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7. Abstract

The Solid Waste Performance Assessment calculations by PNL in 1990 were redone to incorporate changes in methods and parameters since then. The ten scenarios found in their report were reduced to three, the Post-Drilling Resident, the Post-Excavation Resident, and an All Pathways Irrigator. In addition, estimates of population dose to people along the Columbia River are also included. The attached report describes the methods and parameters used in the calculations, and derives dose factors for each scenario. In addition, waste concentrations, ground water concentrations, and river water concentrations needed to reach the performance objectives of 100 mrem/yr and 500 person-rem/yr are computed.

Internal dose factors from DOE-0071 were applied when computing internal dose. External dose rate factors came from the GENII Version 1.485 software package. Dose calculations were carried out on a spreadsheet. The calculations are described in detail in the report for 63 nuclides, including 5 not presently in the GENII libraries. The spreadsheet calculations were checked by comparison with GENII, as described in Appendix D.

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Dose Estimates for the Solid Waste Performance Assessment
by Paul D. Rittmann, PhD CHP August 17, 1994

The potential consequences of intrusion into a Hanford solid waste burial ground at some time in the future were first estimated by R. L. Aaberg and W. E. Kennedy, Jr, (1990). In that time there have been significant changes in the parameters used for performance assessment calculations (Kincaid 1993; Rittmann 1993b). Therefore the Aaberg and Kennedy (1990) calculations were performed using a spreadsheet. The spreadsheet permits calculations with nuclides not presently in the GENII library. In addition, the spreadsheet permits the use of DOE-0071 internal dose factors. The GENII program was used to verify that the spreadsheet performs correctly. These tests are provided in Appendix D. Differences between the two methods are due to model improvements and simplifications in the spreadsheet, or limitations in GENII.

The Aaberg and Kennedy (1990) calculations used 10 scenarios to evaluate potential consequences to future residents near the disposal site. These are summarized below.

(a) Well Driller - a 30 cm diameter well is driven through the waste. Dose to the intruder comes from the 40 hour drilling activity.
(b) Post-Drilling Resident - someone has a vegetable garden in the soil exhumed by the well-drilling operation. This garden as with all the others, supplies 25% of the resident's vegetable intake each year.
(c) Excavation - about 100 m^3 of waste is exhumed in the course of constructing a house with a basement. Dose to the intruder comes from the 80 hour excavation operation.
(d) Post-Excavation - someone has a vegetable garden in the soil exhumed by the excavation operation.
(e) Residential Garden, Shallow Waste - 30% of garden plants roots reach into the waste. The waste is otherwise undisturbed.
(f) Residential Garden, Deeper Waste - 1% of garden plants roots reach into the waste. The waste is otherwise undisturbed.
(g) Residential Garden, Deeper Waste, Biotic Transport - same as #6, except the plants sending roots into the waste as well as animals burrowing into the waste have been bringing contamination to the surface.
(h) Farming - a farm over the waste site has 1% of plant roots in the waste. One-fourth (25%) of the farmer's vegetable intake and all (100%) of his meat & milk intakes are locally produced, i.e., contaminated.
(i) Irrigated Garden - a well near the waste site is used to irrigate a vegetable garden.
(j) Drinking Water - well water is consumed by the resident directly.

Of these ten scenarios, two were selected to represent inadvertent intrusion. These are (1) Post-Drilling Resident which is (b) above, and (2) Post-Excavation Resident which is (d) above.

To represent the potential dose from all pathways via irrigation, a combination of (h) and (i) was used. This All Pathways Irrigator scenario would apply to an individual a short distance away from the waste disposal site, so that crop roots did not invade the waste. In addition, the consumption rates for contaminated milk and meat were reduced to 50% based on the fractions given in the EPA Exposure Factors Handbook (EPA 1989).

A fourth scenario considers the collective dose to as many as 5 million people living along the Columbia River. The parameters for this scenario were taken from the Grouted Waste Performance Assessment (Kincaid 1993). The sections below describe the assumptions peculiar to each of the newer exposure scenarios.

The environmental dose estimation methods and assumptions used in the current document are very similar to those found in the Grouted Waste Performance Assessment (Kincaid 1993). The differences are almost entirely simplifications which will not materially affect the computed doses. For example, the Grout PA used the EPA values for local food production of 25 percent for vegetables and 20 percent for fruit. In the current document, these were simplified to 25 percent for all garden produce. Another example is the drinking water consumption rate for the all pathways irrigator. The Grout PA used 655 liters per year, while the present report uses the standard regulatory value of 730 liters per year. (The Grout PA used the regulatory value for the drinking water only scenario.)

1.0 ASSUMED EXPOSURE SCENARIOS AND EXPOSURE PATHWAYS

In each of the exposure scenarios described below, some unsuspecting individuals could receive radiation exposure due to their proximity to buried radioactive waste. No initial inventory is assumed. Rather, unit concentrations of radionuclides are assumed to be present in the waste at the time of its disposal, or in the ground water at the time it is pumped out and put to use. The thickness of the underground layer of waste is assumed to be 5 meters.

1.1 Post-Drilling and Post-Excavation Residents

As mentioned above, these two scenarios assume that the intruder has exhumed some of the waste and has relocated it to his garden. The scenarios differ only in the assumed initial soil concentration in the garden. All doses are proportional to this concentration. GENII assumes the added waste is uniformly distributed through the top 15 cm of soil in the garden (the tilling depth). This contaminated surface soil becomes the basis for the dose estimates for the resident gardener. The area of the garden (2500 m^2 or 0.63 acre) is deemed adequate to supply a significant portion of the resident's diet. This same size garden has been used in prior Hanford documents such as the Grouted Waste Performance Assessment (Kincaid 1993) and NUREG/CR-5512 (Kennedy & Strenge 1992).

In the well drilling operation, 0.35 m^3 of waste (0.3 meter diameter well through 5 meters of waste) is brought to the surface and spread over a 2500 m^2 garden. For input to GENII, the "Manual Redistribution Factor" takes the value (0.35 m^3)/(2500 m^2) = 1.4E-04 m. In effect, 0.14 mm of waste is added to the garden.

In the excavation operation, 100 m^3 is exhumed and spread over the garden. The large area exhumed is assumed to have 25% clean soil interspersed with the waste. Thus the actual volume of waste exhumed is 75 m^3. The resulting redistribution factor is (75 m^3)/(2500 m^2) = 0.03 m. In effect, 3 cm of waste is added to the garden.

The pathways by which the resident gardener may be exposed to contamination from the exhumed waste are listed below.

- ingestion of vegetables grown in the contaminated soil
- ingestion of small amounts of contaminated soil each day.

- inhalation of radionuclides suspended in the air by gardening activities and wind
- external exposure to contaminated soil while working in the garden or residing in the house built on top of the waste site

The inhalation and external exposures are based on the following exposure times (Aaberg and Kennedy 1990). The gardener is assumed to spend 1800 hours in his garden, and 4380 hours in his house. The remaining 2580 hours is spent elsewhere.

For estimating external exposure from the soil contamination, the house is assumed to reduce the dose rate to 1/3 the direct dose rate. The factor of 1/3 is discussed at length in NUREG/CR-5512. In effect, the average time exposed at the unshielded dose rate is

$$(1800\ hr/yr)*1 + (4380\ hr/yr)*(1/3) = 3260\ hr/yr$$

For estimating inhalation exposure, the air concentrations shown on the table below are used to estimate the equivalent time of exposure to an air concentration of 0.1 mg/m^3. The actual air concentrations used in the table are discussed at length in NUREG/CR-5512. The 4380 hour period has been divided into two equal periods of activity and sleep. The breathing rates shown below in Table 1 are for the ICRP Reference Man (ICRP 1975).

