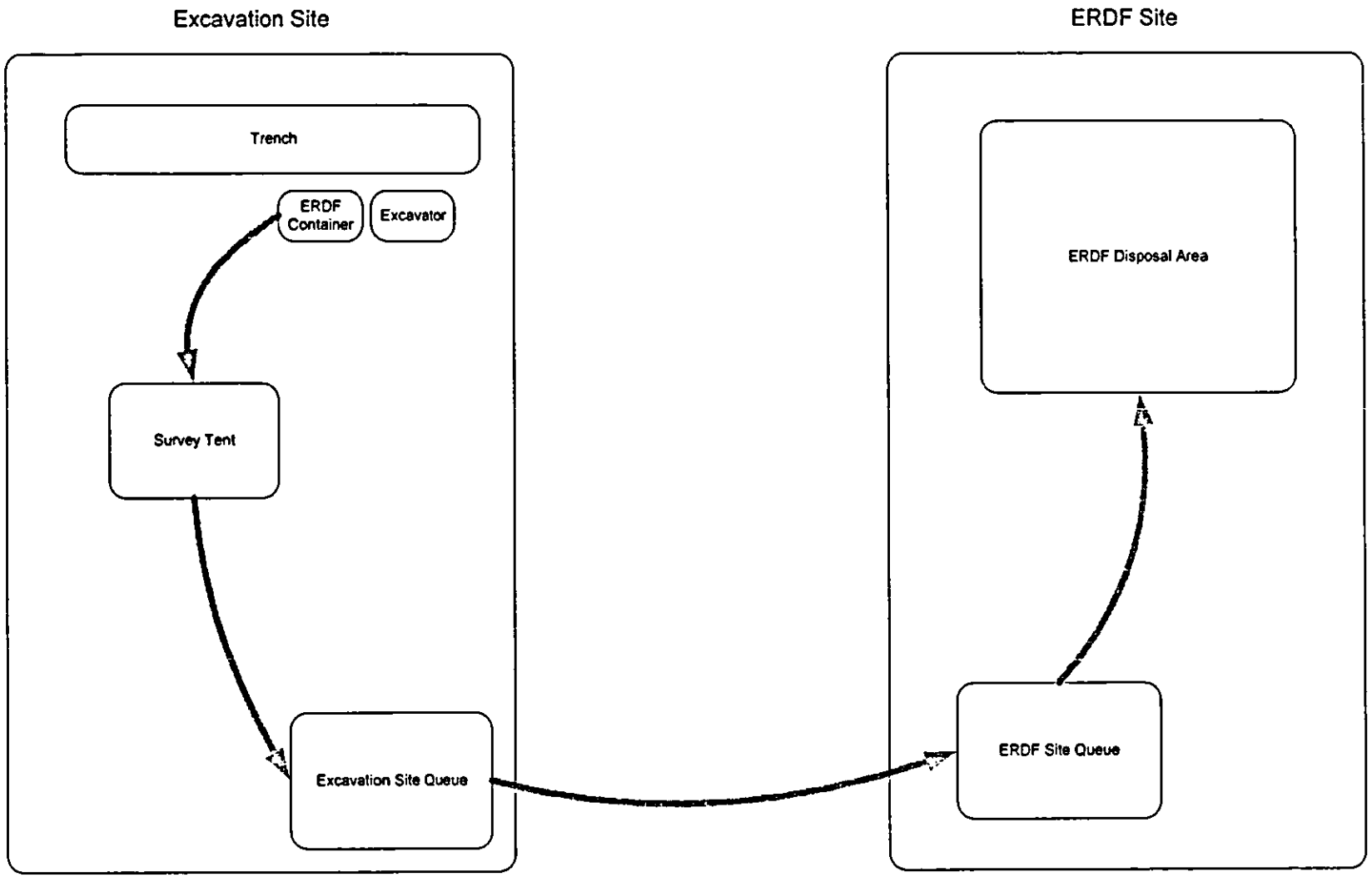
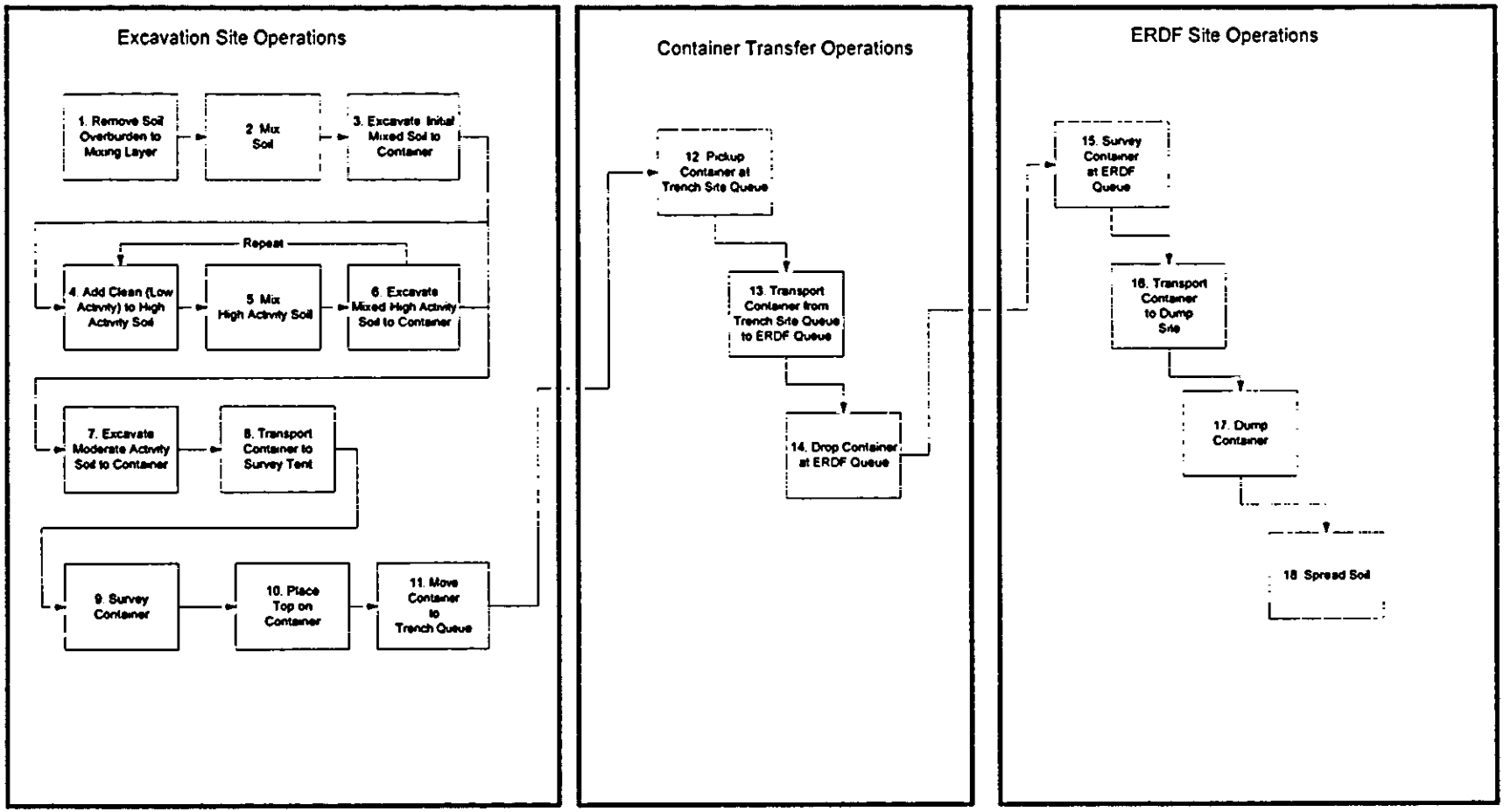


Figure F3-2. Overview of Protected Worker Excavation with In-Trench Mixing Scenario.



NOTE: The 1,500 ft^3 are added because this is six times the volume of a 1-ft layer of contaminated soil (250 ft^3). Because the sides are sloped, this layer will be approximately 3.8 ft thick.

Step 3: Mixing Low-Activity Soil with 1 Ft of High-Activity Soil

An excavator operator and a laborer watering for dust suppression will be exposed to the radiation from the trench. The mixing of the high-activity soil will be modeled as the total time with half the high-activity layer mixed. Assuming that the soil has to be handled three times to mix it, the volume handled is 5,250 ft^3 (3 times 1,750 ft^3). At 1,120 ft^3/h, this is about 4.7 hours. For four 1-ft layers, this about 18.8 hours.

Step 4: Excavation of 1,750 ft^3 of Mixed High-Activity Soil to an ERDF Container

An excavator operator, a laborer watering for dust suppression, and an HPT to occasionally check activity levels in the soil as it is excavated will be exposed to the radiation from the trench. The removal of the soil will be modeled as the total time with half the underlying high-activity layer uncovered. It is estimated to take 1.6 hours to remove the soil (1,750 ft^3 at 1,120 ft^3 per hour). For four layers, this is about 6.4 hours. The dose to the HPT will be modeled as a period of time (15 seconds) for every fifth bucket at a given distance (1 ft) from the bucket. The time for the HPT to take a measurement is estimated to about 0.03 hour (about 1.5 minutes) for the entire trench section (for six buckets or about one fifth of the total 31 buckets). For two layers, this is about 0.12 hour.

Step 5: Excavation of the Moderate-Activity Soil to an ERDF Container

An excavator operator, a laborer watering for dust suppression, and an HPT to occasionally check activity levels in the soil as it is excavated will be exposed to the radiation from the trench. The removal of the soil will be modeled as the total time with half the underlying low-activity layer uncovered. The total volume of soil to be excavated is 5,800 ft^3. This includes some clean soil from the sloping sides. At 1,120 ft^3/h, this will take about 5.2 hours. The dose to the HPT will be modeled as a period of time to perform a survey (15 seconds) for every fifth bucket at a given distance from the hoe bucket. Because there are 1,000 ft^3 of actual moderately contaminated soil that will give exposure, there will be about 18 buckets total or about 4 measured buckets. The time to take the measurement is estimated to be about 1.0 minute (or 0.02 hour).

Step 6: Transport of the Mixed High-Activity Containers from the Trench to the Excavation Site Queue Area

The shuttle truck driver will be exposed to radiation while driving the shuttle truck with the high-activity container from the trench to the queue area. The model assumes that there is a 2-in. steel shield between the driver and the container. It is estimated that this trip will take 0.17 hour/container (10 minutes). The shuttle truck driver is assumed to be situated 3.5 ft (see BHI-01558) from the front surface of the ERDF container. The ERDF container is assumed to be fabricated of ¼-in. (6 mm) steel (see BHI-01558). The total

volume of soil to be moved is 2,000 ft^3. The volume of an ERDF container filled to 2 ft is about 320 ft^3 (21.98 by 7.25 by 2 ft). Thus, it will require about 22 ERDF containers to remove the mixed high-activity soil. At 0.17 hour/container, this will result in about 3.7 hours of exposure to the driver for all mixed high-activity soil.

Step 7: Transport of the Moderate-Activity Container from the Trench to the Excavation Site Queue Area

The shuttle truck driver will be exposed to radiation while driving the shuttle truck with the high-activity container from trench to the queue area. The model assumes that there is a 2-in. steel shield between the driver and the container. It is estimated that this trip will take 0.17 hour/container (10 minutes). The shuttle truck driver is assumed to be situated 3.5 ft (see BHI-01558) from the front surface of the ERDF container. The ERDF container is assumed to be fabricated of ¼-in. (6 mm) steel (see BHI-01558). The total volume of soil to be moved is 1,000 ft^3. The volume of an ERDF container filled to 2 ft is about 320 ft^3 (21.98 by 7.25 by 2 ft). Thus, it will require about three ERDF containers to remove the moderate-activity soil. At 0.17 hour/container, this will result in about 0.5 hour of exposure to the driver for all mixed moderate-activity soil.

Step 8: Installation of the Seal and Cover Over the Mixed High-Activity Container

Two workers will install the seal and fabric dust cover over the high-activity container while standing on a scaffold beside the container. As such, they will be directly exposed to the high-activity soil in the container without any shielding from the container wall. The estimated time to install one cover is 0.033 hour (2 minutes). (It is assumed that the cover will be installed at some distance from the trench such that the laborers will not be exposed from the trench.) The volume of soil to which they are exposed is that of one ERDF container filled to 2 ft approximately 22 ft long by 7.25 ft wide by 2 ft deep (see BHI-01558). The total volume of soil held by one ERDF container filled to 2 ft is about 320 ft^3. Because there will be about 22 containers and the time per container is 0.033 hour, the total exposure time will be 0.73 hour.

Step 9: Survey the Mixed High-Activity ERDF Containers

An HPT will perform the radiation surveys (shipping surveys) and will be exposed to the container while it is being surveyed. This will be modeled as a single exposure rate for HPTs for the period of exposure. Any time spent in the tent in addition to that required to perform the tasks is assumed to be spent behind concrete shield walls.

This scenario assumes that the HPT time spent surveying each ERDF container is 5 minutes (0.083 hour/container) or 1.83 hours for 22 containers. The HPT will be positioned beside the ERDF container at 3 ft and will be shielded by the thickness of the container.

Step 10: Installation of the Seal and Fabric Cover Over the Moderate-Activity Container

Two workers will install the fabric dust cover over the moderate-activity container while standing on a scaffold beside the container. As such, they will be directly exposed to the

moderate-activity soil in the container without any shielding from the container wall. The estimated time to install one cover is 0.033 hour (2 minutes). (It is assumed that the cover will be installed at some distance from the trench such that the laborers will not be exposed from the trench.) Thus, for three containers, the total exposure time is 0.1 hour (6 minutes).

Step 11: Survey the Moderate-Activity ERDF Containers

An HPT will perform the radiation surveys (shipping surveys) and will be exposed to the container while it is being surveyed. This will be modeled as a single exposure rate for HPTs for the period of exposure. Any time spent in the tent in addition to that required to perform the tasks is assumed to be spent behind concrete shield walls.

This scenario assumes that the HPT time spent surveying each ERDF container is 5 minutes (0.083 hour/container) or 0.25 hour for three containers. The HPT will be positioned beside the ERDF container at 3 ft and will be shielded by the thickness of the container.

Step 12: Transport of the Mixed High-Activity Containers from the Excavation Site Queue to the ERDF Queue

The cross-site truck driver will be exposed to radiation from the mixed high-activity container while driving the container from the excavation site queue to the ERDF queue. The transport time is taken to be 0.5 hour/container (30 minutes). Thus, for 22 containers, the total time of exposure will be about 11 hours. The cross-site truck driver is assumed to be situated 9.0 ft (see BHI-01558) from the front surface of the ERDF container. The ERDF container is assumed to be fabricated of ¼-in. (6 mm) steel (see BHI-01558).

Step 13: Transport of the Moderate-Activity Container from the Excavation Site Queue to the ERDF Queue

The cross-site truck driver will be exposed to radiation from the moderate-activity container while driving the container from the excavation site queue to the ERDF queue. The transport time is taken to be 0.5 hour/container (30 minutes). Thus, for three containers, the total time of exposure will be about 1.5 hours. The cross-site truck driver is assumed to be situated 9.0 ft (see BHI-01558) from the front surface of the ERDF container. The ERDF container is assumed to be fabricated of ¼-in. (6 mm) steel (see BHI-01558).

Step 14: Survey of the Mixed High-Activity Containers in the ERDF Queue

The receipt survey of the mixed high-activity containers is assumed to be about half as rigorous as the shipping survey (the shipping survey would have only recently been done on-site) and will be assumed to result in half the dose of the original shipping survey. The time for these surveys is 0.92 hour.

Step 15: Survey of the Moderate-Activity Containers in the ERDF Queue

The receipt survey of the moderate-activity containers is assumed to be about half as rigorous as the shipping survey (the shipping survey would have only recently been done on-site) and will be assumed to result in half the dose of the original shipping survey. The time for these surveys is 0.13 hour.

Step 16: Transport of the Mixed High-Activity Container from the ERDF Queue to the Dump Site

The shuttle truck driver will be exposed to radiation while driving the shuttle truck with the high-activity container from the ERDF queue to the dump site. It is estimated that this trip will take 0.25 hour/container (15 minutes). Thus, for 22 containers, the total time of exposure will be about 5.5 hours. The shuttle truck driver is assumed to be situated 3.5 ft (see BHI-01558) from the front surface of the ERDF container. The driver is assumed to be shielded by a 2-in. steel shield between the truck cab and the container. The ERDF container is assumed to be fabricated of ¼-in. (6 mm) steel (see BHI-01558).

Step 17: Transport of the Moderate-Activity Container from the Trench to the Excavation Site Queue Area

The shuttle truck driver will be exposed to radiation while driving the shuttle truck with the moderate-activity container from the ERDF queue to the dump site. It is estimated that this trip will take 0.25 hour/container (15 minutes). Thus, for three containers, the total time of exposure will be about 0.75 hour. The shuttle truck driver is assumed to be situated 3.5 ft (see BHI-01558) from the front surface of the ERDF container. The driver is assumed to be shielded by a 2-in. steel shield between the truck cab and the container. The ERDF container is assumed to be fabricated of ¼-in. (6 mm) steel (see BHI-01558).

Step 18: Dumping of the Mixed High-Activity Container at the ERDF Disposal Site

The laborer assisting with the dumping of the high-activity container will be exposed to radiation at the ERDF disposal site. The laborer opens the back of the truck and sprays for dust suppression. It is estimated that this activity will take 0.08 hour/container (5 minutes). Thus, for 22 containers, the total time of exposure will be 1.8 hours.

Step 19: Dumping of the Moderate-Activity Container at the ERDF Disposal Site

The laborer assisting with the dumping of the moderate-activity container will be exposed to radiation at the ERDF disposal site. It is estimated that this activity will take 0.08 hour/container (5 minutes). Thus, for three containers, the total time of exposure is about 0.24 hour.

Step 20: Spreading of the Contaminated Soil by the ERDF Bulldozer Operator

The bulldozer operator will be exposed to radiation from the spreading of the mixed high- and moderate-activity soil at the ERDF disposal site. The average exposure rate to the bulldozer operator will be determined by calculating the exposure rate to the operator's

location from a 0.25 ft (3 in.) high cylinder whose diameter is determined by half the volume of the mixed highly and moderately contaminated soil excavated from the trench and whose concentrations are the volume-weighted average of the mixed high- and moderate-activity soil activities for the radionuclides. The exposure time is taken to be 0.08 hour/container (5 minutes). Thus, the exposure time for a 25-ft section of trench is 2.0 hours.

Half the total volume of mixed high- and moderate-activity soil excavated from the trench is 80,000 ft^3. The radius of a cylinder with this volume and 0.25 ft deep is 320 ft.

Thus, the dose rate to the bulldozer operator will be calculated by determining the dose rate at a distance of 6 ft above the edge of a 320-ft radius, 0.25 ft high cylinder with average activity in the soil. The dose per container then will be calculated using the exposure time per container (0.08 hour). The total direct dose for this activity is then the dose rate per container times the total number of containers.

Because the volume of the mixed high-activity soil is 7 times the volume of the moderate-activity soil, the average-activity concentration is just a 7-to-1 weighted average or

- Cs-137: 0. 33 μCi/cc
- Ba-137m: 0.32 μCi/cc
- Sr-90: 0.59 μCi/cc
- Y-90: 0.59 μCi/cc
- Pu-239: 0.0001 μC/cc
- Ni-63: 0.001 μC/cc.

F3.4 INDIVIDUAL (DETAILED) CALCULATIONS OF EXTERNAL DOSE

As will be seen in Table F3-1, a large part of the activity in the trench is from Sr-Y-90, which have only beta emissions of consequence, and, consequently, they are not included in the calculations made by MicroShield, because MicroShield models the photon dose only. Section F2.5 gives an assessment of the external potential doses from Sr-Y-90. Because the external dose form of Sr-Y-90 is expected to be a very small fraction of the dose from Cs-137 (Ba-137m), it will not be further assessed here.

Calc 1: Removal of Top 6 Ft of Soil Overburden

The exposure rate for this activity is simply the person-rem background exposure rate for the site; this is about 0.0025 mR/h. (See Project Hanford Survey Report No. GW-04-0158, February 26, 2004.) This minor dose will not be considered in the dose estimate for this trench.

Calc 2: Addition of 1,500 ft^3 of Clean Soil to High-Activity Soil: Excavator Operator

The average dose rate for this activity will be modeled as a soil slab with half the top surface and half the depth of the high activity or 10 ft wide by 12.5 length by 2 ft thick. The top of

the slab will be at a depth of 11 ft. The excavator operator will be 16 ft above and 21.5 ft from the slab. The excavator operator will be shielded with 2 in. of leaded glass. Thus, the dose rate to the excavator operator will be 3.5 mrem/h. See Appendix M.

Calc 3: Addition of 1,500 ft^3 of Clean Soil to High-Activity Soil: Sprayer

The average dose rate for this activity will be modeled as a soil slab with half the top surface and half the depth of the high activity or 10 ft wide by 12.5 length by 2 ft thick. The top of the slab will be at a depth of 11 ft. Thus, the laborer will be 11 ft above and 16.5 ft from the slab. Thus, the dose rate to the laborer with the water hose is 16.7 mrem/h. See Appendix N.

Calc 4: Mixing Clean Soil with 1 Ft of High-Activity Soil: Excavator Operator

Mixing will be modeled as the total time of exposure multiplied by the dose rate from half the trench fully mixed. This will be modeled as a soil slab 22 ft wide by 12.5 ft long by 4 ft thick. The depth of the surface is taken to be 8 ft below grade. Thus, the excavator operator will be 13 ft above and 17 ft from the slab. The excavator operator will be shielded with 2 in. of leaded glass. See Appendix O for the exposure rates at the excavator operator's location. For mixing the high-activity soil, the dose rate at the excavator operator's location is 1.15 mrem/h.

Calc 5: Mixing Clean Soil with 1 Ft of High-Activity Soil: Sprayer

Mixing will be modeled as the total time of exposure multiplied by the dose rate from half the trench fully mixed. This will be modeled as a soil slab 22 ft wide by 12.5 ft long by 4 ft thick. The depth of the surface is taken to be 8 ft below grade. Thus, the sprayer will be 8 ft above and 12 ft from the slab. See Appendix P for the exposure rates at the laborer's location. For mixing the high-activity soil, the dose rate at the laborer's location is 7.92 mrem/h.

Calc 6: Excavation of 1,750 ft^3 of Mixed High-Activity Soil to ERDF Container

Removal will be modeled as the total time with half the trench mixed and half with the underlying high-activity layer exposed. The dose rate will be calculated by summing these two calculations. See Appendices M, N, O, and P. Thus, for this removal, the total dose rate for the sprayer is 24.62 mrem/h and the total dose rate for the excavator operator is 4.65 mrem/h.

Calc 7: Surveying Mixed High-Activity Soil in Bucket

The dose rate to the HPT will be modeled as the dose 1 ft from the side of a bucket that has internal dimensions of 5 ft wide by 3 ft deep by 5 ft high and is constructed of 2-in. thick steel (BHI-01558). The bucket is assumed to be 75 percent full or filled to a height of 3.75 ft. Thus, the source is 5 ft wide by 3 ft deep by 3.75 ft high and is shielded with a 2-in. thick steel shield. See Appendix Q. The dose rate to the HPT is 6.81 mrem/h.

Calc 8: Excavate Moderate-Activity Soil to ERDF Container: Excavator Operator

The dose rate from the moderate slab will be modeled as the dose rate from a soil slab 10 ft wide by 4 ft thick by 12.5 ft long for the entire period of the excavation. The surface of the slab will be 14 ft below grade. The excavator operator will be 19 ft above and 26 ft to the side of the slab. See Appendix R. The dose rate to the excavator operator is 0.086 mrem/h. The exposure rate from the low-activity slab will be very small and will not be considered.

Calc 9: Excavate Moderate-Activity Soil to ERDF Container: Sprayer

The dose rate from the moderate slab will be modeled as the dose rate from a soil slab 10 ft wide by 4 ft thick by 12.5 ft long for the entire period of the excavation. The surface of the slab will be 14 ft below grade. Thus, the sprayer will be 14 ft above and 21 ft to the side of the surface of the slab. See Appendix S. The dose rate to the sprayer is 0.53 mrem/h. The exposure rate from the low-activity slab will be very small and will not be considered.

Calc 10: Surveying Moderate-Activity Soil in Bucket

The dose rate to the HPT will be modeled as the dose 1 ft from the side of a bucket that has internal dimensions of 5 ft wide by 3 ft deep by 5 ft high and is constructed of 2 in. thick steel (BHI-01558). The bucket is assumed to be 75 percent full or filled to a height of 3.75 ft. Thus, the source is 5 ft wide by 3 ft deep by 3.75 ft high and is shielded with a 2-in. thick steel shield. See Appendix T. The dose rate to the HPT is 1.36 mrem/h.

Calc 11: Movement of the Mixed High-Activity ERDF Containers from the Trench Through the Survey Tent to the BC Queue Area

The dose rate to the driver will be modeled as the dose rate from the end of a 22 ft long by 7.25 ft wide by 2 ft thick soil slab shielded with 2.25 in. of steel (2 in. steel shield plus 0.25 in. container thickness). The driver is 3.5 ft from the container. See Appendix U. The dose rate to the driver is 1.80 mrem/h.

Calc 12: Movement of the Moderate-Activity ERDF Containers from the Trench Through the Survey Tent to the BC Queue Area

The dose rate to the driver will be modeled as the dose rate from the end of a 22 ft long by 7.25 ft wide by 2 ft thick soil slab shielded with 2.25 in. of steel (2 in. steel shield plus 0.25 in. container thickness). The driver is 3.5 ft from the container. See Appendix V. The dose rate to the driver is 0.36 mrem/h.

Calc 13: Surveying the Mixed High-Activity ERDF Containers

The dose rate to the HPT surveying the ERDF container will be modeled as the dose rate at a point 3 ft from the side of the container and 11 ft from the end and 1 ft from the bottom. The source is a 22 ft long by 7.25 ft wide by 2 ft thick soil slab shielded by a 0.25 in. (0.02 ft) thick steel shield. See Appendix W. The dose rate to the HPT is 20.86 mrem/h.

Calc 14: Surveying the Moderate-Activity ERDF Containers

The dose rate to the HPT surveying the ERDF container will be modeled as the dose rate at a point 3 ft from the side of the container and 11 ft from the end and 1 ft from the bottom. The source is a 22 ft long by 7.25 ft wide by 2 ft thick soil slab shielded by a 0.25 in. (0.02 ft) thick steel shield. See Appendix X. The dose rate to the HPT is 4.17 mrem/h.

Calc 15: Sealing the Mixed High-Activity ERDF Containers

Two laborers will seal the ERDF container. The dose rate will be modeled as the dose rate from a 22 ft long by 7.25 ft wide by 2 ft thick soil slab at a point half way down the slab and 1 ft from the side surface of the slab and 5 ft above the surface of the slab. There is no shielding. See Appendix Y. The dose rate to the laborers is 33.53 mrem/h.

Calc 16: Sealing the Moderate-Activity ERDF Containers

Two laborers will seal the ERDF container. The dose rate will be modeled as the dose rate from a 22 ft long by 7.25 ft wide by 2 ft thick soil slab at a point half way down the slab and 1 ft from the side surface of the slab and 5 ft above the surface of the slab. There is no shielding. See Appendix Z. The dose rate to the laborers is 6.71 mrem/h.

Calc 17: Transport of the Mixed High-Activity Containers from the BC Queue to the ERDF Queue

The dose rate to the driver will be modeled as a point 9 ft from the end of the ERDF container and 3 ft from the side and 1 ft above the bottom of the container. See Appendix AA. The dose rate to the driver is 3.06 mrem/h.

Calc 18: Transport of the Moderate-Activity Containers from the BC Queue to the ERDF Queue

The dose rate to the driver from a moderate-activity container will be modeled as a point 9 ft from the end of the ERDF container and 3 ft from the side and 1 ft above the bottom of the container. See Appendix BB. The dose rate to the driver is 0.61 mrem/h.

Calc 19: Surveys of the Mixed High-Activity Containers at the ERDF Queue

The dose to the HPT performing receipt surveys of the containers at the ERDF queue will be modeled as taking half the time taken by the HPT doing the transportation survey at the excavation site queue. It is expected that this survey will be less detailed. The dose rate for this calculation is given in calculation 13 above. The dose rate is 20.86 mrem/h.

Calc 20: Surveys of the Moderate-Activity Containers at the ERDF Queue

The dose to the HPT performing receipt surveys of the containers at the ERDF queue will be modeled as taking half the time taken by the HPT doing the transportation survey at the excavation site queue. It is expected that this survey will be less detailed. The dose rate for this calculation is given in calculation 14 above. The dose rate is 4.17 mrem/h.

Calc 21: Transport of Mixed High-Activity Containers from ERDF Queue to Dump Site

The dose rate to the driver will be modeled as the dose rate from the end of a 22 ft long by 7.25 ft wide by 2 ft thick soil slab shielded with 2.25 in. of steel (2 in. steel shield plus 0.25 in. container thickness). The driver is 3.5 ft from the container. This is the same calculation given in calculation 11. The dose rate is 1.80 mrem/h.

Calc 22: Transport of Moderate-Activity Containers from ERDF Queue to Dump Site

The dose rate to the driver will be modeled as the dose rate from the end of a 22 ft long by 7.25 ft wide by 2 ft thick soil slab shielded with 2.25 in. of steel (2 in. steel shield plus 0.25 in. container thickness). The driver is 3.5 ft from the container. This is the same calculation as calculation 12. The dose rate is 0.36 mrem/h.

Calc 23: Dumping Mixed High-Activity Soil at the ERDF Dump Site

The dose rate to a laborer helping with dumping soil will be modeled as the rate at a point along the side of the container that is 1 ft from the end and 1 ft above the bottom of the container. See Appendix CC. The dose rate is 38.34 mrem/h.

Calc 24: Dumping Moderate-Activity Soil at the ERDF Dump Site

The dose rate to a laborer helping with dumping soil will be modeled as the rate at a point along the side of the container that is 1 ft from the end and 1 ft above the bottom of the container. See Appendix DD. The dose rate is 7.67 mrem/h.

Calc 25: Spreading the Contaminated Soil at ERDF

The dose rate to the bulldozer operator is modeled as the dose rate at a point 6 ft above and at the edge of a cylinder of contaminated soil that is 3 in. thick and 320 ft in radius. See Appendix EE. The dose rate from the cylinder is 22.85 mrem/h.