Table 1. Calculation of the Inhalation Time for the Intruders

Activity	Air Conc mg/m^3	Exposure Time, hr	Breathing Rate, m^3/hr	Soil Inhaled mg/yr
Indoor (active)	0.05	2190	1.2	131.4
Indoor (asleep)	0.05	2190	0.45	49.3
Outdoor	0.1	1700	1.2	204
Gardening	0.5	100	1.2	60
			Total Soil Inhaled:	445 mg/yr

Note that for routine input to GENII, one must use a daily average breathing rate of 0.95 m^3/hr. Thus an inhalation exposure time of 4680 hours is needed to inhale the projected 445 mg at the average air concentration of 0.1 mg/m^3. This differs from the previous calculations by Aaberg and Kennedy (1990), which gave 4390 hr/yr. The difference follows from the various breathing rates which were used.

Human intakes of radioactivity from the ingestion of food grown in the garden uses transport models in GENII which were developed from NRC Regulatory Guide 1.109 (USNRC 1977). The consumption parameters for the "West" region in a recent survey were used (Yang and Nelson 1986). These are listed in Table 2 below, under the column "grams per day". Meat and milk consumption values are also given on this table, but are only used in the irrigation scenario described later.

The last two columns on Table 2 were computed from the first column of numbers. Both of the computed columns have units of kilograms per year. The values shown in the column labelled "Calculated" are the same as the values in the first column, only the units have been changed. The last column

("Intake") gives the consumption rates actually used in the calculations. These have been adjusted for the fraction of the individual's diet which is locally produced based on the fractions given in the EPA Exposure Factors Handbook (EPA 1989). Thus it is assumed that 25 percent of the vegetable diet actually came from the garden, and is contaminated. The other 75 percent is assumed to be obtained from uncontaminated sources. Further, it is assumed that 50 percent of the animal products are locally produced.

Table 2. Human Food Consumption (Yang & Nelson, 1986)

Type of Produce		grams per day	kilograms per year[2] Calculated	kilograms per year[2] Intake
Leafy	(leafy)	45.3	16.53	4.1
Other	(protected)	152.5	55.66	13.9
Fruit	(exposed + misc)	105.3	38.43	9.6
Cereal	(grain)	202.6	73.95	18.5
Meat	(beef & pork)	115.0	41.98	21.0
Milk		283.5	103.48	51.7

[2]For explanation of the Table Headings, see text.

Inadvertent soil ingestion is assumed to occur at the rate of 100 mg per day for adults, and at twice this rate for children (EPA 1989).

1.2 All Pathways Irrigator

This individual is some distance away from the waste disposal site, and is only exposed through the use of ground water which has become contaminated. Air transport from the original waste site is assumed to be unimportant.

Since this is an arid climate, and is likely to remain arid for centuries to come, the exposed individual is assumed to use the contaminated ground water on his garden, to grow feed for the family cows, and even to drink it directly.

The pathways by which the irrigator may be exposed to radiation from the contaminated water are listed below. The length of the list is the reason for naming this the "All Pathways" scenario.

- direct ingestion of the contaminated water (730 liters per year). Note that this value is normally used for regulatory purposes (eg 40 CFR 141). However, measured consumption rates (Roseberry and Burmaster 1992) are somewhat lower.
- ingestion of small amounts of contaminated soil (100 mg per day).
- ingestion of the vegetables grown in a garden irrigated with contaminated water. As before, only 25 percent of the individual's vegetable diet comes from the garden.
- ingestion of meat and milk from animals raised on grass and grains irrigated with the contaminated water. The animals also drink the contaminated water. Half (50%) of the resident farmer's meat and milk intake comes from uncontaminated sources, as shown on Table 2.
- external exposure to soil which becomes contaminated through irrigation.
- inhalation of radionuclides suspended in the air from the contaminated soil.

The drinking water is assumed to be untreated well water. It is assumed to be suitable for human consumption directly from the ground, except for trace amounts of radioactivity.

The exposure times for external and inhalation doses are assumed to be the same as those for the intruder. The food consumption rates are also the same. Since the ingestion dose is the largest contributor to the irrigator's total dose, the assumed exposure times for external and inhalation exposure have little effect on the final doses.

1.3 Columbia River Population

This scenario is used to estimate dose to a population of 5 million people (Kincaid 1993) exposed to contamination in the Columbia River. The contamination enters the Columbia as a result of groundwater flow into the river. Because groundwater concentrations decrease by more than 5 orders of magnitude when they enter the river, the dose to any individual would be much less than the dose to the All Pathways Irrigator. Population dose was computed to provide an upper bound on potential impacts to people using the river between Hanford and the Pacific Ocean.

The pathways by which people living near the Columbia River may be exposed to radiation from the contaminated water are listed below. This scenario is similar to the Irrigated Farm

- direct ingestion of the contaminated water (730 liters per year). This includes small amounts of ingestion which may occur during swimming.
- ingestion of small amounts of contaminated soil (100 mg per day).
- ingestion of fish taken from the Columbia River.
- ingestion of the vegetables grown in a garden irrigated with contaminated water. As before, only 25 percent of the individual's vegetable diet comes from the garden.
- ingestion of meat and milk from animals raised on grass and grains irrigated with the contaminated water. The animals also drink the contaminated water. Half of the resident farmer's meat and milk intake comes from uncontaminated sources.
- external exposure to soil which becomes contaminated through irrigation, as well as exposure to contaminated river water and sediment during recreational activity.
- inhalation of radionuclides suspended in the air from the contaminated soil.

The total fish harvested from the Columbia River annually and consumed locally is assumed to be 15 metric tons (Woodruff 1993). The average amount of fish consumed per person is thus 3 grams per year.

The assumptions used in this scenario will overestimate the population dose. First, the Columbia River is diluted by a inflows of water from tributaries immediately below the Tri-Cities, and all along its length to the Pacific Ocean. This will lower the radionuclide concentrations. Second, most drinking water passes through community water treatment systems. Such systems reduce the radionuclide concentrations reaching the affected people. Drinking water was the principal dose contributor for most nuclides. Third, the population estimate of 5 million is a significant increase over the present conditions. In addition, the production of nearly all food consumed by the downriver population with contaminated river water would require a very large increase in crop production below the site.

2.0 RADIONUCLIDES OF IMPORTANCE

There are a variety of nuclides which may be present in radioactive waste. However, many of the nuclides found in radioactive waste are not important in the dose analysis for the above exposure scenarios. Many nuclides have half-lives which are short compared to the time required to reach the ground water, or the 100 year period assumed between the closure of the waste site and the arrival of the intruder.

The radionuclides considered important for this dose assessment are listed in Table 3. Five of these are not in the current GENII radionuclide library. These are Ba-133, Eu-150, Gd-152, Bi-207 and Po-209. In addition, several of the nuclides decay to nuclides which are themselves radioactive. Some of these progeny nuclides give significant radiation doses in addition to the parent. The progeny are listed on Table 3. The halflives of all the progeny nuclides is less than one year.

The GENII program treats most of the nuclides on Table 3 individually. A few of the very short-lived progeny are lumped with the parent to simplify the decay chains. This introduces no errors, since the very-short lived progeny will always be present in equilibrium amounts with the parent.

To simplify calculations in the spreadsheet, the dose factors for the progeny nuclides shown on Table 3 are added to the parent nuclides. Due to the short half-lives of the progeny nuclides (compared to the parent), the progeny are assumed to be in equilibrium. The equilibrium amounts are shown in parentheses if they are not equal to 1. The spreadsheet includes the ingrowth of longer lived progeny using the ordinary radioactive decay equations. Table 4 shows which of the blocks of nuclides in Table 3 are combined when doing radioactive decay chains in the spreadsheet.

For a few nuclides the spreadsheet approach introduces errors due to the different plant and animal uptake factors that exist for different members of a decay chain. For example, Ra-225 is always included in the Th-229 dose factor because, in equilibrium, there are equal amounts of Th-229 and Ra-225. However, plants take up much more radium from the soil than thorium. Thus the human who eats the contaminated plants receives more dose than the spreadsheet predicts due to the excess Ra-225. The comparisons with GENII found in Appendix D show that this limitation of the spreadsheet affects the total dose by less than 10 percent in all scenarios.

Table 3. Radionuclides Considered in the Dose Analysis

Nuclide	Halflife years	Progeny Combined with Parent for Dose Calculations
H-3	12.28	
Be-10	1.60E+06	
C-14	5730	
Cl-36	301,000	
K-40	1.277E+09	
Co-60	5.271	
Ni-59	75,000	
Ni-63	100.1	
Se-79	65,000	
Sr-90	28.6	Y-90
Zr-93	1.53E+06	
Nb-93m	14.6	
Nb-94	20,300	
Mo-93	3500	
Tc-99	213,000	
Pd-107	6.50E+06	
Cd-113m	13.7	
Sn-121m	55	Sn-121 (0.778)
Sn-126	100,000	Sb-126m, Sb-126 (0.14)
I-129	1.57E+07	
Cs-135	2.30E+06	
Cs-137	30.17	Ba-137m (0.946)
Ba-133	10.5	
Sm-147	1.06E+11	
Sm-151	90	
Eu-150	36	
Eu-152	13.6	
Eu-154	8.8	
Gd-152	1.10E+14	
Re-187	4.7E+10	
Pb-210	22.26	Bi-210, Po-210
Bi-207	33.4	
Po-209	102	
Ra-226	1600	Rn-222, Po-218, Pb-214, Bi-214, Po-214
Ra-228	5.75	Ac-228
Ac-227	21.773	Th-227 (0.9862), Fr-223 (0.0138), Ra-223, Rn-219, Po-215, Pb-211, Bi-211, Tl-207 (0.99727), Po-211 (0.00273)
Th-228	1.9132	Ra-224, Rn-220, Po-216, Pb-212, Bi-212, Po-212 (0.6407), Tl-208 (0.3593)
Th-229	7340	Ra-225, Ac-225, Fr-221, At-217, Bi213, Po-213, Tl-209
Th-230	77,000	
Th-232	1.405E+10	
Pa-231	32,764	
U-232	72	
U-233	159,200	
U-234	244,500	
U-235	7.038E+08	Th-231
U-236	2.34E+07	
U-238	4.468E+09	Th-234, Pa-234m, Pa-234 (0.0016)
Np-237	2.14E+06	Pa-233
Pu-238	86.75	
Pu-239	24,131	
Pu-240	6569	
Pu-241	14.4	U-237 (2.45E-05)
Pu-242	375,800	
Pu-244	8.26E+07	U-240, Np-240m, Np-240 (0.0011)
Am-241	432.2	
Am-242m	152	Am-242 (0.99524), Cm-242 (0.827), Np-238 (0.00476)
Am-243	7380	Np-239
Cm-243	28.5	
Cm-244	18.11	
Cm-245	8500	
Cm-246	4750	
Cm-247	1.56E+07	Pu-243
Cm-248	339,000	

Table 4. Radioactive Decay Chains Computed in the Spreadsheet

Parent Nuclide	Progeny Nuclides
Zr-93	Nb-93m
Mo-93	Nb-93m
Ra-226	Pb-210
Ra-228	Th-228
Th-230	Ra-226 & Pb-210
Th-232	Ra-228 & Th-228
U-232	Th-228
U-233	Th-229
Pu-241	Am-241 & Np-237
Pu-244	Pu-240
Am-241	Np-237
Am-242m	Pu-242, Pu-238, U-234
Am-243	Pu-239
Cm-243	Pu-239 & Am-243
Cm-244	Pu-240
Cm-245	Pu-241, Am-241, Np-237
Cm-247	Am-243

3.0 MODELS AND PARAMETER VALUES FOR EXPOSURE PATHWAYS

In this section the details for each exposure pathway are described. It follows the progression from soil through plants and animals into the human.

3.1 Soil Concentration for the Intruder Garden Scenarios

In the intruder scenarios the initial waste concentration is given. The age of the waste may require additional nuclides (progeny) to be included. The initial soil concentration in the garden is calculated from the assumed volume exhumed and the surface area of the garden. No other calculations are required to determine the initial soil concentration.

The soil concentration decreases with time due to leaching and radioactive decay. Leaching is the process by which radioactive materials migrate from the surface layer of soil into deeper layers below. The driving force behind the leaching process is the application of water to the soil. Leaching is treated as a removal rate constant giving the fraction of the material in the surface layer which is removed per unit of time. It is calculated using the equation shown below.

$$\lambda_s = \frac{P + I - E}{\theta\ d\ (1 + \rho/\theta\ K_d)}$$

where,

λ_s= annual average soil leaching coefficient, fraction removed from a soil layer of thickness "d" per year
P = total precipitation, in centimeters per year
I = total irrigation, assumed to be 82.3 cm per year (32.4 inches/yr)
E = total evapo-transpiration, in centimeters per year

d = thickness of soil from which nuclides migrate, in centimeters. This is assumed to be 15 cm (5.9 inches).
ρ = bulk density of the surface soil, in grams per cubic centimeter. In GENII this is 1.5 g/cc.
θ = volumetric water content of the surface soil, milliliters of water per cubic centimeter of soil. A value of 0.4 ml/cc is assumed.
K_d= distribution coefficient in surface soil for an element, in milliliters per gram

For input to GENII, the leaching parameters are placed in the data file named FTRANS.DAT. The values for the nuclides considered in this dose assessment are listed in Tables 5 and 6. The following assumptions were used to relate the λ_s and K_d values: ρ = 1.5 g/cc; θ = 0.4 ml/cc; d = 15 cm; and P+I-E = 15 cm/yr. Note that the amount of irrigation was the same for all plant types.

For the intruder scenarios, the initial soil concentration in the top layer of soil decreases exponentially with time until the plant type is harvested. This is shown in the equation below. Time zero is when the intrusion occurs.

$$W^s = W_o \, \mathrm{Exp}[-(\lambda_s + \lambda_r)T]$$

where,
W^s= surface soil concentration after time T, in curies per kilogram of soil
W_o= surface soil concentration immediately after intrusion, in curies per kilogram of soil
λ_r= radioactive decay constant, namely, the natural logarithm of 2 divided by the radioactive decay halflife in years
T = soil leaching time, in years

The soil leaching times for the ingestion dose pathways differ from those for inhalation and external pathways. The ingestion doses are based on the soil concentration 100 days after intrusion. The inhalation and external dose accumulates during the year after intrusion. These assumptions differ from those coded into GENII, namely no decay or leaching for inhalation and external, and 10 to 30 days of radioactive decay only for ingestion pathways. This latter time is the time between harvest and consumption of the produce.

3.2 Soil Concentration for the Irrigation Scenarios

The sources of contaminated irrigation water are either groundwater or Columbia River water, as discussed in Sections 1.2 and 1.3.

The radioactivity in the irrigation water accumulates in the plants and the soil differently. For accumulation on plants by direct deposition, the rate of deposition determines the final concentration in the plants. For determining the soil concentration (which determines the root uptake, inhalation and external doses), the total activity remaining in the surface layer of soil at the end of the year is all that matters. These differences are included in the equations below.