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APPENDIX A

DOSE RATE FROM HIGH-ACTIVITY SLAB TO UNPROTECTED EXCAVATOR OPERATOR AND SPRAYER

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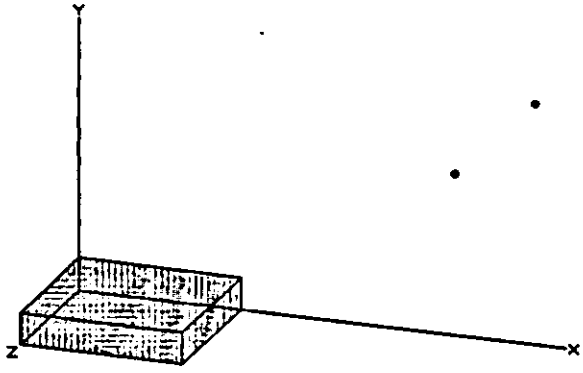
MicroShield v6.02 (6.02-00206)
Fluor_Hanford

Page : 1
DOS File : B26UWHASlabEO&S.ms6
Run Date: June 16, 2004
Run Time: 11:21:08 AM
Duration : 00:00:01

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: B26 HA Slab
Description: Excavator Op & Sprayer High Act Slab Trench B26
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	304.8 cm	10 ft 0.0 in
Width	304.8 cm	10 ft 0.0 in
Height	60.96 cm	2 ft

Dose Points

	X	Y	Z
# 1	762 cm 25 ft	365.76 cm 12 ft	152.4 cm 5 ft 0.0 in
# 2	914.4 cm 30 ft	518.16 cm 17 ft	152.4 cm 5 ft 0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	200.0 ft³	BC Dry Sandy Soil	1.6
Air Gap		Air	0.00122
Immersion		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	1.4158e+001	5.2386e+011	2.5000e+000	9.2500e+004
Cs-137	1.4725e+001	5.4482e+011	2.6000e+000	9.6200e+004
Ni-63	5.6634e-002	2.0954e+009	1.0000e-002	3.7000e+002
Pu-239	5.6634e-003	2.0954e+008	1.0000e-003	3.7000e+001
Sr-90	2.6051e+001	9.6391e+011	4.6000e+000	1.7020e+005
Y-90	2.6051e+001	9.6391e+011	4.6000e+000	1.7020e+005

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	20

Results - Dose Point # 1 - (25,12,5) ft

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	5.438e+09	1.076e-04	1.180e-04	7.372e-05	8.091e-05
0.0136	9.250e+06	5.566e-07	6.108e-07	6.497e-08	7.131e-08
0.0318	1.085e+10	2.858e-01	4.063e-01	2.381e-03	3.384e-03
0.0322	2.001e+10	5.527e-01	7.922e-01	4.448e-03	6.376e-03
0.0364	7.282e+09	3.257e-01	5.235e-01	1.851e-03	2.974e-03
0.1129	9.971e+04	7.586e-05	3.022e-04	1.173e-07	4.674e-07
0.6616	4.714e+11	4.453e+03	1.067e+04	8.633e+00	2.069e+01
TOTALS:	5.150e+11	4.455e+03	1.067e+04	8.642e+00	2.070e+01

Results - Dose Point # 2 - (30,17,5) ft

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	5.438e+09	6.932e-05	7.607e-05	4.751e-05	5.214e-05

Page : 2
DOS File : B26UWHASlabEO&S.ms6
Run Date : June 16, 2004
Run Time: 11:21:08 AM
Duration : 00:00:01

Energy eV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0136	9.250e+06	3.587e-07	3.937e-07	4.188e-08	4.596e-08
0.0318	1.085e+10	1.740e-01	2.495e-01	1.449e-03	2.078e-03
0.0322	2.001e+10	3.365e-01	4.868e-01	2.708e-03	3.918e-03
0.0364	7.282e+09	1.983e-01	3.214e-01	1.127e-03	1.826e-03
0.1129	9.971e+04	4.504e-05	1.836e-04	6.966e-08	2.840e-07
0.6616	4.714e+11	2.691e+03	6.540e+03	5.216e+00	1.268e+01
TOTALS:	5.150e+11	2.691e+03	6.541e+03	5.221e+00	1.269e+01

APPENDIX B

DOSE RATE FROM MODERATE-ACTIVITY SLAB TO UNPROTECTED EXCAVATOR OPERATOR AND SPRAYER

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MicroShield v6.02 (6.02-00206)
Fluor_Hanford

Page : 1
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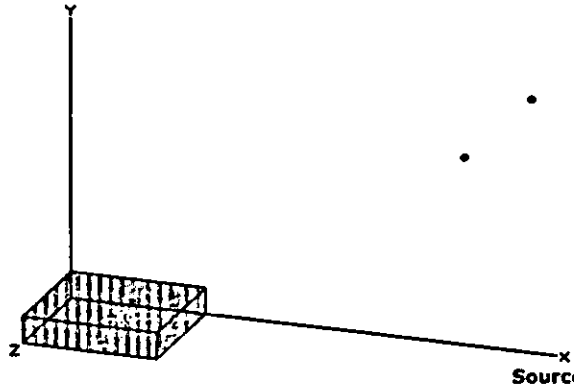
Run Date: June 16, 2004
Run Time: 11:25:50 AM
Duration : 00:00:01

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: B26 UW MA Slab
Description: Excavator Op & Sprayer Unprot Work Mod Act Slab Trench B26
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	304.8 cm	10 ft 0.0 in
Width	304.8 cm	10 ft 0.0 in
Height	60.96 cm	2 ft

Dose Points

	X	Y	Z
# 1	944.88 cm	487.68 cm	152.4 cm
	31 ft	16 ft	5 ft 0.0 in
# 2	1097.28 cm	640.08 cm	152.4 cm
	36 ft	21 ft 0.0 in	5 ft 0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	200.0 ft³	BC Dry Sandy Soil	1.6
Air Gap		Air	0.00122
Immersion		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	3.9644e-001	1.4668e+010	7.0000e-002	2.5900e+003
Cs-137	3.9644e-001	1.4668e+010	7.0000e-002	2.5900e+003
Ni-63	1.6990e-003	6.2863e+007	3.0000e-004	1.1100e+001
Pu-239	1.6990e-004	6.2863e+006	3.0000e-005	1.1100e+000
Sr-90	7.3624e-001	2.7241e+010	1.3000e-001	4.8100e+003
Y-90	7.3624e-001	2.7241e+010	1.3000e-001	4.8100e+003

Buildup
The material reference is : Immersion

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	20

Results - Dose Point # 1 - (31,16,5) ft

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	1.523e+08	1.325e-06	1.892e-06	9.083e-07	1.297e-06
0.0136	2.775e+05	7.347e-09	1.049e-08	8.577e-10	1.225e-09
0.0318	3.037e+08	4.385e-03	1.265e-02	3.653e-05	1.054e-04
0.0322	5.603e+08	8.489e-03	2.500e-02	6.832e-05	2.012e-04
0.0364	2.039e+08	5.045e-03	1.904e-02	2.866e-05	1.082e-04
0.1129	2.991e+03	1.263e-06	8.835e-06	1.953e-09	1.367e-08
0.6616	1.320e+10	7.036e+01	1.859e+02	1.364e-01	3.605e-01
TOTALS:	1.442e+10	7.038e+01	1.860e+02	1.365e-01	3.609e-01

Results - Dose Point # 2 - (36,21,5) ft

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	1.523e+08	8.427e-07	1.206e-06	5.776e-07	8.266e-07

Page : 2
DOS File : B26UWMASlabEO&S.ms6
Run Date: June 16, 2004
Run Time: 11:25:50 AM
Duration : 00:00:01

ergy eV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0136	2.775e+05	4.672e-09	6.686e-09	5.455e-10	7.806e-10
0.0318	3.037e+08	2.909e-03	8.603e-03	2.423e-05	7.166e-05
0.0322	5.603e+08	5.635e-03	1.700e-02	4.535e-05	1.368e-04
0.0364	2.039e+08	3.358e-03	1.288e-02	1.908e-05	7.317e-05
0.1129	2.991e+03	8.347e-07	6.032e-06	1.291e-09	9.330e-09
0.6616	1.320e+10	4.734e+01	1.269e+02	9.178e-02	2.459e-01
TOTALS:	1.442e+10	4.736e+01	1.269e+02	9.187e-02	2.462e-01

APPENDIX C

DOSE RATE FROM LOW-ACTIVITY SLAB TO UNPROTECTED EXCAVATOR OPERATOR AND SPRAYER

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MicroShield v6.02 (6.02-00206)
Fluor_Hanford

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Run Time: 11:30:28 AM
Duration : 00:00:01

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: B26 UW LA Slab
Description: Excavator Op & Sprayer Unprot Work Low Act Slab Trench B26
Geometry: 13 - Rectangular Volume

Source Dimensions

Length	7.6e+3 cm	250 ft
Width	304.8 cm	10 ft 0.0 in
Height	60.96 cm	2 ft

Dose Points

	X	Y	Z
# 1	8442.96 cm 277 ft	609.6 cm 20 ft 0.0 in	152.4 cm 5 ft 0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	5000.0 ft³	BC Dry Sandy Soil	1.6
Air Gap		Air	0.00122
Immersion		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	5.6634e-001	2.0954e+010	4.0000e-003	1.4800e+002
Cs-137	5.6634e-001	2.0954e+010	4.0000e-003	1.4800e+002
Ni-63	1.4158e-003	5.2386e+007	1.0000e-005	3.7000e-001
Pu-239	2.8317e-004	1.0477e+007	2.0000e-006	7.4000e-002
Sr-90	9.9109e-001	3.6670e+010	7.0000e-003	2.5900e+002
Y-90	9.9109e-001	3.6670e+010	7.0000e-003	2.5900e+002

Buildup
The material reference is : Immersion

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	20

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	2.175e+08	4.101e-08	5.934e-08	2.811e-08	4.068e-08
0.0136	4.625e+05	2.652e-10	3.839e-10	3.097e-11	4.481e-11
0.0318	4.338e+08	3.082e-04	9.670e-04	2.567e-06	8.055e-06
0.0322	8.004e+08	5.982e-04	1.910e-03	4.814e-06	1.538e-05
0.0364	2.913e+08	3.571e-04	1.382e-03	2.029e-06	7.852e-06
0.1129	4.985e+03	8.797e-08	6.902e-07	1.361e-10	1.068e-09
0.6616	1.885e+10	4.490e+00	1.298e+01	8.704e-03	2.517e-02
TOTALS:	2.060e+10	4.491e+00	1.299e+01	8.714e-03	2.520e-02

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APPENDIX D

DOSE RATE FROM HIGH-ACTIVITY SOIL TO UNPROTECTED CONTAINER SEALER

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MicroShield v6.02 (6.02-00206)
Fluor_Hanford

Page : 1
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Run Time: 11:35:51 AM
Duration : 00:00:01

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By: _____
Checked: _____

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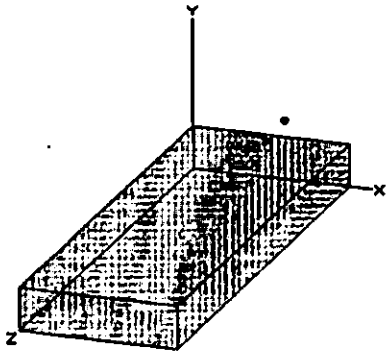
Description: B26 Unprot Wrker High Activity Sealing Can
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	220.98 cm	7 ft 3.0 in
Width	669.95 cm	21 ft 11.8 in
Height	60.96 cm	2 ft

Dose Points

	X	Y	Z
# 1	251.46 cm	213.36 cm	334.9752 cm
	8 ft 3.0 in	7 ft 0.0 in	10 ft 11.9 in

Shields

Shield Name	Dimension	Material	Density
Source	318.71 ft³	BC Dry Sandy Soil	1.6
Air Gap		Air	0.00122
Immersion		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	2.2562e+001	8.3480e+011	2.5000e+000	9.2500e+004
Cs-137	2.3465e+001	8.6819e+011	2.6000e+000	9.6200e+004
Ni-63	9.0249e-002	3.3392e+009	1.0000e-002	3.7000e+002
Pu-239	9.0249e-003	3.3392e+008	1.0000e-003	3.7000e+001
Sr-90	4.1514e+001	1.5360e+012	4.6000e+000	1.7020e+005
Y-90	4.1514e+001	1.5360e+012	4.6000e+000	1.7020e+005

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	20

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	8.666e+09	1.048e-02	1.129e-02	7.186e-03	7.738e-03
0.0136	1.474e+07	5.425e-05	5.842e-05	6.334e-06	6.820e-06
0.0318	1.728e+10	4.995e+00	6.809e+00	4.161e-02	5.672e-02
0.0322	3.189e+10	9.613e+00	1.319e+01	7.736e-02	1.062e-01
0.0364	1.160e+10	5.339e+00	7.996e+00	3.033e-02	4.543e-02
0.1129	1.589e+05	8.792e-04	3.263e-03	1.360e-06	5.047e-06
0.6616	7.512e+11	5.044e+04	1.234e+05	9.779e+01	2.393e+02
TOTALS:	8.206e+11	5.046e+04	1.235e+05	9.795e+01	2.395e+02

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APPENDIX E

DOSE RATE FROM MODERATE-ACTIVITY SOIL TO UNPROTECTED CONTAINER SEALER

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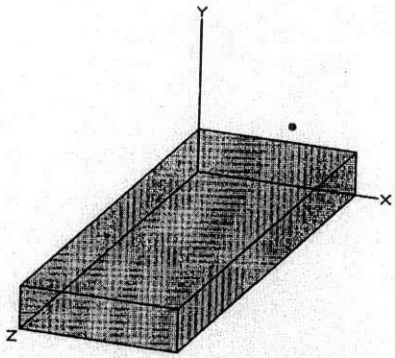
MicroShield v6.02 (6.02-00206)
Fluor_Hanford

Page : 1
DOS File : B26UWMACanSealer.ms6
Run Date : June 16, 2004
Run Time : 11:39:47 AM
Duration : 00:00:01

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: B26 UW MA Can Sealer
Description: B26 Unprot Wrker Moderate Activity Sealing Can
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	220.98 cm	7 ft 3.0 in
Width	669.95 cm	21 ft 11.8 in
Height	60.96 cm	2 ft

Dose Points

	X	Y	Z
# 1	251.46 cm 8 ft 3.0 in	213.36 cm 7 ft 0.0 in	334.9752 cm 10 ft 11.9 in

Shields

Shield Name	Dimension	Material	Density
Source	318.71 ft³	BC Dry Sandy Soil	1.6
Air Gap		Air	0.00122
Immersion		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	6.3174e-001	2.3374e+010	7.0000e-002	2.5900e+003
Cs-137	6.3174e-001	2.3374e+010	7.0000e-002	2.5900e+003
Ni-63	2.7075e-003	1.0018e+008	3.0000e-004	1.1100e+001
Pu-239	2.7075e-004	1.0018e+007	3.0000e-005	1.1100e+000
Sr-90	1.1732e+000	4.3410e+010	1.3000e-001	4.8100e+003
Y-90	1.1732e+000	4.3410e+010	1.3000e-001	4.8100e+003

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	20

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	2.426e+08	2.936e-04	3.161e-04	2.012e-04	2.167e-04
0.0136	4.422e+05	1.628e-06	1.752e-06	1.900e-07	2.046e-07
0.0318	4.839e+08	1.399e-01	1.907e-01	1.165e-03	1.588e-03
0.0322	8.928e+08	2.692e-01	3.694e-01	2.166e-03	2.973e-03
0.0364	3.249e+08	1.495e-01	2.239e-01	8.494e-04	1.272e-03
0.1129	4.767e+03	2.638e-05	9.790e-05	4.080e-08	1.514e-07
0.6616	2.103e+10	1.412e+03	3.456e+03	2.738e+00	6.700e+00
TOTALS:	2.298e+10	1.413e+03	3.457e+03	2.742e+00	6.706e+00