The rate of addition of contamination to the soil is given by the equation shown below. The conversion factor from inches of water applied to the soil to units of liters applied per square meter is shown in the equation.

$$D_p = C_w \, I_p \, (25.4 \text{ L/m}^2\text{/inch}) \,/\, F_i$$

Table 5. Transfer Factors in NUREG/CR-5512 (Kennedy & Strenge, 1992)

Name	Dry Plant/Soil Leafy	Conc Ratio (B_p) Root	Fruit	Grain	Beef day/kg (F_b)	Milk day/L (F_m)	Fish (B_f)	Leaching per yr (λ_s)	Distr ml/g (K_d)
H		(special model)					1	2.5	0
BE	1.0E-2	1.5E-3	1.5E-3	1.5E-3	1.0E-3	9.0E-7	2	2.77E-3	240
C	7.0E-1	7.0E-1	7.0E-1	7.0E-1	4.9E-2	1.1E-2	4600	9.57E-2	6.7
CL	70	70	70	70	8.0E-2	1.5E-2	50	3.39E-1	1.7
K	1.0	5.5E-1	5.5E-1	5.5E-1	2.0E-2	7.0E-3	1000	3.65E-2	18
CO	8.1E-2	4.0E-2	7.0E-3	3.7E-3	2.0E-2	2.0E-3	330	1.11E-2	60
NI	2.8E-1	6.0E-2	6.0E-2	3.0E-2	6.0E-3	1.0E-3	100	1.67E-3	400
SE	2.5E-2	2.5E-2	2.5E-2	2.5E-2	1.5E-2	4.0E-3	170	4.75E-3	140
SR	1.6	8.1E-1	1.7E-1	1.3E-1	3.0E-4	1.5E-3	50	4.37E-2	15
Y	1.5E-2	6.0E-3	6.0E-3	6.0E-3	3.0E-4	2.0E-5	25	3.50E-3	190
ZR	2.0E-3	5.0E-4	5.0E-4	5.0E-4	5.5E-3	3.0E-5	200	1.15E-3	580
NB	2.0E-2	5.0E-3	5.0E-3	5.0E-3	2.5E-1	2.0E-2	200	4.16E-3	160
MO	2.5E-1	6.0E-2	6.0E-2	6.0E-2	6.0E-3	1.5E-3	10	6.49E-2	10
TC	44	1.1	1.5	7.3E-1	8.5E-3	1.0E-2	15	1.82	0.1
PD	1.5E-1	4.0E-2	4.0E-2	4.0E-2	4.0E-3	1.0E-2	10	1.28E-2	52
CD	5.5E-1	1.5E-1	1.5E-1	1.5E-1	5.5E-4	1.0E-3	200	1.66E-2	40
IN	4.0E-3	4.0E-4	4.0E-4	4.0E-4	8.0E-3	1.0E-4	100000	1.71E-3	390
SN	3.0E-2	6.0E-3	6.0E-3	6.0E-3	8.0E-2	1.0E-3	3000	5.12E-3	130
SB	1.3E-4	5.6E-4	8.0E-5	3.0E-2	1.0E-3	1.0E-4	200	1.47E-2	45
TE	2.5E-2	4.0E-3	4.0E-3	4.0E-3	1.5E-2	2.0E-4	400	4.75E-3	140
I	3.4E-3	5.0E-2	5.0E-2	5.0E-2	7.0E-3	1.0E-2	500	5.26E-1	1
CS	1.3E-1	4.9E-2	2.2E-1	2.6E-2	2.0E-2	7.0E-3	2000	2.47E-3	270
BA	1.5E-1	1.5E-2	1.5E-2	1.5E-2	1.5E-4	3.5E-4	200	1.28E-2	52
SM	1.0E-2	4.0E-3	4.0E-3	4.0E-3	5.0E-3	2.0E-5	25	2.77E-3	240
EU	1.0E-2	4.0E-3	4.0E-3	4.0E-3	5.0E-3	2.0E-5	25	2.77E-3	240
GD	1.0E-2	4.0E-3	4.0E-3	4.0E-3	3.5E-3	2.0E-5	25	2.77E-3	240
RE	1.5	3.5E-1	3.5E-1	3.5E-1	8.0E-3	1.5E-3	120	4.67E-2	14
PB	5.8E-3	3.2E-3	9.0E-3	4.7E-3	3.0E-4	2.5E-4	100	2.47E-3	270
BI	3.5E-2	5.0E-3	5.0E-3	5.0E-3	4.0E-4	5.0E-4	15	5.54E-3	120
PO	2.5E-3	9.0E-3	4.0E-4	4.0E-4	3.0E-4	3.5E-4	500	4.44E-3	150
RN	0.0	0.0	0.0	0.0	0.0	0.0	1	2.5	0
FR		(none given)					2000		
RA	7.5E-2	3.2E-3	6.1E-3	1.2E-3	2.5E-4	4.5E-4	70	1.33E-3	500
AC	3.5E-3	3.5E-4	3.5E-4	3.5E-4	2.5E-5	2.0E-5	25	1.59E-3	420
TH	6.6E-3	1.2E-4	8.5E-5	3.4E-5	6.0E-6	5.0E-6	100	2.08E-4	3200
PA	2.5E-3	2.5E-4	2.5E-4	2.5E-4	1.0E-5	5.0E-6	11	1.31E-3	510
U	1.7E-2	1.4E-2	4.0E-3	1.3E-3	2.0E-4	6.0E-4	50	4.37E-2	15
NP	1.3E-2	9.4E-3	1.0E-2	2.7E-3	5.5E-5	5.0E-6	250	1.27E-1	5
PU	3.9E-4	2.0E-4	4.5E-5	2.6E-5	5.0E-7	1.0E-7	250	1.21E-3	550
AM	5.8E-4	4.1E-4	2.5E-4	5.9E-5	3.5E-6	4.0E-7	250	3.51E-4	1900
CM	3.0E-4	2.4E-4	1.5E-5	2.1E-5	3.5E-6	2.0E-5	250	1.67E-4	4000

Note: Animal fresh forage and stored hay are treated as leafy vegetables.

Table 6. Transfer Factors from ORNL-5785 (Baes, 1984)

Nuc Name	Leafy Vegt. (B_p)	Grains* (B_p)	Beef day/kg (F_b)	Milk day/L (F_m)	Leaching per yr (λ_s)	Distr ml/g (K_d)	Atomic No. (Z)
H	(special model)				2.50	0	1
BE	0.01	0.0015	0.001	9E-07	1.03E-3	650	4
CL	70	70	0.08	0.015	1.29	0.25	17
K	1	0.55	0.02	0.007	0.116	5.5	19
CO	0.02	0.007	0.02	0.002	1.47E-2	45	27
NI	0.06	0.06	0.006	0.001	4.44E-3	150	28
SE	0.025	0.025	0.015	0.004	2.22E-3	300	34
SR	2.5	0.25	0.0003	0.0015	1.89E-2	35	38
Y	0.015	0.006	0.0003	2E-05	1.33E-3	500	39
ZR	0.002	0.0005	0.0055	3E-05	2.22E-4	3000	40
NB	0.02	0.005	0.25	0.02	1.90E-3	350	41
MO	0.25	0.06	0.006	0.0015	3.29E-2	20	42
TC	9.5	1.5	0.0085	0.01	0.377	1.5	43
PD	0.15	0.04	0.004	0.01	1.11E-2	60	46
CD	0.55	0.15	0.00055	0.001	9.85E-2	6.5	48
IN	0.004	0.0004	0.008	0.0001	4.44E-4	1500	49
SN	0.03	0.006	0.08	0.001	2.66E-3	250	50
SB	0.2	0.03	0.001	0.0001	1.47E-2	45	51
TE	0.025	0.004	0.015	0.0002	2.22E-3	300	52
I	0.15	0.05	0.007	0.01	1.11E-2	60	53
CS	0.08	0.03	0.02	0.007	6.66E-4	1000	55
BA	0.15	0.015	0.00015	0.00035	1.11E-2	60	56
SM	0.01	0.004	0.005	2E-05	1.03E-3	650	62
EU	0.01	0.004	0.005	2E-05	1.03E-3	650	63
GD	0.01	0.004	0.0035	2E-05	1.03E-3	650	64
RE	1.5	0.35	0.008	0.0015	8.58E-2	7.5	75
PB	0.045	0.009	0.0003	0.00025	7.41E-4	900	82
BI	0.035	0.005	0.0004	0.0005	3.33E-3	200	83
PO	0.0025	0.0004	0.0003	0.00035	1.33E-3	500	84
RN	0	0	0	0	2.50	0	86
FR	0.03	0.008	0.0025	0.02	2.66E-3	250	87
RA	0.015	0.0015	0.00025	0.00045	1.48E-3	450	88
AC	0.0035	0.00035	2.5E-05	2E-05	4.44E-4	1500	89
TH	0.00085	8.5E-05	6E-06	5E-06	4.44E-6	150000	90
PA	0.0025	0.00025	1E-05	5E-06	2.67E-4	2500	91
U	0.0085	0.004	0.0002	0.0006	1.48E-3	450	92
NP	0.1	0.01	5.5E-05	5E-06	2.20E-2	30	93
PU	0.00045	4.5E-05	5E-07	1E-07	1.48E-4	4500	94
AM	0.0055	0.00025	3.5E-06	4E-07	9.52E-4	700	95
CM	0.00085	1.5E-05	3.5E-06	2E-05	3.33E-3	200	96

*The ratios for Grains were also used on Root Vegetables and Fruit.

where,

D_p= activity deposition rate due to irrigation of soils growing plant type p, in curies per square meter per year (Ci/yr/m²)

C_w= irrigation water concentration, in curies per liter (Ci/L). This concentration is assumed to be constant (no decay) during the 6 month application period.

I_p= inches of irrigation water applied each year to plant type p. For the maximum individual cases, this value is 32.4 inches per year. For the population dose, this value was lowered to 25 inches per year due to less irrigation in humid areas along the Columbia River (Kincaid 1993).

F_i= fraction of the year that irrigation water is applied. The value 0.5 is used since the irrigation is assumed to take place 6 months per year.

The soil concentration in the irrigation model increases due to the application of water, but the increase is offset by the removal of contaminants by leaching and radioactive decay. The function used to represent this is shown in the equation below. The soil concentration has units of Ci/kg. At the end of the irrigation period, the soil concentration is given by the equation below.

$$W_p^i = \frac{F_i\ D_p\ (1 - \mathrm{Exp}[-(\lambda_s + \lambda_r)T])}{\rho\ d\ (\lambda_s + \lambda_r)}$$

where,

W_p^i= soil concentration due to irrigation, in curies per kilogram of soil

λ_r= radioactive decay constant, namely, the natural logarithm of 2 divided by the radioactive decay halflife in years

T = soil leaching time, in years. In the GENII program, this time is always one year for irrigation scenarios.

The GENII software also considers reduction in the soil concentration due to uptake in plants and their subsequent harvest. This is a smaller effect which was not included in the spreadsheet.

3.3 Concentration in Vegetables

The calculation of radionuclide concentrations in living plants uses three main routes, (1) root uptake, (2) resuspension to leaves (also called "rain splash"), and (3) direct deposition of irrigation water on foliage. Each of these will be considered separately below. The three uptake routes are then combined to get the total concentration in the vegetables.

GENII includes the effects of radioactive decay between the time a plant type is harvested and when it is consumed. This time period is called the holdup time. It enters the equations for plant concentration as shown below.

$$C_p = (C_p^d + C_p^f + C_p^r)\ \mathrm{Exp}(-\lambda_r\ T_p^h)$$

where,

C_p= radionuclide concentration in plant type p at the time it is consumed, in curies per kilogram

C_p^d= concentration of a radionuclide in plant type p due to direct deposition of irrigation water. The units for C_p^d are Ci/kg.

C_p^r= concentration of a radionuclide in plant type p due to absorption from the soil through the roots. The units for C_p^r are Ci/kg.

C_p^f= concentration of a radionuclide in plant type p due to foliar deposition from soil resuspension. The units for C_p^f are Ci/kg.

T_p^h= holdup time, i.e. the time between harvest and consumption of plant type p, in days

It was not necessary to include the effects of holdup due to the long half-lives of the important nuclides. However, for a few nuclides, the ingrowth of progeny activity due to radioactive decay leads to a small increase in certain doses. Since this effect is small, the calculation of holdup was not included in the spreadsheet.

3.3.1 Root Uptake into Edible Portions

Root uptake is calculated using two sets of concentration ratios. These ratios are listed in Tables 5 and 6. The Hanford Site is very dry and sandy, so that plant uptake factors would likely differ from the generic values used in surveys such as NUREG/CR-5512 and ORNL-5785. However, the preparation of the soil for a garden changes the properties of surface layer. The tilling, watering and addition of fertilizers produces soil which resembles the generic garden soil of NUREG/CR-5512 and ORNL-5785. It is therefore assumed that the concentration ratios found in these documents are adequate to describe plant uptakes in possible future gardens on the Hanford Site.

Notes for Table 5 and 6 are the following. "Leafy" refers to vegetables whose leafy parts are normally eaten. "Root", "Fruit", and "Grains" refers to all other types of vegetables whose reproductive parts are eaten. In applying the ORNL ratios, the "Leafy Vegt." ratios were only applied to Leafy Vegetables. All other vegetable types use the ratios shown under "Grains".

The ratios under both "Leafy Vegt.", "Leafy", "Root", "Fruit" and "Grains" are the Ci/kg dry weight of vegetables to Ci/kg of soil. For this reason, a dry-to-wet ratio must be used when calculating the plant concentrations from root uptake. The dry-to-wet ratios are listed in Table 7 under "R_p". The values shown are from GENII Version 1.485 (Napier, 1988).

The plant concentration due to root uptake into the various types of vegetation is described with the equation shown below. In GENII there are four plant types consumed by humans: leafy vegetables, other vegetables, fruit, and grain. There are also two plant types consumed by animals: grass (forage) and grain (stored feed). Forage is treated as a leafy vegetable.

$$C_p^r = R_p \, B_p \, W$$

where,

R_p= dry to wet ratio for plant type p. See Table 7 for values.
B_p= soil to plant concentration ratio, as Ci/kg dry weight of vegetables to Ci/kg of soil. See Tables 5 and 6 for values.
W = soil concentration at the time of harvest, in Ci/kg (either W^s or W_p^i)

3.3.2 Resuspension of Surface Soil to Foliage (Rain Splash)

The resuspension of dust by wind, or water drops splashing soil onto the foliage leads to some contamination of the edible portion of the plant. The concentration of the radionuclide in the plant is approximated by the equation shown below. This method is also used in the GENII program.

$$C_p^f = \frac{W \, R^a \, \rho \, d \, V_d \, T_v \, F_p^f \, \{ 1 - \mathrm{Exp}[-(\lambda_w + \lambda_r) T_p^f] \}}{Y_p \, (\lambda_w + \lambda_r) \, (1 \text{ day}/86400 \text{ sec})}$$

where,

R^a= resuspension factor, i.e. the ratio of the air concentration to the surface contamination causing it. The GENII value of 1E-9 per meter is used to calculate the rain splash onto plants.

V_d= diffusion attachment speed, or ground deposition speed, in meters per second. The GENII value of 0.001 m/s is used for every nuclide.

T_v= translocation factor, i.e. the fraction of what deposits on the foliage that ends up in the edible portions of the plant. See Table 7.

F_p^f= interception fraction for plant type p. The fraction of what falls to the earth that lands on the plant. See Table 7.