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APPENDIX F

DOSE RATE FROM HIGH-ACTIVITY SOIL TO UNPROTECTED SHUTTLE AND CROSS-SITE DRIVER

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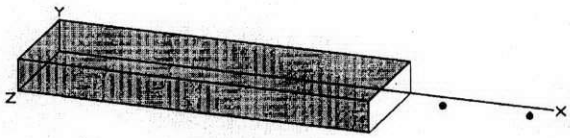
MicroShield v6.02 (6.02-00206)
Fluor_Hanford

Page : 1
DOS File : B26UWHAShutCSDrv.ms6
Run Date: June 16, 2004
Run Time: 11:43:39 AM
D on : 00:00:02

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: B26 UW HA Shut&CS Dr
Description: B26 Unprot Wrker High Act Soil Shuttle & Cross-site Drivers
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	669.95 cm	21 ft 11.8 in
Width	220.98 cm	7 ft 3.0 in
Height	60.96 cm	2 ft

Dose Points

	X	Y	Z
# 1	776.6304 cm	30.48 cm	121.92 cm
	25 ft 5.8 in	1 ft	4 ft
# 2	944.88 cm	30.48 cm	121.92 cm
	31 ft	1 ft	4 ft

Shields

Shield Name	Dimension	Material	Density
Source	318.71 ft³	BC Dry Sandy Soil	1.6
Shield 1	.02 ft	Iron	7.86
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	2.2562e+001	8.3480e+011	2.5000e+000	9.2500e+004
Cs-137	2.3465e+001	8.6819e+011	2.6000e+000	9.6200e+004
Ni-63	9.0249e-002	3.3392e+009	1.0000e-002	3.7000e+002
Pu-239	9.0249e-003	3.3392e+008	1.0000e-003	3.7000e+001
Sr-90	4.1514e+001	1.5360e+012	4.6000e+000	1.7020e+005
Y-90	4.1514e+001	1.5360e+012	4.6000e+000	1.7020e+005

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	20

Results - Dose Point # 1 - (25.48,1,4) ft

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	8.666e+09	8.519e-159	3.299e-25	5.840e-159	2.261e-25
0.0136	1.474e+07	4.409e-161	1.707e-27	5.147e-162	1.993e-28
0.0318	1.728e+10	2.388e-18	8.323e-18	1.989e-20	6.933e-20
0.0322	3.189e+10	1.827e-17	6.574e-17	1.470e-19	5.290e-19
0.0364	1.160e+10	1.453e-12	7.162e-12	8.258e-15	4.069e-14
0.1129	1.589e+05	5.864e-05	7.771e-04	9.070e-08	1.202e-06
0.6616	7.512e+11	1.576e+04	5.145e+04	3.056e+01	9.975e+01
TOTALS:	8.206e+11	1.576e+04	5.145e+04	3.056e+01	9.975e+01

Results - Dose Point # 2 - (31,1,4) ft

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	8.666e+09	5.951e-159	1.154e-25	4.079e-159	7.910e-26

Page : 2
DOS File : B26UWHAShutCSDrv.ms6
Run Date: June 16, 2004
Run Time: 11:43:39 AM
Duration : 00:00:02

Energy eV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0136	1.474e+07	3.080e-161	5.972e-28	3.595e-162	6.971e-29
0.0318	1.728e+10	1.262e-18	4.399e-18	1.052e-20	3.664e-20
0.0322	3.189e+10	9.576e-18	3.444e-17	7.707e-20	2.772e-19
0.0364	1.160e+10	6.965e-13	3.422e-12	3.957e-15	1.944e-14
0.1129	1.589e+05	1.520e-05	1.877e-04	2.351e-08	2.904e-07
0.6616	7.512e+11	3.582e+03	1.127e+04	6.943e+00	2.186e+01
TOTALS:	8.206e+11	3.582e+03	1.127e+04	6.943e+00	2.186e+01

APPENDIX G

DOSE RATE FROM MODERATE-ACTIVITY SOIL TO UNPROTECTED SHUTTLE AND CROSS-SITE DRIVER

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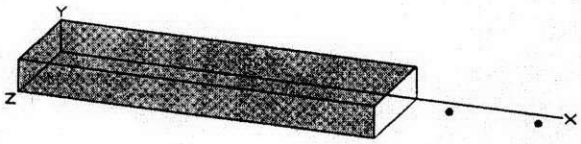
MicroShield v6.02 (6.02-00206)
Fluor_Hanford

Page : 1
DOS File : B26UWMAShutCSDrv.ms6
Run Date: June 16, 2004
Run Time: 11:50:27 AM
Duration : 00:00:01

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: B26 UW MA Shut&CS Dr
Description: B26 Unprot Wrker Mod Act Soil Shuttle & Cross-site Drivers
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	669.95 cm	21 ft 11.8 in
Width	220.98 cm	7 ft 3.0 in
Height	60.96 cm	2 ft

Dose Points

	X	Y	Z
# 1	776.6304 cm	30.48 cm	121.92 cm
	25 ft 5.8 in	1 ft	4 ft
# 2	944.88 cm	30.48 cm	121.92 cm
	31 ft	1 ft	4 ft

Shields

Shield Name	Dimension	Material	Density
Source	318.71 ft³	BC Dry Sandy Soil	1.6
Shield 1	.02 ft	Iron	7.86
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	6.3174e-001	2.3374e+010	7.0000e-002	2.5900e+003
Cs-137	6.3174e-001	2.3374e+010	7.0000e-002	2.5900e+003
Ni-63	2.7075e-003	1.0018e+008	3.0000e-004	1.1100e+001
Pu-239	2.7075e-004	1.0018e+007	3.0000e-005	1.1100e+000
Sr-90	1.1732e+000	4.3410e+010	1.3000e-001	4.8100e+003
Y-90	1.1732e+000	4.3410e+010	1.3000e-001	4.8100e+003

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	20

Results - Dose Point # 1 - (25.48,1,4) ft

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	2.426e+08	2.385e-160	9.236e-27	1.635e-160	6.331e-27
0.0136	4.422e+05	1.323e-162	5.121e-29	1.544e-163	5.978e-30
0.0318	4.839e+08	6.686e-20	2.330e-19	5.569e-22	1.941e-21
0.0322	8.928e+08	5.116e-19	1.841e-18	4.117e-21	1.481e-20
0.0364	3.249e+08	4.069e-14	2.005e-13	2.312e-16	1.139e-15
0.1129	4.767e+03	1.759e-06	2.331e-05	2.721e-09	3.606e-08
0.6616	2.103e+10	4.414e+02	1.441e+03	8.557e-01	2.793e+00
TOTALS:	2.298e+10	4.414e+02	1.441e+03	8.557e-01	2.793e+00

Results - Dose Point # 2 - (31,1,4) ft

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	2.426e+08	1.666e-160	3.231e-27	1.142e-160	2.215e-27

Page : 2
DOS File : B26UWMAShutCSDrv.ms6
Run Date : June 16, 2004
Run Time : 11:50:27 AM
Duration : 00:00:01

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0136	4.422e+05	9.239e-163	1.791e-29	1.079e-163	2.091e-30
0.0318	4.839e+08	3.535e-20	1.232e-19	2.944e-22	1.026e-21
0.0322	8.928e+08	2.681e-19	9.644e-19	2.158e-21	7.761e-21
0.0364	3.249e+08	1.950e-14	9.583e-14	1.108e-16	5.444e-16
0.1129	4.767e+03	4.559e-07	5.632e-06	7.052e-10	8.711e-09
0.6616	2.103e+10	1.003e+02	3.157e+02	1.944e-01	6.120e-01
TOTALS:	2.298e+10	1.003e+02	3.157e+02	1.944e-01	6.120e-01

APPENDIX H

DOSE RATE FROM HIGH-ACTIVITY SOIL TO UNPROTECTED DUMP ASSISTANT

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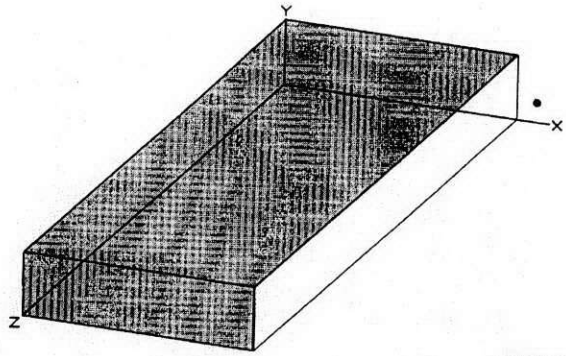
MicroShield v6.02 (6.02-00206)
Fluor_Hanford

Page : 1
DOS File : B26UWHADumpAsst.ms6
Run Date : June 16, 2004
Run Time : 11:53:37 AM
Duration : 00:00:01

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: B26 UW HA Can Dump A
Description: B26 Unprot Wrker High Activity Dump Asst
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	220.98 cm	7 ft 3.0 in
Width	669.95 cm	21 ft 11.8 in
Height	60.96 cm	2 ft

Dose Points

	X	Y	Z
# 1	251.46 cm 8 ft 3.0 in	30.48 cm 1 ft	30.48 cm 1 ft

Shields

Shield Name	Dimension	Material	Density
Source	318.71 ft³	BC Dry Sandy Soil	1.6
Shield 1	.02 ft	Iron	7.86
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	2.2562e+001	8.3480e+011	2.5000e+000	9.2500e+004
Cs-137	2.3465e+001	8.6819e+011	2.6000e+000	9.6200e+004
Ni-63	9.0249e-002	3.3392e+009	1.0000e-002	3.7000e+002
Pu-239	9.0249e-003	3.3392e+008	1.0000e-003	3.7000e+001
Sr-90	4.1514e+001	1.5360e+012	4.6000e+000	1.7020e+005
Y-90	4.1514e+001	1.5360e+012	4.6000e+000	1.7020e+005

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	20

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	8.666e+09	1.749e-132	7.478e-25	1.199e-132	5.125e-25
0.0136	1.474e+07	9.052e-135	3.869e-27	1.057e-135	4.517e-28
0.0318	1.728e+10	1.765e-15	6.000e-15	1.470e-17	4.998e-17
0.0322	3.189e+10	1.098e-14	3.833e-14	8.838e-17	3.085e-16
0.0364	1.160e+10	1.545e-10	7.091e-10	8.776e-13	4.029e-12
0.1129	1.589e+05	2.720e-04	2.380e-03	4.207e-07	3.681e-06
0.6616	7.512e+11	4.982e+04	1.435e+05	9.659e+01	2.781e+02
TOTALS:	8.206e+11	4.982e+04	1.435e+05	9.659e+01	2.781e+02

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APPENDIX I

DOSE RATE FROM MODERATE-ACTIVITY SOIL TO UNPROTECTED DUMP ASSISTANT

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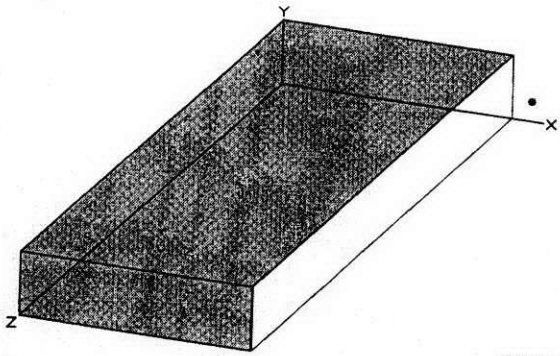
MicroShield v6.02 (6.02-00206)
Fluor_Hanford

Page : 1
DOS File : B26UWMADumpAsst.ms6
Run Date : June 16, 2004
Run Time : 11:57:20 AM
Duration : 00:00:01

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: B26 UW MA Can Dump A
Description: B26 Unprot Wrker Moderat Activity Dump Asst
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	220.98 cm	7 ft 3.0 in
Width	669.95 cm	21 ft 11.8 in
Height	60.96 cm	2 ft

Dose Points

	X	Y	Z
# 1	251.46 cm 8 ft 3.0 in	30.48 cm 1 ft	30.48 cm 1 ft

Shields

Shield Name	Dimension	Material	Density
Source	318.71 ft³	BC Dry Sandy Soil	1.6
Shield 1	.02 ft	Iron	7.86
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	6.3174e-001	2.3374e+010	7.0000e-002	2.5900e+003
Cs-137	6.3174e-001	2.3374e+010	7.0000e-002	2.5900e+003
Ni-63	2.7075e-003	1.0018e+008	3.0000e-004	1.1100e+001
Pu-239	2.7075e-004	1.0018e+007	3.0000e-005	1.1100e+000
Sr-90	1.1732e+000	4.3410e+010	1.3000e-001	4.8100e+003
Y-90	1.1732e+000	4.3410e+010	1.3000e-001	4.8100e+003

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	20

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	2.426e+08	4.898e-134	2.094e-26	3.357e-134	1.435e-26
0.0136	4.422e+05	2.716e-136	1.161e-28	3.170e-137	1.355e-29
0.0318	4.839e+08	4.942e-17	1.680e-16	4.116e-19	1.399e-18
0.0322	8.928e+08	3.075e-16	1.073e-15	2.475e-18	8.638e-18
0.0364	3.249e+08	4.325e-12	1.985e-11	2.457e-14	1.128e-13
0.1129	4.767e+03	8.161e-06	7.140e-05	1.262e-08	1.104e-07
0.6616	2.103e+10	1.395e+03	4.017e+03	2.705e+00	7.788e+00
TOTALS:	2.298e+10	1.395e+03	4.017e+03	2.705e+00	7.788e+00

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APPENDIX J

DOSE RATE FROM AVERAGE-ACTIVITY SOIL IN A LARGE CYLINDER TO UNPROTECTED BULLDOZER DRIVER

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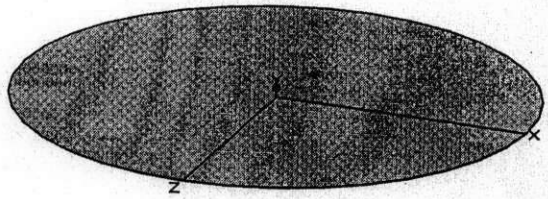
MicroShield v6.02 (6.02-00206)
Fluor_Hanford

Page : 1
DOS File : B26UWAADozDBigCyl.ms6
Run Date: June 16, 2004
Run Time: 12:09:59 PM
Duration : 00:00:00

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: B26 UW AA DzDr BigCy
Description: B26 Unprot Wrker Average Act Dozer Drivr 160-Ft Cylinder
Geometry: 8 - Cylinder Volume - End Shields



Source Dimensions

Height	7.62 cm	3.0 in
Radius	4.9e+3 cm	160 ft 0.0 in

Dose Points

	X	Y	Z
# 1	0 cm 0.0 in	190.5 cm 6 ft 3.0 in	0 cm 0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	2.01e+04 ft³	BC Dry Sandy Soil	1.6
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	6.8321e+002	2.5279e+013	1.2000e+000	4.4400e+004
Cs-137	7.4015e+002	2.7385e+013	1.3000e+000	4.8100e+004
Ni-63	2.8467e+000	1.0533e+011	5.0000e-003	1.8500e+002
Pu-239	2.8467e-001	1.0533e+010	5.0000e-004	1.8500e+001
Sr-90	1.3664e+003	5.0558e+013	2.4000e+000	8.8800e+004
Y-90	1.3664e+003	5.0558e+013	2.4000e+000	8.8800e+004

Buildup
The material reference is : Source

Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	2.624e+11	4.237e-02	4.462e-02	2.904e-02	3.059e-02
0.0136	4.649e+08	2.284e-04	2.405e-04	2.666e-05	2.808e-05
0.0318	5.233e+11	9.073e+00	1.253e+01	7.557e-02	1.044e-01
0.0322	9.656e+11	1.748e+01	2.434e+01	1.407e-01	1.959e-01
0.0364	3.514e+11	9.840e+00	1.508e+01	5.591e-02	8.569e-02
0.1129	5.012e+06	1.665e-03	5.615e-03	2.575e-06	8.685e-06
0.6616	2.275e+13	8.070e+04	1.580e+05	1.564e+02	3.063e+02
TOTALS:	2.485e+13	8.073e+04	1.580e+05	1.567e+02	3.067e+02

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APPENDIX K

DOSE RATE FROM AVERAGE-ACTIVITY SOIL IN A SMALL CYLINDER TO UNPROTECTED BULLDOZER DRIVER

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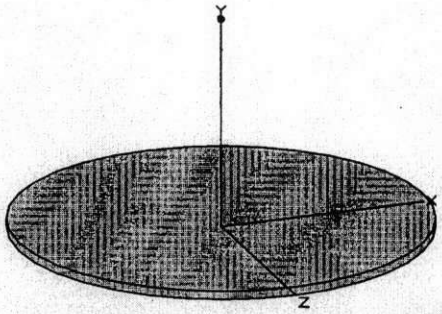
MicroShield v6.02 (6.02-00206)
Fluor_Hanford

Page : 1
DOS File : B26UWAADozDLitCyl.ms6
Run Date: June 16, 2004
Run Time: 12:12:23 PM
Duration : 00:00:00

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: B26 UW AA DzDr LtlCy
Description: B26 Unprot Wrker Average Act Dozer Drivr 6-Foot Cylinder
Geometry: 8 - Cylinder Volume - End Shields



Source Dimensions

Height	7.62 cm	3.0 in
Radius	182.88 cm	6 ft

Dose Points

	X	Y	Z
# 1	0 cm	190.5 cm	0 cm
	0.0 in	6 ft 3.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	8.01e+05 cm³	BC Dry Sandy Soil	1.6
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	9.6077e-001	3.5548e+010	1.2000e+000	4.4400e+004
Cs-137	1.0408e+000	3.8511e+010	1.3000e+000	4.8100e+004
Ni-63	4.0032e-003	1.4812e+008	5.0000e-003	1.8500e+002
Pu-239	4.0032e-004	1.4812e+007	5.0000e-004	1.8500e+001
Sr-90	1.9215e+000	7.1097e+010	2.4000e+000	8.8800e+004
Y-90	1.9215e+000	7.1097e+010	2.4000e+000	8.8800e+004

Buildup
The material reference is : Source

Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	3.690e+08	1.929e-02	2.024e-02	1.322e-02	1.388e-02
0.0136	6.538e+05	1.040e-04	1.091e-04	1.214e-05	1.274e-05
0.0318	7.360e+08	3.119e+00	4.219e+00	2.598e-02	3.514e-02
0.0322	1.358e+09	6.002e+00	8.180e+00	4.830e-02	6.583e-02
0.0364	4.941e+08	3.328e+00	4.970e+00	1.891e-02	2.824e-02
0.1129	7.048e+03	4.982e-04	1.340e-03	7.706e-07	2.072e-06
0.6616	3.199e+10	2.012e+04	3.016e+04	3.901e+01	5.847e+01
TOTALS:	3.494e+10	2.013e+04	3.018e+04	3.911e+01	5.861e+01

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APPENDIX L

DOSE RATE AT 1 FOOT FROM SIDE OF ENVIRONMENTAL RESTORATION DISPOSAL FACILITY CONTAINER FROM TRENCH 216-B-29 HIGH-ACTIVITY SOIL

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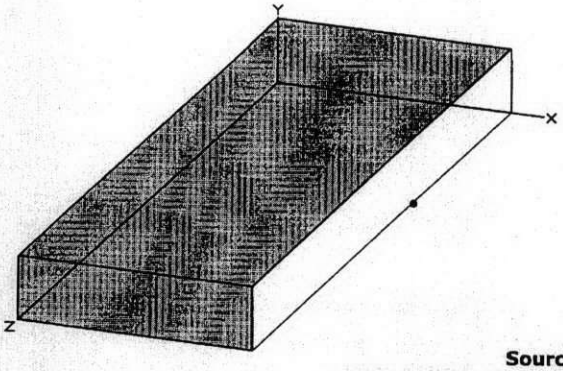
MicroShield v6.02 (6.02-00206)
Fluor_Hanford

Page : 1
DOS File : HRSoilCanDoseat1Ft.ms6
Run Date: June 25, 2004
Run Time: 3:21:31 PM
Duration : 00:00:01

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: B29IT HA Can 1 FT Do
Description: B26 IT High Activity ERDF Can Dose at 1 Ft
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	220.98 cm	7 ft 3.0 in
Width	669.95 cm	21 ft 11.8 in
Height	60.96 cm	2 ft

Dose Points

	X	Y	Z
# 1	252.0696 cm	30.48 cm	334.9752 cm
	8 ft 3.2 in	1 ft	10 ft 11.9 in

Shields

Shield Name	Dimension	Material	Density
Source	9.02e+06 cm³	BC Dry Sandy Soil	1.6
Shield 1	.61 cm	Iron	7.86
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	2.2562e+001	8.3480e+011	2.5000e+000	9.2500e+004
Cs-137	2.3465e+001	8.6819e+011	2.6000e+000	9.6200e+004
Ni-63	9.0249e-002	3.3392e+009	1.0000e-002	3.7000e+002
Pu-239	9.0249e-003	3.3392e+008	1.0000e-003	3.7000e+001
Sr-90	4.1514e+001	1.5360e+012	4.6000e+000	1.7020e+005
Y-90	4.1514e+001	1.5360e+012	4.6000e+000	1.7020e+005

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	20

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	8.666e+09	6.121e-133	1.066e-24	4.196e-133	7.306e-25
0.0136	1.474e+07	3.167e-135	5.516e-27	3.698e-136	6.439e-28
0.0318	1.728e+10	2.095e-15	7.118e-15	1.745e-17	5.929e-17
0.0322	3.189e+10	1.296e-14	4.519e-14	1.043e-16	3.637e-16
0.0364	1.160e+10	1.687e-10	7.716e-10	9.585e-13	4.384e-12
0.1129	1.589e+05	2.935e-04	2.665e-03	4.540e-07	4.122e-06
0.6616	7.512e+11	5.837e+04	1.759e+05	1.132e+02	3.409e+02
TOTALS:	8.206e+11	5.837e+04	1.759e+05	1.132e+02	3.409e+02

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APPENDIX M

PROTECTED WORKER WITH IN-TRENCH MIXING – DOSE RATE FROM A SLAB OF HIGH-ACTIVITY SOIL: EXCAVATOR OPERATOR

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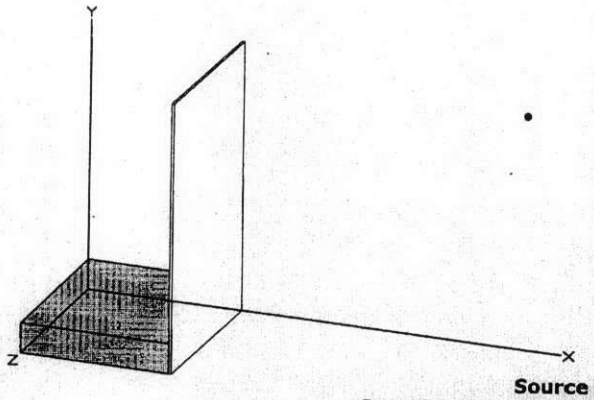
MicroShield v6.02 (6.02-00206)
Fluor_Hanford

Page : 1
DOS File : B26ITHASlabEO.ms6
Run Date: June 26, 2004
Run Time: 1:57:08 PM
Duration : 00:00:01

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: B26 IT HA Slab
Description: Excavator Op High Act Slab Trench B26
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	304.8 cm	10 ft 0.0 in
Width	381.0 cm	12 ft 6.0 in
Height	60.96 cm	2 ft

Dose Points

	X	Y	Z
# 1	960.12 cm 31 ft 6.0 in	548.64 cm 18 ft	190.5 cm 6 ft 3.0 in

Shields

Shield Name	Dimension	Material	Density
Source	7.08e+06 cm³	BC Dry Sandy Soil	1.6
Shield 1	5.182 cm	4.36 PbGlass	4.36
Air Gap		Air	0.00122
Immersion		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	1.7698e+001	6.5483e+011	2.5000e+000	9.2500e+004
Cs-137	1.8406e+001	6.8102e+011	2.6000e+000	9.6200e+004
Ni-63	7.0792e-002	2.6193e+009	1.0000e-002	3.7000e+002
Pu-239	7.0792e-003	2.6193e+008	1.0000e-003	3.7000e+001
Sr-90	3.2564e+001	1.2049e+012	4.6000e+000	1.7020e+005
Y-90	3.2564e+001	1.2049e+012	4.6000e+000	1.7020e+005

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	20

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	6.798e+09	0.000e+00	2.626e-26	0.000e+00	1.800e-26
0.0136	1.156e+07	0.000e+00	1.359e-28	0.000e+00	1.587e-29
0.0318	1.356e+10	1.940e-152	1.067e-24	1.616e-154	8.886e-27
0.0322	2.501e+10	3.081e-148	2.057e-24	2.479e-150	1.656e-26
0.0364	9.102e+09	1.415e-114	1.288e-24	8.039e-117	7.316e-27
0.1129	1.246e+05	2.486e-38	2.488e-26	3.844e-41	3.847e-29
0.6616	5.892e+11	2.444e+02	1.800e+03	4.739e-01	3.489e+00
TOTALS:	6.437e+11	2.444e+02	1.800e+03	4.739e-01	3.489e+00

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APPENDIX N

PROTECTED WORKER WITH IN-TRENCH MIXING – DOSE RATE FROM A SLAB OF HIGH-ACTIVITY SOIL: SPRAYER

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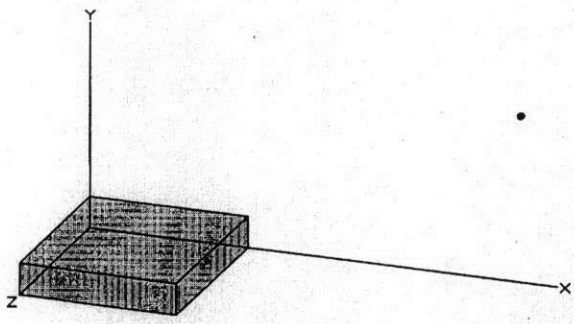
MicroShield v6.02 (6.02-00206)
Fluor_Hanford

Page : 1
DOS File : B26ITHASlabSpyr.ms6
Run Date: June 26, 2004
Run Time: 2:10:10 PM
Duration : 00:00:01

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: B26 IT HA Slab
Description: IT Mixing Sprayer High Act Slab Trench B26
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	304.8 cm	10 ft 0.0 in
Width	381.0 cm	12 ft 6.0 in
Height	60.96 cm	2 ft

Dose Points

	X	Y	Z
# 1	899.16 cm	396.24 cm	190.5 cm
	29 ft 6.0 in	13 ft 0.0 in	6 ft 3.0 in

Shields

Shield Name	Dimension	Material	Density
Source	7.08e+06 cm³	BC Dry Sandy Soil	1.6
Air Gap		Air	0.00122
Immersion		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	1.7698e+001	6.5483e+011	2.5000e+000	9.2500e+004
Cs-137	1.8406e+001	6.8102e+011	2.6000e+000	9.6200e+004
Ni-63	7.0792e-002	2.6193e+009	1.0000e-002	3.7000e+002
Pu-239	7.0792e-003	2.6193e+008	1.0000e-003	3.7000e+001
Sr-90	3.2564e+001	1.2049e+012	4.6000e+000	1.7020e+005
Y-90	3.2564e+001	1.2049e+012	4.6000e+000	1.7020e+005

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	20

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	6.798e+09	4.317e-05	4.754e-05	2.959e-05	3.259e-05
0.0136	1.156e+07	2.234e-07	2.460e-07	2.608e-08	2.872e-08
0.0318	1.356e+10	2.121e-01	3.058e-01	1.767e-03	2.547e-03
0.0322	2.501e+10	4.109e-01	5.976e-01	3.307e-03	4.809e-03
0.0364	9.102e+09	2.468e-01	4.039e-01	1.402e-03	2.295e-03
0.1129	1.246e+05	6.007e-05	2.417e-04	9.291e-08	3.738e-07
0.6616	5.892e+11	3.556e+03	8.596e+03	6.894e+00	1.666e+01
TOTALS:	6.437e+11	3.557e+03	8.597e+03	6.901e+00	1.667e+01

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APPENDIX O

PROTECTED WORKER WITH IN-TRENCH MIXING – DOSE RATE FROM A SLAB OF MIXED HIGH-ACTIVITY SOIL: EXCAVATOR OPERATOR

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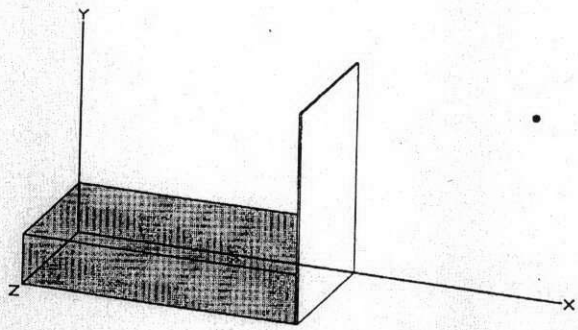
MicroShield v6.02 (6.02-00206)
Fluor_Hanford

Page : 1
DOS File : B26ITMHASlabEO.ms6
Run Date: June 26, 2004
Run Time: 2:29:38 PM
Duration : 00:00:01

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: B29 IT MHA Slab
Description: Excavator Op Mixed High Act Slab Trench B29
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	670.56 cm	22 ft
Width	381.0 cm	12 ft 6.0 in
Height	121.92 cm	4 ft

Dose Points

	X	Y	Z
# 1	1188.72 cm	518.16 cm	190.5 cm
	39 ft 0.0 in	17 ft	6 ft 3.0 in

Shields

Shield Name	Dimension	Material	Density
Source	3.11e+07 cm³	BC Dry Sandy Soil	1.6
Shield 1	5.182 cm	4.36 PbGlass	4.36
Air Gap		Air	0.00122
Immersion		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	1.0902e+001	4.0337e+011	3.5000e-001	1.2950e+004
Cs-137	1.1525e+001	4.2642e+011	3.7000e-001	1.3690e+004
Ni-63	3.1149e-002	1.1525e+009	1.0000e-003	3.7000e+001
Pu-239	3.1149e-003	1.1525e+008	1.0000e-004	3.7000e+000
Sr-90	2.0558e+001	7.6065e+011	6.6000e-001	2.4420e+004
Y-90	2.0558e+001	7.6065e+011	6.6000e-001	2.4420e+004

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	20

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	4.187e+09	0.000e+00	1.699e-26	0.000e+00	1.165e-26
0.0136	5.087e+06	0.000e+00	6.282e-29	0.000e+00	7.334e-30
0.0318	8.351e+09	3.247e-144	6.904e-25	2.705e-146	5.751e-27
0.0322	1.541e+10	3.064e-140	1.331e-24	2.466e-142	1.071e-26
0.0364	5.607e+09	1.494e-108	8.333e-25	8.491e-111	4.734e-27
0.1129	5.484e+04	3.223e-37	1.150e-26	4.985e-40	1.778e-29
0.6616	3.630e+11	7.831e+01	5.932e+02	1.518e-01	1.150e+00
TOTALS:	3.965e+11	7.831e+01	5.932e+02	1.518e-01	1.150e+00