Y_p= yield of crop type p, in kilograms per square meter (wet weight). Also called the standing biomass. See Table 7.

λ_w= weathering removal coefficient, 0.0495105 per day, or 18.0713 per year, which corresponds to a 14 day half time.

λ_r= radioactive decay constant, namely, the natural logarithm of 2 divided by the radioactive decay halflife in days (1 year = 365.25 days)

T_p^f= exposure time of the plant type p to the airborne contamination depositing on the foliage, in days (also called growing period)

The weathering process removes contaminants from the outer surfaces of the plants due to the action of wind and water. The method used in GENII to compute interception fractions from the standing biomass uses the equation shown below.

$$F_p^f = 1 - \mathrm{Exp}(\ -K_p^f\ Y_p\ R_p\ )$$

where,

F_p^f= interception fraction for plant type p. The fraction of what falls to the earth that lands on the plant. See Table 7.

K_p^f= constant used to relate the standing biomass (dry) and the interception fraction for plant type p, in square meters per kilogram

Y_p= yield of crop type p, in kilograms per square meter (wet weight). Also called the standing biomass.

R_p= dry to wet ratio for plant type p. See Table 7 for values.

3.3.3 Direct Deposition of Irrigation Water on Foliage

The previous two avenues by which contamination reaches the edible portions of the plants apply only to activity which is present in the soil. This section discusses direct deposition of contaminants in irrigation water onto the foliage. The concentration in the edible portion of the plants due to direct deposition on foliage is given in the equation below.

$$C_p^d = \frac{D_p\ T_v\ F_p^f\ \{\ 1 - \mathrm{Exp}[-(\lambda_w + \lambda_r)T_p^f]\ \}}{Y_p\ (\lambda_w + \lambda_r)\ (365\ \text{days}/1\ \text{year})}$$

where,

D_p= activity deposition rate due to irrigation of soils growing plant type p, in curies per square meter per year (Ci/yr/m²)

T_v= translocation factor, i.e. the fraction of what deposits on the foliage that ends up in the edible portions of the plant. See Table 7.

F_p^f= interception fraction for plant type p. The fraction of what falls to the earth that lands on the plant. For direct deposition on plants by irrigating water, the interception fraction takes the value 0.25 for all plant types.

λ_w= weathering removal coefficient, 0.0495105 per day, or 18.0713 per year, which corresponds to a 14 day half time.

λ_r= radioactive decay constant, namely, the natural logarithm of 2 divided by the radioactive decay halflife in days (1 year = 365.25 days)
T_p^f= exposure time of the plant type p to the airborne contamination depositing on the foliage, in days (also called growing period)
Y_p= yield of crop type p, in kilograms per square meter (wet weight). Also called the standing biomass. See Table 7.

The plant concentration due to direct deposition depends on the rate at which water is applied. In the previous two pathways, root uptake and rain splash, the determining factor is the total amount of water (and thus activity) applied to the soil.

Table 7. Agricultural Parameters for the Maximum Individual[1]

Type, p	T_v	K_p^f	Y_p	R_p	F_p^f	I_p	T_p^f	T_p^h
Plants Consumed by Humans								
Leafy	1.0	2.9	2.0	0.10	0.440	32.4	90	1
Other	0.1	3.6	2.0	0.25	0.835	32.4	90	5
Fruit	0.1	3.6	3.0	0.18	0.857	32.4	90	5
Grain	0.1	2.9	0.8	0.18	0.341	0.0	90	180
Plants Consumed by Beef Cattle								
Forage	1.0	2.9	1.0	0.20	0.440	32.4	45	100
Stored[2]	0.1	2.9	0.8	0.18	0.341	32.4	90	180
Plants Consumed by Milk Cows								
Forage	1.0	2.9	1.5	0.20	0.581	32.4	45	0
Stored[2]	0.1	2.9	1.0	0.18	0.407	32.4	90	100

[1]These were also used in the exposure scenarios in the Grouted Waste Performance Assessment (Kincaid 1993; Rittmann 1993b).
[2]In GENII, the stored feed model uses the translocation factor (T_v) and soil-to-plant concentration ratio (B_p) for grain.

<u>Explanation of Column Headings:</u>

T_v= translocation factors

K_p^f= parameter used to compute interception fractions, m^2/kg

Y_p= standing biomass (crop yield), kg/m^2

R_p= dry to wet ratios

F_p^f= interception fractions. The values shown were calculated. For direct deposition of nuclides on plants by irrigation water, the interception fraction (F_p^f) is 0.25 for all plant types.

I_p= irrigation water application rate, inches per year

T_p^f= growing period, days

T_p^h= holdup period between harvest and consumption, days

<u>3.4 Concentration in Animals and Fish</u>

Radionuclide concentrations in animal products (meat and milk) are derived from two sources, drinking water and feed. In GENII, the cattle used for milk production and meat production are considered separately. Each has its own dietary parameters. These were listed on Table 7. The nuclide concentrations in drinking water and feed determine the meat or milk concentration through a concentration ratio. These concentration ratios were listed in Tables 5 and 6. The equation relating feed and water concentrations to the eventual concentration in meat and milk is shown below.

$$C_q = F_q \, [Q_v^q \, (F_f^q \, C_l^q + F_s^q \, C_g^q) + Q_w^q \, C_w]$$

where,

C_q= radionuclide concentration in beef or milk (q), in curies per kilogram

F_q= ratio of the equilibrium concentration of a nuclide in the animal product (beef or milk) to the daily intake by cattle. For beef the units are Ci/kg(beef) per Ci/day, while for milk the units are Ci/L(milk) per Ci/day. See Tables 5 and 6 for values.

Q_v^q= amount of fresh forage consumed by beef or milk cattle on an average day, in kilograms per day. The assumed values for beef cattle and milk cows are 68 kg/day and 55 kg/day (Napier, 1988).

F_f^q= fraction of cattle diet which is forage. In GENII this is 0.75, and forage (grass & hay) is treated as a leafy vegetable for both types of cattle.

C_l^q= radionuclide concentration in forage (leafy vegetables) the cattle eat, in curies per kilogram. This includes the decay during holdup.

F_s^q= fraction of cattle diet which is stored feed. In GENII this is 0.25, and stored feed is treated as a grain.

C_g^q= radionuclide concentration in stored feed (grain) the cattle eat, in curies per kilogram. This includes the decay during holdup.

Q_w^q= amount of drinking water consumed by cattle, in liters per day. It is assumed (Napier, 1988) that the beef cattle drink 50 L/day, while the milk cows drink 60 L/day.

C_w= irrigation water concentration, in curies per liter (Ci/L)

Radionuclide concentrations in fish are assumed to be at equilibrium with the water in which they are raised. The fish concentration is therefore the product of the water concentration and the concentration ratio for that element as shown in the equation below. The fish concentration ratios are sometimes called bioaccumulation factors.

$$C_f = C_w \, B_f$$

where,

B_f= bioaccumulation factor for a given radionuclide in fish, in liters per kilogram. The values assumed are shown on Table 5.

C_f= radionuclide concentration in fish, in curies per kilogram.

3.5 Special Models for Tritium

Tritium in the soil of the intruder's garden is assumed to be present in only trace amounts in the food crops. The ingestion dose from root uptake is assumed to be zero. Tritium in the soil gives a small inhalation dose and even smaller external dose. The main dose pathway is the small amount of soil ingested each day. These assumptions are also made by the GENII program as it deals with tritium in the surface layer.

For the scenario using contaminated irrigation water, the concentrations of tritium in food crops, beef and milk are calculated using a specific activity model based on the concentration of tritium in the irrigation water. This same concentration is assumed to exist in the water present in all food items, since the plants and animals obtain nearly all their water from the contaminated source.