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APPENDIX P

PROTECTED WORKER WITH IN-TRENCH MIXING – DOSE RATE FROM A SLAB OF MIXED HIGH-ACTIVITY SOIL: SPRAYER

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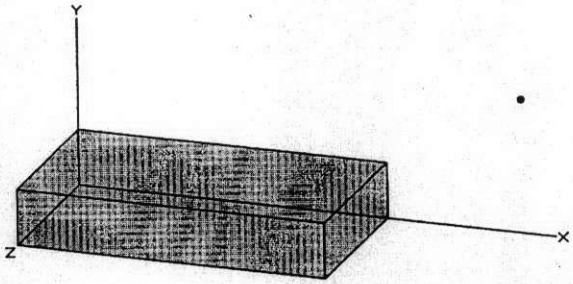
MicroShield v6.02 (6.02-00206)
Fluor_Hanford

Page : 1
DOS File : B26ITMHASlabSpyr.ms6
Run Date: June 26, 2004
Run Time: 2:57:09 PM
Duration : 00:00:01

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: B26 IT MHA Slab
Description: Sprayer Mixed High Act Slab Trench B26
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	670.56 cm	22 ft
Width	381.0 cm	12 ft 6.0 in
Height	121.92 cm	4 ft

Dose Points

	X	Y	Z
# 1	1036.32 cm	365.76 cm	190.5 cm
	34 ft	12 ft	6 ft 3.0 in

Shields

Shield Name	Dimension	Material	Density
Source	3.11e+07 cm³	BC Dry Sandy Soil	1.6
Air Gap		Air	0.00122
Immersion		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	1.0902e+001	4.0337e+011	3.5000e-001	1.2950e+004
Cs-137	1.1525e+001	4.2642e+011	3.7000e-001	1.3690e+004
Ni-63	3.1149e-002	1.1525e+009	1.0000e-003	3.7000e+001
Pu-239	3.1149e-003	1.1525e+008	1.0000e-004	3.7000e+000
Sr-90	2.0558e+001	7.6065e+011	6.6000e-001	2.4420e+004
Y-90	2.0558e+001	7.6065e+011	6.6000e-001	2.4420e+004

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	20

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	4.187e+09	6.232e-07	6.971e-07	4.272e-07	4.778e-07
0.0136	5.087e+06	2.304e-09	2.577e-09	2.689e-10	3.008e-10
0.0318	8.351e+09	7.974e-02	1.204e-01	6.642e-04	1.003e-03
0.0322	1.541e+10	1.554e-01	2.363e-01	1.251e-03	1.902e-03
0.0364	5.607e+09	9.440e-02	1.549e-01	5.364e-04	8.802e-04
0.1129	5.484e+04	1.545e-05	7.802e-05	2.389e-08	1.207e-07
0.6616	3.630e+11	1.546e+03	4.083e+03	2.998e+00	7.915e+00
TOTALS:	3.965e+11	1.547e+03	4.083e+03	3.000e+00	7.919e+00

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APPENDIX Q

PROTECTED WORKER WITH IN-TRENCH MIXING – DOSE RATE TO HEALTH PHYSICS TECHNICIAN FROM MIXED HIGH-ACTIVITY SOIL IN EXCAVATION BUCKET

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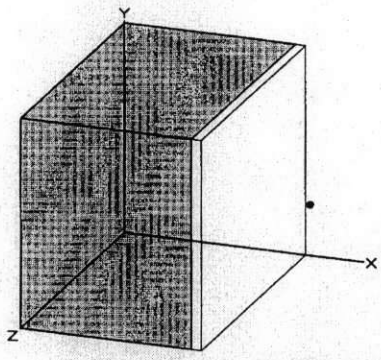
MicroShield v6.02 (6.02-00206)
Fluor_Hanford

Page : 1
DOS File : B26ITMHABucketHPT.ms6
Run Date: June 26, 2004
Run Time: 3:16:58 PM
Duration : 00:00:01

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: B26 IT MHA Bucket
Description: B26 In-Trench Mixed Hi Act Dose Rate HPT Bucket
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	91.44 cm	3 ft
Width	152.4 cm	5 ft 0.0 in
Height	114.3 cm	3 ft 9.0 in

Dose Points

	X	Y	Z
# 1	127.1016 cm 4 ft 2.0 in	57.3024 cm 1 ft 10.6 in	76.2 cm 2 ft 6.0 in

Shields

Shield Name	Dimension	Material	Density
Source	1.59e+06 cm³	BC Dry Sandy Soil	1.6
Shield 1	5.182 cm	Iron	7.86
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	5.5749e-001	2.0627e+010	3.5000e-001	1.2950e+004
Cs-137	5.8934e-001	2.1806e+010	3.7000e-001	1.3690e+004
Ni-63	1.5928e-003	5.8934e+007	1.0000e-003	3.7000e+001
Pu-239	1.5928e-004	5.8934e+006	1.0000e-004	3.7000e+000
Sr-90	1.0513e+000	3.8897e+010	6.6000e-001	2.4420e+004
Y-90	1.0513e+000	3.8897e+010	6.6000e-001	2.4420e+004

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	20

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	2.141e+08	0.000e+00	9.751e-26	0.000e+00	6.684e-26
0.0136	2.601e+05	0.000e+00	3.604e-28	0.000e+00	4.208e-29
0.0318	4.270e+08	3.291e-121	3.961e-24	2.742e-123	3.299e-26
0.0322	7.879e+08	5.776e-117	7.638e-24	4.649e-119	6.147e-26
0.0364	2.867e+08	4.975e-83	4.781e-24	2.826e-85	2.716e-26
0.1129	2.804e+03	4.215e-10	3.886e-08	6.520e-13	6.010e-11
0.6616	1.856e+10	3.420e+02	3.512e+03	6.630e-01	6.809e+00
TOTALS:	2.028e+10	3.420e+02	3.512e+03	6.630e-01	6.809e+00

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APPENDIX R

PROTECTED WORKER WITH IN-TRENCH MIXING – DOSE RATE FROM A SLAB OF MODERATE-ACTIVITY SOIL: EXCAVATOR OPERATOR

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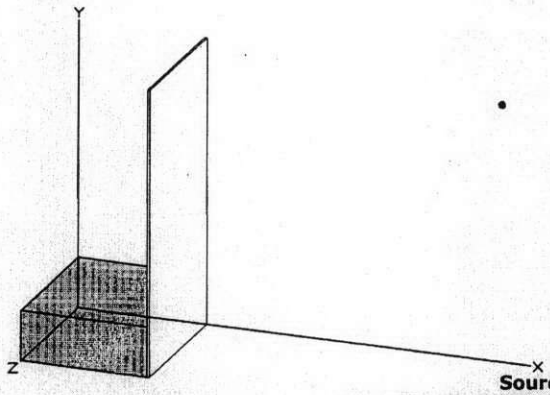
MicroShield v6.02 (6.02-00206)
Fluor_Hanford

Page : 1
DOS File : B26ITMASlabEO.ms6
Run Date: June 26, 2004
Run Time: 3:24:34 PM
Duration : 00:00:01

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: B26 IT MA Slab
Description: Excavator Op IT Mod Act Slab Trench B26
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	304.8 cm	10 ft 0.0 in
Width	381.0 cm	12 ft 6.0 in
Height	121.92 cm	4 ft

Dose Points

	X	Y	Z
# 1	1097.28 cm	701.04 cm	190.5 cm
	36 ft	23 ft	6 ft 3.0 in

Shields

Shield Name	Dimension	Material	Density
Source	1.42e+07 cm³	BC Dry Sandy Soil	1.6
Shield 1	5.182 cm	4.36 PbGlass	4.36
Air Gap		Air	0.00122
Immersion		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	9.9109e-001	3.6670e+010	7.0000e-002	2.5900e+003
Cs-137	9.9109e-001	3.6670e+010	7.0000e-002	2.5900e+003
Ni-63	4.2475e-003	1.5716e+008	3.0000e-004	1.1100e+001
Pu-239	4.2475e-004	1.5716e+007	3.0000e-005	1.1100e+000
Sr-90	1.8406e+000	6.8102e+010	1.3000e-001	4.8100e+003
Y-90	1.8406e+000	6.8102e+010	1.3000e-001	4.8100e+003

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	20

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	3.807e+08	0.000e+00	1.039e-27	0.000e+00	7.121e-28
0.0136	6.937e+05	0.000e+00	5.760e-30	0.000e+00	6.725e-31
0.0318	7.592e+08	2.824e-155	4.220e-26	2.352e-157	3.515e-28
0.0322	1.401e+09	4.860e-151	8.138e-26	3.911e-153	6.550e-28
0.0364	5.097e+08	4.384e-117	5.094e-26	2.491e-119	2.894e-28
0.1129	7.478e+03	3.577e-40	1.054e-27	5.533e-43	1.631e-30
0.6616	3.300e+10	5.921e+00	4.440e+01	1.148e-02	8.608e-02
TOTALS:	3.605e+10	5.921e+00	4.440e+01	1.148e-02	8.608e-02

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APPENDIX S

PROTECTED WORKER WITH IN-TRENCH MIXING – DOSE RATE FROM A SLAB OF MODERATE-ACTIVITY SOIL: SPRAYER

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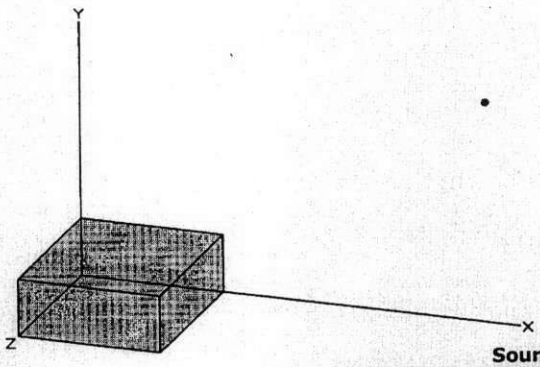
MicroShield v6.02 (6.02-00206)
Fluor_Hanford

Page : 1
DOS File : B26ITMASlabSpyr.ms6
Run Date: June 26, 2004
Run Time: 3:28:33 PM
Duration : 00:00:01

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: B26 IT MA Slab
Description: Sprayer IT Mod Act Slab Trench B26
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	304.8 cm	10 ft 0.0 in
Width	381.0 cm	12 ft 6.0 in
Height	121.92 cm	4 ft

Dose Points

	X	Y	Z
# 1	944.88 cm 31 ft	548.64 cm 18 ft	190.5 cm 6 ft 3.0 in

Shields

Shield Name	Dimension	Material	Density
Source	1.42e+07 cm³	BC Dry Sandy Soil	1.6
Air Gap		Air	0.00122
Immersion		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	9.9109e-001	3.6670e+010	7.0000e-002	2.5900e+003
Cs-137	9.9109e-001	3.6670e+010	7.0000e-002	2.5900e+003
Ni-63	4.2475e-003	1.5716e+008	3.0000e-004	1.1100e+001
Pu-239	4.2475e-004	1.5716e+007	3.0000e-005	1.1100e+000
Sr-90	1.8406e+000	6.8102e+010	1.3000e-001	4.8100e+003
Y-90	1.8406e+000	6.8102e+010	1.3000e-001	4.8100e+003

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	20

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	3.807e+08	4.182e-08	4.679e-08	2.866e-08	3.207e-08
0.0136	6.937e+05	2.319e-10	2.594e-10	2.707e-11	3.029e-11
0.0318	7.592e+08	5.249e-03	7.924e-03	4.373e-05	6.600e-05
0.0322	1.401e+09	1.023e-02	1.558e-02	8.235e-05	1.254e-04
0.0364	5.097e+08	6.434e-03	1.093e-02	3.656e-05	6.210e-05
0.1129	7.478e+03	1.961e-06	8.230e-06	3.032e-09	1.273e-08
0.6616	3.300e+10	1.110e+02	2.716e+02	2.153e-01	5.265e-01
TOTALS:	3.605e+10	1.111e+02	2.716e+02	2.154e-01	5.268e-01

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APPENDIX T

PROTECTED WORKER WITH IN-TRENCH MIXING – DOSE RATE TO HEALTH PHYSICS TECHNICIAN FROM MODERATE-ACTIVITY SOIL IN EXCAVATION BUCKET

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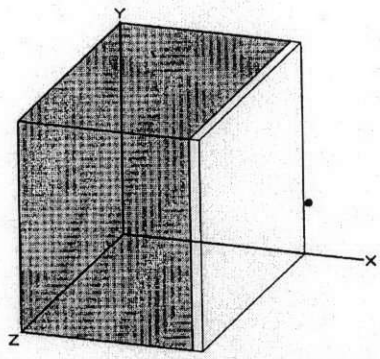
MicroShield v6.02 (6.02-00206)
Fluor_Hanford

Page : 1
DOS File : B26ITMABucketHPT.ms6
Run Date: June 26, 2004
Run Time: 3:36:55 PM
Duration : 00:00:01

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: B26 IT MA Bucket
Description: B26 In-Trench Moderate Act Dose Rate HPT Bucket
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	91.44 cm	3 ft
Width	152.4 cm	5 ft 0.0 in
Height	114.3 cm	3 ft 9.0 in

Dose Points

	X	Y	Z
# 1	127.1016 cm 4 ft 2.0 in	57.3024 cm 1 ft 10.6 in	76.2 cm 2 ft 6.0 in

Shields

Shield Name	Dimension	Material	Density
Source	1.59e+06 cm³	BC Dry Sandy Soil	1.6
Shield 1	5.182 cm	Iron	7.86
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	1.1150e-001	4.1254e+009	7.0000e-002	2.5900e+003
Cs-137	1.1150e-001	4.1254e+009	7.0000e-002	2.5900e+003
Ni-63	4.7785e-004	1.7680e+007	3.0000e-004	1.1100e+001
Pu-239	4.7785e-005	1.7680e+006	3.0000e-005	1.1100e+000
Sr-90	2.0707e-001	7.6615e+009	1.3000e-001	4.8100e+003
Y-90	2.0707e-001	7.6615e+009	1.3000e-001	4.8100e+003

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	20

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	4.283e+07	0.000e+00	1.950e-26	0.000e+00	1.337e-26
0.0136	7.804e+04	0.000e+00	1.081e-28	0.000e+00	1.262e-29
0.0318	8.541e+07	6.583e-122	7.922e-25	5.483e-124	6.599e-27
0.0322	1.576e+08	1.155e-117	1.528e-24	9.297e-120	1.229e-26
0.0364	5.734e+07	9.950e-84	9.562e-25	5.653e-86	5.433e-27
0.1129	8.413e+02	1.265e-10	1.166e-08	1.956e-13	1.803e-11
0.6616	3.712e+09	6.840e+01	7.024e+02	1.326e-01	1.362e+00
TOTALS:	4.055e+09	6.840e+01	7.024e+02	1.326e-01	1.362e+00

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APPENDIX U

PROTECTED WORKER WITH IN-TRENCH MIXING – DOSE RATE TO THE SHUTTLE TRUCK DRIVER FROM MIXED HIGH-ACTIVITY SOIL

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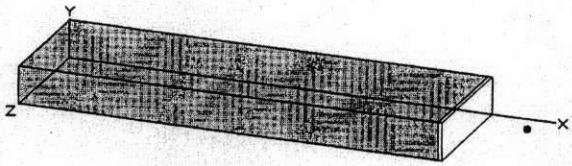
MicroShield v6.02 (6.02-00206)
Fluor_Hanford

Page : 1
DOS File : B26ITMHAShutDrv.ms6
Run Date: June 26, 2004
Run Time: 3:44:51 PM
Duration : 00:00:01

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: B26 IT MHA Shuttle
Description: B26 IT Mixed High Act Soil Shuttle Drivers
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	669.95 cm	21 ft 11.8 in
Width	220.98 cm	7 ft 3.0 in
Height	60.96 cm	2 ft

Dose Points

	X	Y	Z
# 1	777.24 cm	30.48 cm	121.92 cm
	25 ft 6.0 in	1 ft	4 ft

Shields

Shield Name	Dimension	Material	Density
Source	9.02e+06 cm³	BC Dry Sandy Soil	1.6
Shield 1	5.791 cm	Iron	7.86
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	3.1587e+000	1.1687e+011	3.5000e-001	1.2950e+004
Cs-137	3.3392e+000	1.2355e+011	3.7000e-001	1.3690e+004
Ni-63	9.0249e-003	3.3392e+008	1.0000e-003	3.7000e+001
Pu-239	9.0249e-004	3.3392e+007	1.0000e-004	3.7000e+000
Sr-90	5.9564e+000	2.2039e+011	6.6000e-001	2.4420e+004
Y-90	5.9564e+000	2.2039e+011	6.6000e-001	2.4420e+004

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	20

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	1.213e+09	0.000e+00	4.593e-26	0.000e+00	3.148e-26
0.0136	1.474e+06	0.000e+00	1.698e-28	0.000e+00	1.982e-29
0.0318	2.420e+09	1.705e-138	1.866e-24	1.420e-140	1.554e-26
0.0322	4.464e+09	1.141e-133	3.598e-24	9.181e-136	2.895e-26
0.0364	1.625e+09	9.681e-95	2.252e-24	5.500e-97	1.279e-26
0.1129	1.589e+04	4.122e-11	5.077e-09	6.375e-14	7.853e-12
0.6616	1.052e+11	8.596e+01	9.295e+02	1.666e-01	1.802e+00
TOTALS:	1.149e+11	8.596e+01	9.295e+02	1.666e-01	1.802e+00

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APPENDIX V

PROTECTED WORKER WITH IN-TRENCH MIXING – DOSE RATE TO THE SHUTTLE TRUCK DRIVER FROM MODERATE-ACTIVITY SOIL

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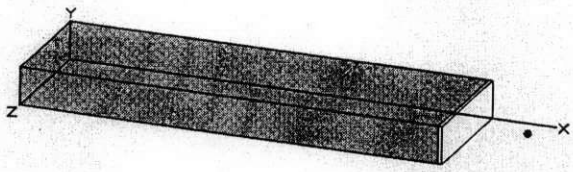
MicroShield v6.02 (6.02-00206)
Fluor_Hanford

Page : 1
DOS File : B26ITMAShutDrv.ms6
Run Date : June 26, 2004
Run Time : 3:52:25 PM
Duration : 00:00:01

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: B26 IT MA Shuttle
Description: B26 IT Moderate Act Soil Shuttle Drivers
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	669.95 cm	21 ft 11.8 in
Width	220.98 cm	7 ft 3.0 in
Height	60.96 cm	2 ft

Dose Points

	X	Y	Z
# 1	777.24 cm	30.48 cm	121.92 cm
	25 ft 6.0 in	1 ft	4 ft

Shields

Shield Name	Dimension	Material	Density
Source	9.02e+06 cm³	BC Dry Sandy Soil	1.6
Shield 1	5.791 cm	Iron	7.86
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	6.3174e-001	2.3374e+010	7.0000e-002	2.5900e+003
Cs-137	6.3174e-001	2.3374e+010	7.0000e-002	2.5900e+003
Ni-63	2.7075e-003	1.0018e+008	3.0000e-004	1.1100e+001
Pu-239	2.7075e-004	1.0018e+007	3.0000e-005	1.1100e+000
Sr-90	1.1732e+000	4.3410e+010	1.3000e-001	4.8100e+003
Y-90	1.1732e+000	4.3410e+010	1.3000e-001	4.8100e+003

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	20

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	2.426e+08	0.000e+00	9.185e-27	0.000e+00	6.296e-27
0.0136	4.422e+05	0.000e+00	5.093e-29	0.000e+00	5.945e-30
0.0318	4.839e+08	3.410e-139	3.731e-25	2.840e-141	3.108e-27
0.0322	8.928e+08	2.282e-134	7.195e-25	1.836e-136	5.791e-27
0.0364	3.249e+08	1.936e-95	4.504e-25	1.100e-97	2.559e-27
0.1129	4.767e+03	1.237e-11	1.523e-09	1.912e-14	2.356e-12
0.6616	2.103e+10	1.719e+01	1.859e+02	3.333e-02	3.604e-01
TOTALS:	2.298e+10	1.719e+01	1.859e+02	3.333e-02	3.604e-01

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APPENDIX W

PROTECTED WORKER WITH IN-TRENCH MIXING – DOSE RATE TO HEALTH PHYSICS TECHNICIAN SURVEYING ENVIRONMENTAL RESTORATION DISPOSAL FACILITY CONTAINER WITH MIXED HIGH-ACTIVITY SOIL

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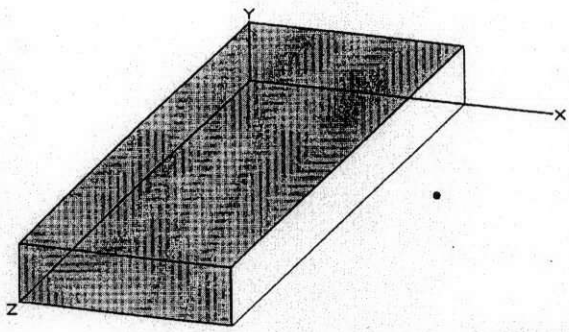
MicroShield v6.02 (6.02-00206)
Fluor_Hanford

Page : 1
DOS File : B26ITMHACanSurvey.ms6
Run Date: June 26, 2004
Run Time: 3:56:24 PM
Duration : 00:00:01

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: B26 IT MHA Can Survy
Description: B26 IT Mixed High Activity ERDF Can Survey HPT
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	220.98 cm	7 ft 3.0 in
Width	669.95 cm	21 ft 11.8 in
Height	60.96 cm	2 ft

Dose Points

	X	Y	Z
# 1	313.0296 cm	30.48 cm	334.9752 cm
	10 ft 3.2 in	1 ft	10 ft 11.9 in

Shields

Shield Name	Dimension	Material	Density
Source	9.02e+06 cm³	BC Dry Sandy Soil	1.6
Shield 1	.61 cm	Iron	7.86
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	3.1587e+000	1.1687e+011	3.5000e-001	1.2950e+004
Cs-137	3.3392e+000	1.2355e+011	3.7000e-001	1.3690e+004
Ni-63	9.0249e-003	3.3392e+008	1.0000e-003	3.7000e+001
Pu-239	9.0249e-004	3.3392e+007	1.0000e-004	3.7000e+000
Sr-90	5.9564e+000	2.2039e+011	6.6000e-001	2.4420e+004
Y-90	5.9564e+000	2.2039e+011	6.6000e-001	2.4420e+004

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	20

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	1.213e+09	2.394e-133	7.675e-26	1.641e-133	5.261e-26
0.0136	1.474e+06	8.848e-136	2.837e-28	1.033e-136	3.312e-29
0.0318	2.420e+09	2.323e-16	7.895e-16	1.935e-18	6.576e-18
0.0322	4.464e+09	1.441e-15	5.026e-15	1.159e-17	4.045e-17
0.0364	1.625e+09	1.912e-11	8.750e-11	1.086e-13	4.972e-13
0.1129	1.589e+04	1.399e-05	1.212e-04	2.163e-08	1.874e-07
0.6616	1.052e+11	3.589e+03	1.076e+04	6.958e+00	2.086e+01
TOTALS:	1.149e+11	3.589e+03	1.076e+04	6.958e+00	2.086e+01

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APPENDIX X

PROTECTED WORKER WITH IN-TRENCH MIXING – DOSE RATE TO HEALTH PHYSICS TECHNICIAN SURVEYING ENVIRONMENTAL RESTORATION DISPOSAL FACILITY CONTAINER WITH MODERATE-ACTIVITY SOIL

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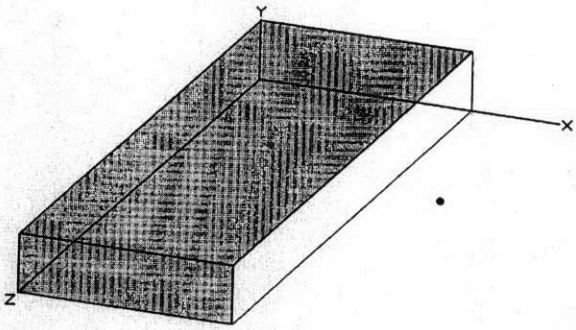
MicroShield v6.02 (6.02-00206)
Fluor_Hanford

Page : 1
DOS File : B26ITMACanSurvey.ms6
Run Date : June 26, 2004
Run Time : 3:59:46 PM
Duration : 00:00:01

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: B29 IT MA Can Survey
Description: B26 IT Moderate Activity Can Survey DoseRate
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	220.98 cm	7 ft 3.0 in
Width	669.95 cm	21 ft 11.8 in
Height	60.96 cm	2 ft

Dose Points

	X	Y	Z
# 1	313.0296 cm 10 ft 3.2 in	30.48 cm 1 ft	334.9752 cm 10 ft 11.9 in

Shields

Shield Name	Dimension	Material	Density
Source	9.02e+06 cm³	BC Dry Sandy Soil	1.6
Shield 1	.61 cm	Iron	7.86
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	6.3174e-001	2.3374e+010	7.0000e-002	2.5900e+003
Cs-137	6.3174e-001	2.3374e+010	7.0000e-002	2.5900e+003
Ni-63	2.7075e-003	1.0018e+008	3.0000e-004	1.1100e+001
Pu-239	2.7075e-004	1.0018e+007	3.0000e-005	1.1100e+000
Sr-90	1.1732e+000	4.3410e+010	1.3000e-001	4.8100e+003
Y-90	1.1732e+000	4.3410e+010	1.3000e-001	4.8100e+003

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	20

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	2.426e+08	4.788e-134	1.535e-26	3.282e-134	1.052e-26
0.0136	4.422e+05	2.654e-136	8.511e-29	3.099e-137	9.936e-30
0.0318	4.839e+08	4.646e-17	1.579e-16	3.870e-19	1.315e-18
0.0322	8.928e+08	2.881e-16	1.005e-15	2.319e-18	8.091e-18
0.0364	3.249e+08	3.824e-12	1.750e-11	2.173e-14	9.943e-14
0.1129	4.767e+03	4.196e-06	3.635e-05	6.490e-09	5.621e-08
0.6616	2.103e+10	7.178e+02	2.153e+03	1.392e+00	4.173e+00
TOTALS:	2.298e+10	7.178e+02	2.153e+03	1.392e+00	4.173e+00

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APPENDIX Y

PROTECTED WORKER WITH IN-TRENCH MIXING – DOSE RATE TO LABORERS SEALING MIXED HIGH-ACTIVITY ENVIRONMENTAL RESTORATION DISPOSAL FACILITY CONTAINER

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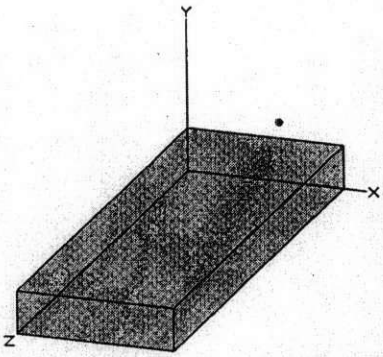
MicroShield v6.02 (6.02-00206)
Fluor_Hanford

Page : 1
DOS File : B26ITMHACanSealer.ms6
Run Date: June 26, 2004
Run Time: 4:04:35 PM
Duration : 00:00:01

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: B26IT MHA Can Sealer
Description: B26 IT Mix High Activity Can Sealer DoseRate
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	220.98 cm	7 ft 3.0 in
Width	669.95 cm	21 ft 11.8 in
Height	60.96 cm	2 ft

Dose Points

	X	Y	Z
# 1	251.46 cm	213.36 cm	334.9752 cm
	8 ft 3.0 in	7 ft 0.0 in	10 ft 11.9 in

Shields

Shield Name	Dimension	Material	Density
Source	9.02e+06 cm³	BC Dry Sandy Soil	1.6
Air Gap		Air	0.00122
Immersion		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	3.1587e+000	1.1687e+011	3.5000e-001	1.2950e+004
Cs-137	3.3392e+000	1.2355e+011	3.7000e-001	1.3690e+004
Ni-63	9.0249e-003	3.3392e+008	1.0000e-003	3.7000e+001
Pu-239	9.0249e-004	3.3392e+007	1.0000e-004	3.7000e+000
Sr-90	5.9564e+000	2.2039e+011	6.6000e-001	2.4420e+004
Y-90	5.9564e+000	2.2039e+011	6.6000e-001	2.4420e+004

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	20

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	1.213e+09	1.468e-03	1.580e-03	1.006e-03	1.083e-03
0.0136	1.474e+06	5.425e-06	5.842e-06	6.334e-07	6.820e-07
0.0318	2.420e+09	6.994e-01	9.533e-01	5.825e-03	7.940e-03
0.0322	4.464e+09	1.346e+00	1.847e+00	1.083e-02	1.486e-02
0.0364	1.625e+09	7.475e-01	1.119e+00	4.247e-03	6.360e-03
0.1129	1.589e+04	8.792e-05	3.263e-04	1.360e-07	5.047e-07
0.6616	1.052e+11	7.062e+03	1.728e+04	1.369e+01	3.350e+01
TOTALS:	1.149e+11	7.065e+03	1.728e+04	1.371e+01	3.353e+01

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APPENDIX Z

PROTECTED WORKER WITH IN-TRENCH MIXING – DOSE RATE TO LABORERS SEALING MODERATE-ACTIVITY ENVIRONMENTAL RESTORATION DISPOSAL FACILITY CONTAINER

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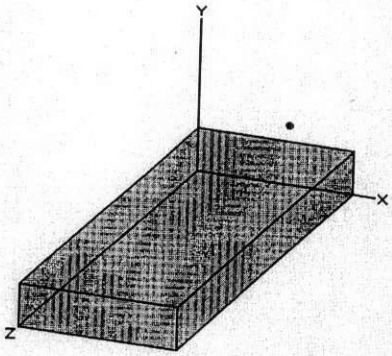
MicroShield v6.02 (6.02-00206)
Fluor_Hanford

Page : 1
DOS File : B26ITMACanSealer.ms6
Run Date : June 26, 2004
Run Time : 4:07:41 PM
Duration : 00:00:01

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: B26IT MA Can Sealer
Description: B26 IT Moderate Activity Can Sealer DoseRate
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	220.98 cm	7 ft 3.0 in
Width	669.95 cm	21 ft 11.8 in
Height	60.96 cm	2 ft