The soil concentration of tritium due to irrigation is based on the assumption that all of the soil moisture is contaminated at the same level as the water. The concentration of tritium in the air is calculated from the soil contamination, just as it is for all the nuclides. The formula for soil concentration of tritium is shown below.

$$W = \theta_w C_w$$

where,

θ_w= moisture content of soil assumed for the tritium model, in liters per kilogram of soil. The value 0.1 L/kg (Kennedy and Strenge, 1992) is used for this parameter.

The plants derive nearly all of their water from the irrigation applied, thus the tritium concentration in the plant water is the same as the ground water. Since the feed given the cattle as well as the water are contaminated with tritium, all of the water in the animal will have the same tritium concentration as the ground water. Using this simple assumption, the tritium concentration in plants, cows and milk is calculated from the equation shown below.

$$C_p = F_p^W C_w$$

where,

F_p^W= fraction of water in produce type p, where p refers to meat and milk as well as vegetables. The dry to wet ratio (R_p) can be calculated from this since $R_p = 1 - F_p^W$.

The tritium model considers the organically bound hydrogen in the produce to be contaminated as well as the water. The specific activity model actually requires that the concentration of tritium in the hydrogen in the water be reproduced throughout the food product. In GENII, an effective water fraction is added to the actual water fraction, and this is used to calculate results. The formula used to adjust the water fractions is shown below. Values for these parameters are shown in Table 8. Values from ORNL-5785 (water only) are also shown for comparison.

$$F_p^{W2} = F_p^W + (1 - F_p^W)\ F_p^H\ 9$$

where,

F_p^{W2}= effective water fraction in produce type p, where p refers to meat and milk as well as vegetables. This water fraction includes hydrogen which is not in the form of water. It is used in place of F_p^W.

F_p^H= fraction of hydrogen in the dry produce. The scale factor of 9 converts this to an effective water fraction.

Table 8. Parameters Used in the Tritium and Carbon-14 Models

	Tritium Model Parameters			C-14	ORNL-5785	
Type, p	F_p^W	F_p^H	F_p^{W2}	B & F	F_p^W	C_p^C
Leafy	0.80	0.0625	0.9125	1.0	0.93	0.026
Other	0.80	0.0625	0.9125	1.0	0.77	0.116
Fruit	0.80	0.0625	0.9125	1.0	0.87	0.050
Grain	0.12	0.0625	0.6150	1.0	0.11	0.293
Beef	0.60	0.094	0.9384	0.031	0.61	0.228
Milk	0.88	0.083	0.9696	0.012	0.85	0.069

The water fractions shown above are only used in the tritium model. The water fractions taken from ORNL-5785 were used in the tritium results shown for ORNL-5785 assumptions.

3.6 Special Parameters for Carbon-14

In GENII, the concentrations of ^{14}C in food crops, beef and milk are calculated using a specific activity model based on the concentration of ^{14}C in the soil. In GENII, the plants are assumed to obtain 90 percent of their carbon from the air, and 10 percent from the soil. The ratio of the ^{14}C concentration in plants to the concentration of carbon in the soil is assumed to be the same in all plant types. This specific activity model is not used in the present calculations.

Based on recent data for ^{14}C uptake in plants (Sheppard, 1991), ^{14}C will be treated like the other nuclides described earlier. The specific activity model used by GENII on plants is not used here. Parameters found in NUREG/CR-5512 are applied. The soil leaching coefficient is 0.0957 per year based on a Kd of 6.7 ml/g, as well as the other soil parameters discussed earlier. The concentration ratio for all plant types is assumed to be 0.7, on a dry-weight basis.

Continuing with the NUREG/CR-5512 model for ^{14}C, the transfer of ^{14}C into beef and milk are computed using a specific activity model. The concentration of ^{14}C in animal products (beef and milk) is computed using the equation shown below. This equation gives the ratio of ^{14}C activity consumed by the cow, to total carbon consumed by the cow. In the specific activity model, the ^{14}C is a combination of the ^{14}C in each component of the cow's diet.

$$\frac{C_q^{C14}}{C_q^C} = \frac{Q_f^q C_f^q + Q_h^q C_h^q + Q_g^q C_g^q + Q_w^q C_w}{Q_f^q C_f^C + Q_h^q C_h^C + Q_g^q C_g^C + Q_w^q C_w^C}$$

where,

C_q^{C14} = concentration of ^{14}C in animal product q (beef or milk) consumed by the human, in Ci/kg

C_q^C = concentration of carbon in animal product q consumed by the human, in kg carbon per kilogram (wet) of animal product q (beef or milk)

C_p^C = concentration of carbon in animal feed type p, in kg carbon per kilogram (wet) of plant. In this equation p refers to fresh forage, stored hay, stored grain, and drinking water. The carbon concentration of drinking water is small enough that it can be ignored.

Using the specific equation above, the effective transfer factor (F_q^{C14}) for the cattle can be computed from the parameters given. The diet-to-animal product transfer factor is the ratio of the equilibrium ^{14}C concentration in the cow to the daily intake of activity.

$$F_q^{C14} = \frac{C_q^C}{Q_f^q C_f^C + Q_h^q C_h^C + Q_g^q C_g^C + Q_w^q C_w^C}$$

The effective diet-to-animal transfer factors for ^{14}C was computed from pathway parameters already described. The computed F values for ^{14}C are shown in Table 5.

3.7 Human Intakes and Effective Dose Factors

Human exposure to radiation is estimated for both internal and external sources. External sources are outside the body. The only source of external exposure in these scenarios is the contaminated soil. Internal sources of exposure are located inside the body, and get there by being inhaled or ingested. Each of these types of exposure will be discussed separately below. The total dose is the sum of the different types of exposure.

3.7.1 Internal and External Dose Factors

The internal dose factors applied to unit quantities of ingested or inhaled activity are shown in Table 9. The GENII internal dose factors (from the July, 1993, revision) are shown only for comparison with the other values. The EPA values are from Federal Guidance Report Number 11 (US EPA 1988) and are also only shown for comparison. The DOE internal dose factors were actually used in the calculations. The three collections of internal dose factors are compared by means of ratios in Table 10. All three collections are based on a dose commitment period of 50 years.

External dose rate factors are also shown in Table 9. These are from a large area of soil 15 centimeters thick. The assumed soil density is 1.5 grams per cubic centimeter. The values shown in Table 9 come from the GENII GRDF.DAT file. The last column shows values from a recent recomputation using EXTDF, a program which is part of the GENII software package. The recalculation increased the dose rate factors by about 15 percent in all cases due to a difference in the assumed soil composition. The original GENII dose factors were based on a composition like that of air. The recalculated values used a composition like that of ordinary concrete.

Five of the nuclides shown in Table 9 are not found in the GENII library. The GENII dose factors for Ba-133, Eu-150, Gd-152, and Bi-207 were computed by averaging the values from the EPA and DOE. Dose factors for the fifth nuclide, Po-209, are not found in any dose factor collection. Dose factors for Po-209 were computed by comparison with Po-210. Corrections were made for the energy of the alpha particles emitted, and the decay halflife using the equation shown below.

$$\text{Dose Factor} \propto \frac{E\alpha}{\lambda_{eff}} \left[1 - e^{(-\lambda_{eff} T_d)} \right]$$

where,

$E\alpha$ = total alpha energy per decay. For Po-209 this is 4.882 Mev per decay, while for Po-210 this is 5.3045 Mev per decay.

λ_{eff} = effective removal constant, which combines both the biological elimination and the radioactive decay of the nuclide.

T_d = dose commitment period used in the dose factor collections shown in Table 9, namely, 50 years.