Dose Points

	X	Y	Z
# 1	251.46 cm 8 ft 3.0 in	213.36 cm 7 ft 0.0 in	334.9752 cm 10 ft 11.9 in

Shields

Shield Name	Dimension	Material	Density
Source	9.02e+06 cm³	BC Dry Sandy Soil	1.6
Air Gap		Air	0.00122
Immersion		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	6.3174e-001	2.3374e+010	7.0000e-002	2.5900e+003
Cs-137	6.3174e-001	2.3374e+010	7.0000e-002	2.5900e+003
Ni-63	2.7075e-003	1.0018e+008	3.0000e-004	1.1100e+001
Pu-239	2.7075e-004	1.0018e+007	3.0000e-005	1.1100e+000
Sr-90	1.1732e+000	4.3410e+010	1.3000e-001	4.8100e+003
Y-90	1.1732e+000	4.3410e+010	1.3000e-001	4.8100e+003

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	20

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	2.426e+08	2.936e-04	3.161e-04	2.012e-04	2.167e-04
0.0136	4.422e+05	1.628e-06	1.752e-06	1.900e-07	2.046e-07
0.0318	4.839e+08	1.399e-01	1.907e-01	1.165e-03	1.588e-03
0.0322	8.928e+08	2.692e-01	3.694e-01	2.166e-03	2.973e-03
0.0364	3.249e+08	1.495e-01	2.239e-01	8.494e-04	1.272e-03
0.1129	4.767e+03	2.638e-05	9.790e-05	4.080e-08	1.514e-07
0.6616	2.103e+10	1.412e+03	3.456e+03	2.738e+00	6.700e+00
TOTALS:	2.298e+10	1.413e+03	3.457e+03	2.742e+00	6.706e+00

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APPENDIX AA

PROTECTED WORKER WITH IN-TRENCH MIXING – DOSE RATE TO CROSS-SITE DRIVER FROM MIXED HIGH-ACTIVITY SOIL

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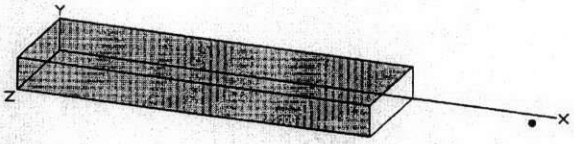
MicroShield v6.02 (6.02-00206)
Fluor_Hanford

Page : 1
DOS File : B26ITMHACrossSiteDrv.ms6
Run Date : June 26, 2004
Run Time : 4:25:44 PM
Duration : 00:00:01

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: B26 IT MHA CS Drv
Description: B26 IT Mixed High Act Soil Cross Site Drivers
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	669.95 cm	21 ft 11.8 in
Width	220.98 cm	7 ft 3.0 in
Height	60.96 cm	2 ft

Dose Points

	X	Y	Z
# 1	944.88 cm	30.48 cm	121.92 cm
	31 ft	1 ft	4 ft

Shields

Shield Name	Dimension	Material	Density
Source	9.02e+06 cm³	BC Dry Sandy Soil	1.6
Shield 1	.61 cm	Iron	7.86
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	3.1587e+000	1.1687e+011	3.5000e-001	1.2950e+004
Cs-137	3.3392e+000	1.2355e+011	3.7000e-001	1.3690e+004
Ni-63	9.0249e-003	3.3392e+008	1.0000e-003	3.7000e+001
Pu-239	9.0249e-004	3.3392e+007	1.0000e-004	3.7000e+000
Sr-90	5.9564e+000	2.2039e+011	6.6000e-001	2.4420e+004
Y-90	5.9564e+000	2.2039e+011	6.6000e-001	2.4420e+004

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	20

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	1.213e+09	8.332e-160	1.616e-26	5.711e-160	1.107e-26
0.0136	1.474e+06	3.080e-162	5.972e-29	3.595e-163	6.971e-30
0.0318	2.420e+09	1.767e-19	6.159e-19	1.472e-21	5.130e-21
0.0322	4.464e+09	1.341e-18	4.822e-18	1.079e-20	3.881e-20
0.0364	1.625e+09	9.752e-14	4.791e-13	5.540e-16	2.722e-15
0.1129	1.589e+04	1.520e-06	1.877e-05	2.351e-09	2.904e-08
0.6616	1.052e+11	5.014e+02	1.578e+03	9.721e-01	3.060e+00
TOTALS:	1.149e+11	5.014e+02	1.578e+03	9.721e-01	3.060e+00

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APPENDIX BB

PROTECTED WORKER WITH IN-TRENCH MIXING – DOSE RATE TO CROSS-SITE DRIVER FROM MODERATE-ACTIVITY SOIL

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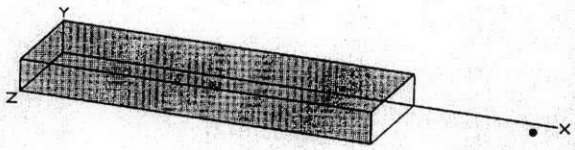
MicroShield v6.02 (6.02-00206)
Fluor_Hanford

Page : 1
DOS File : B26ITMACrossSiteDrv.ms6
Run Date: June 26, 2004
Run Time: 4:28:43 PM
Duration : 00:00:01

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: B26 IT MA CS Drv
Description: B26 IT Moderate Act Soil Cross Site Drivers
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	669.95 cm	21 ft 11.8 in
Width	220.98 cm	7 ft 3.0 in
Height	60.96 cm	2 ft

Dose Points

	X	Y	Z
# 1	944.88 cm 31 ft	30.48 cm 1 ft	121.92 cm 4 ft

Shields

Shield Name	Dimension	Material	Density
Source	9.02e+06 cm³	BC Dry Sandy Soil	1.6
Shield 1	.61 cm	Iron	7.86
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	6.3174e-001	2.3374e+010	7.0000e-002	2.5900e+003
Cs-137	6.3174e-001	2.3374e+010	7.0000e-002	2.5900e+003
Ni-63	2.7075e-003	1.0018e+008	3.0000e-004	1.1100e+001
Pu-239	2.7075e-004	1.0018e+007	3.0000e-005	1.1100e+000
Sr-90	1.1732e+000	4.3410e+010	1.3000e-001	4.8100e+003
Y-90	1.1732e+000	4.3410e+010	1.3000e-001	4.8100e+003

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	20

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	2.426e+08	1.666e-160	3.231e-27	1.142e-160	2.215e-27
0.0136	4.422e+05	9.239e-163	1.791e-29	1.079e-163	2.091e-30
0.0318	4.839e+08	3.535e-20	1.232e-19	2.944e-22	1.026e-21
0.0322	8.928e+08	2.681e-19	9.644e-19	2.158e-21	7.761e-21
0.0364	3.249e+08	1.950e-14	9.583e-14	1.108e-16	5.444e-16
0.1129	4.767e+03	4.559e-07	5.632e-06	7.052e-10	8.711e-09
0.6616	2.103e+10	1.003e+02	3.157e+02	1.944e-01	6.120e-01
TOTALS:	2.298e+10	1.003e+02	3.157e+02	1.944e-01	6.120e-01

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APPENDIX CC

PROTECTED WORKER WITH IN-TRENCH MIXING – DOSE RATE TO LABORER HELPING WITH DUMPING OF MIXED HIGH-ACTIVITY SOIL AT ENVIRONMENTAL RESTORATION DISPOSAL FACILITY

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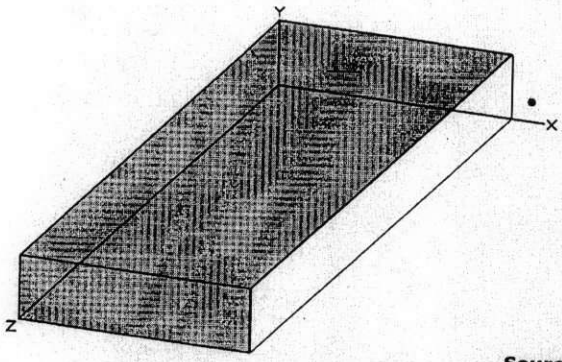
MicroShield v6.02 (6.02-00206)
Fluor_Hanford

Page : 1
DOS File : B26ITMHADumpAsst.ms6
Run Date: June 26, 2004
Run Time: 4:54:46 PM
Duration : 00:00:01

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: B26IT MHA Can Dump A
Description: B26 IT Mixed High Activity Dump Asst
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	220.98 cm	7 ft 3.0 in
Width	669.95 cm	21 ft 11.8 in
Height	60.96 cm	2 ft

Dose Points

	X	Y	Z
# 1	252.0696 cm 8 ft 3.2 in	30.48 cm 1 ft	30.48 cm 1 ft

Shields

Shield Name	Dimension	Material	Density
Source	9.02e+06 cm³	BC Dry Sandy Soil	1.6
Shield 1	.61 cm	Iron	7.86
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	3.1587e+000	1.1687e+011	3.5000e-001	1.2950e+004
Cs-137	3.3392e+000	1.2355e+011	3.7000e-001	1.3690e+004
Ni-63	9.0249e-003	3.3392e+008	1.0000e-003	3.7000e+001
Pu-239	9.0249e-004	3.3392e+007	1.0000e-004	3.7000e+000
Sr-90	5.9564e+000	2.2039e+011	6.6000e-001	2.4420e+004
Y-90	5.9564e+000	2.2039e+011	6.6000e-001	2.4420e+004

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	20

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	1.213e+09	2.461e-133	1.036e-25	1.687e-133	7.104e-26
0.0136	1.474e+06	9.096e-136	3.831e-28	1.062e-136	4.472e-29
0.0318	2.420e+09	2.470e-16	8.397e-16	2.057e-18	6.994e-18
0.0322	4.464e+09	1.537e-15	5.365e-15	1.237e-17	4.318e-17
0.0364	1.625e+09	2.164e-11	9.935e-11	1.230e-13	5.644e-13
0.1129	1.589e+04	2.689e-05	2.347e-04	4.159e-08	3.630e-07
0.6616	1.052e+11	6.872e+03	1.978e+04	1.332e+01	3.834e+01
TOTALS:	1.149e+11	6.872e+03	1.978e+04	1.332e+01	3.834e+01

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APPENDIX DD

PROTECTED WORKER WITH IN-TRENCH MIXING – DOSE RATE TO LABORER HELPING WITH DUMPING OF MODERATE-ACTIVITY SOIL AT ENVIRONMENTAL RESTORATION DISPOSAL FACILITY

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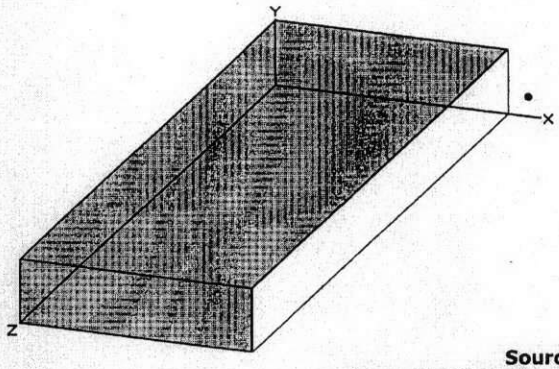
MicroShield v6.02 (6.02-00206)
Fluor_Hanford

Page : 1
DOS File : B26ITMADumpAsst.ms6
Run Date : June 26, 2004
Run Time : 4:57:17 PM
Duration : 00:00:01

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: B26IT MACan Dump A
Description: B26 IT Moderate Activity Dump Asst
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	220.98 cm	7 ft 3.0 in
Width	669.95 cm	21 ft 11.8 in
Height	60.96 cm	2 ft

Dose Points

	X	Y	Z
# 1	252.0696 cm	30.48 cm	30.48 cm
	8 ft 3.2 in	1 ft	1 ft

Shields

Shield Name	Dimension	Material	Density
Source	9.02e+06 cm³	BC Dry Sandy Soil	1.6
Shield 1	.61 cm	Iron	7.86
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	6.3174e-001	2.3374e+010	7.0000e-002	2.5900e+003
Cs-137	6.3174e-001	2.3374e+010	7.0000e-002	2.5900e+003
Ni-63	2.7075e-003	1.0018e+008	3.0000e-004	1.1100e+001
Pu-239	2.7075e-004	1.0018e+007	3.0000e-005	1.1100e+000
Sr-90	1.1732e+000	4.3410e+010	1.3000e-001	4.8100e+003
Y-90	1.1732e+000	4.3410e+010	1.3000e-001	4.8100e+003

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	20

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	2.426e+08	4.921e-134	2.073e-26	3.373e-134	1.421e-26
0.0136	4.422e+05	2.729e-136	1.149e-28	3.185e-137	1.342e-29
0.0318	4.839e+08	4.940e-17	1.679e-16	4.114e-19	1.399e-18
0.0322	8.928e+08	3.074e-16	1.073e-15	2.474e-18	8.636e-18
0.0364	3.249e+08	4.328e-12	1.987e-11	2.459e-14	1.129e-13
0.1129	4.767e+03	8.066e-06	7.042e-05	1.248e-08	1.089e-07
0.6616	2.103e+10	1.374e+03	3.956e+03	2.664e+00	7.669e+00
TOTALS:	2.298e+10	1.374e+03	3.956e+03	2.664e+00	7.669e+00

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APPENDIX EE

PROTECTED WORKER WITH IN-TRENCH MIXING – DOSE RATE TO BULLDOZER DRIVER FROM LARGE CYLINDER OF CONTAMINATED SOIL

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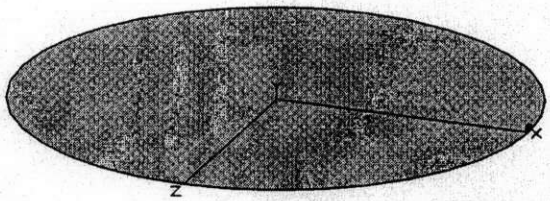
MicroShield v6.02 (6.02-00206)
Fluor_Hanford

Page : 1
DOS File : B26ITDozDBigCyl.ms6
Run Date: June 26, 2004
Run Time: 5:04:56 PM
Duration : 00:00:00

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: B26 IT AA DzDr BigCy
Description: B26 IT Average Act Dozer Drivr 320-Ft Cylinder
Geometry: 8 - Cylinder Volume - End Shields



Source Dimensions

Height	7.62 cm	3.0 in
Radius	9.8e+3 cm	320 ft 0.0 in

Dose Points

	X	Y	Z
# 1	9753.6 cm	190.5 cm	0 cm
	320 ft 0.0 in	6 ft 3.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	2.28e+09 cm³	BC Dry Sandy Soil	1.6
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	7.2876e+002	2.6964e+013	3.2000e-001	1.1840e+004
Cs-137	7.5153e+002	2.7807e+013	3.3000e-001	1.2210e+004
Ni-63	2.2774e+000	8.4263e+010	1.0000e-003	3.7000e+001
Pu-239	2.2774e-001	8.4263e+009	1.0000e-004	3.7000e+000
Sr-90	1.3437e+003	4.9715e+013	5.9000e-001	2.1830e+004
Y-90	1.3437e+003	4.9715e+013	5.9000e-001	2.1830e+004

Buildup
The material reference is : Source

Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	2.799e+11	5.598e-05	6.168e-05	3.837e-05	4.228e-05
0.0136	3.719e+08	2.263e-07	2.494e-07	2.642e-08	2.911e-08
0.0318	5.582e+11	3.502e-01	5.113e-01	2.917e-03	4.259e-03
0.0322	1.030e+12	6.783e-01	9.985e-01	5.459e-03	8.036e-03
0.0364	3.748e+11	3.986e-01	6.483e-01	2.265e-03	3.683e-03
0.1129	4.009e+06	5.935e-05	2.482e-04	9.180e-08	3.838e-07
0.6616	2.426e+13	4.697e+03	1.178e+04	9.106e+00	2.284e+01
TOTALS:	2.651e+13	4.698e+03	1.178e+04	9.117e+00	2.285e+01

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