The biological removal halftime for polonium is 50 days (ICRP 30). The decay halflife of Po-209 is 102 year, thus its λ_{eff} is 0.01388 per day. The decay halflife of Po-210 is 138 days, thus its λ_{eff} is 0.01889 per day. Since these are so large, the dose integration term in brackets is always 1. The ratio of Po-209 to Po-210 internal dose factors is shown below. This ratio was applied to the Po-210 inhalation and ingestion dose factors to arrive at the Po-209 internal dose factors.

Table 9. Internal Dose Factors (mrem/pCi) Used in the Spreadsheet

		Ingestion (mrem/pCi)				Inhalation (mrem/pCi)			External♦ mrem/hr per Ci/m²	
Nuclide	f1	GENII	DOE	EPA	Sol	GENII	DOE	EPA	GENII	Redone
H-3	(1.00)	6.1E-08	6.3E-08	6.40E-08	(V)	9.0E-08	9.5E-08	9.60E-08	2.93E-08	3.50E-08
Be-10	(5E-3)	4.7E-06	4.2E-06	4.66E-06	(Y)	3.5E-04	3.5E-04	3.54E-04	3.66E-01	4.34E-01
C-14	(1.00)	2.1E-06	2.1E-06	2.09E-06	(Org)	2.1E-06	2.1E-06	2.09E-06	6.28E-03	7.51E-03
Cl-36	(1.00)	3.0E-06	3.0E-06	3.03E-06	(W)	2.2E-05	2.0E-05	2.19E-05	7.23E-01	8.57E-01
K-40	(1.00)	1.8E-05	1.9E-05	1.86E-05	(D)	1.2E-05	1.2E-05	1.24E-05	4.31E+02	4.87E+02
Co-60	(0.30)	2.7E-05	2.6E-05	2.69E-05	(Y)	2.0E-04	1.5E-04	2.19E-04	6.61E+03	7.51E+03
Ni-59	(0.05)	2.1E-07	2.0E-07	2.10E-07	(D)	1.3E-06	1.3E-06	1.32E-06	1.10E-01	1.32E-01
Ni-63	(0.05)	5.6E-07	5.4E-07	5.77E-07	(D)	3.0E-06	3.0E-06	3.10E-06	1.59E-04	1.91E-04
Se-79	(0.80)	8.4E-06	8.3E-06	8.70E-06	(W)	9.5E-06	8.9E-06	9.84E-06	4.47E-03	5.36E-03
Sr-90	(0.30)	1.3E-04	1.4E-04	1.53E-04	(D)	2.1E-04	2.4E-04	2.47E-04	1.70E+01	1.97E+01
Zr-93	(2E-3)	1.6E-06	1.6E-06	1.66E-06	(D)	3.2E-04	3.2E-04	3.21E-04	1.12E-04	1.34E-04
Nb-93m	(0.01)	5.1E-07	5.3E-07	5.22E-07	(Y)	3.0E-05	2.8E-05	2.92E-05	4.39E-02	5.28E-02
Nb-94	(0.01)	7.3E-06	5.1E-06	7.14E-06	(Y)	3.9E-04	3.3E-04	4.14E-04	4.08E+03	4.66E+03
Mo-93	(0.80)	1.4E-06	1.3E-06	1.35E-06	(Y)	2.8E-05	2.8E-05	2.84E-05	2.12E-01	2.54E-01
Tc-99	(0.80)	2.2E-06	1.3E-06	1.46E-06	(W)	9.0E-06	7.5E-06	8.33E-06	4.22E-02	5.05E-02
Pd-107	(5E-3)	1.5E-07	1.4E-07	1.49E-07	(Y)	1.3E-05	1.3E-05	1.28E-05	3.49E-06	4.17E-06
Cd-113m	(0.05)	1.6E-04	1.5E-04	1.61E-04	(D)	1.5E-03	1.4E-03	1.53E-03	3.60E-01	4.28E-01
Sn-121m	(0.02)	2.2E-06	2.0E-06	2.25E-06	(W)	1.2E-05	9.3E-06	1.19E-05	0	5.16E+00
Sn-126	(0.02)	2.1E-05	1.8E-05	2.11E-05	(W)	1.0E-04	7.5E-05	1.01E-04	5.71E+03	6.56E+03
I-129	(1.00)	2.5E-04	2.8E-04	2.76E-04	(D)	1.5E-04	1.8E-04	1.74E-04	4.64E+00	5.59E+00
Cs-135	(1.00)	6.9E-06	7.1E-06	7.07E-06	(D)	4.5E-06	4.5E-06	4.55E-06	1.22E-02	1.45E-02
Cs-137	(1.00)	4.8E-05	5.0E-05	5.00E-05	(D)	3.0E-05	3.2E-05	3.19E-05	1.58E+03	1.82E+03
Ba-133◂	(0.10)	3.3E-06	3.2E-06	3.40E-06	(D)	7.4E-06	6.9E-06	7.81E-06	9.57E+02	1.10E+03
Sm-147	(3E-4)	1.9E-04	1.8E-04	1.85E-04	(W)	7.5E-02	7.1E-02	7.47E-02	0	0
Sm-151	(3E-4)	3.9E-07	3.4E-07	3.89E-07	(W)	3.0E-05	2.9E-05	3.00E-05	1.63E-03	1.95E-03
Eu-150◂	(1E-3)	6.3E-06	6.2E-06	6.36E-06	(W)	2.7E-04	2.7E-04	2.68E-04	4.38E+03	5.03E+03
Eu-152	(1E-3)	6.5E-06	6.0E-06	6.48E-06	(W)	2.1E-04	2.2E-04	2.21E-04	3.15E+03	3.59E+03
Eu-154	(1E-3)	9.6E-06	9.1E-06	9.55E-06	(W)	2.8E-04	2.6E-04	2.86E-04	3.26E+03	3.73E+03
Gd-152◂	(3E-4)	1.6E-04	1.5E-04	1.62E-04	(D)	2.4E-01	2.4E-01	2.43E-01	0	0
Re-187	(0.80)	1.5E-08	8.3E-09	9.51E-09	(W)	5.9E-08	4.9E-08	5.44E-08	0	0
Pb-210	(0.20)	7.4E-03	6.7E-03	7.31E-03	(D)	2.4E-02	2.1E-02	2.33E-02	3.29E+00	3.88E+00
Bi-207◂	(0.05)	5.2E-06	4.9E-06	5.48E-06	(D)	1.7E-05	1.4E-05	2.00E-05	4.29E+03	4.93E+03
Po-209★	(0.10)	2.4E-03	2.0E-03	2.38E-03	(D)	1.2E-02	1.0E-02	1.18E-02	7.78E+00	8.93E+00
Ra-226	(0.20)	9.6E-04	1.1E-03	1.32E-03	(W)	8.2E-03	7.9E-03	8.58E-03	4.92E+03	5.60E+03
Ra-228	(0.20)	8.4E-04	1.2E-03	1.44E-03	(W)	4.4E-03	4.3E-03	4.86E-03	2.67E+03	3.04E+03
Ac-227	(1E-3)	1.4E-02	1.5E-02	1.48E-02	(D)	6.7E+00	6.7E+00	6.72E+00	9.26E+02	1.07E+03
Th-228	(2E-4)	5.8E-04	7.5E-04	8.09E-04	(Y)	3.5E-01	3.1E-01	3.45E-01	4.35E+03	4.91E+03
Th-229	(2E-4)	3.9E-03	3.9E-03	4.03E-03	(W)	2.2E+00	2.0E+00	2.16E+00	7.80E+02	9.03E+02
Th-230	(2E-4)	5.4E-04	5.3E-04	5.48E-04	(W)	3.2E-01	3.2E-01	3.26E-01	3.43E-01	4.10E-01
Th-232	(2E-4)	2.7E-03	2.8E-03	2.73E-03	(W)	1.7E+00	1.6E+00	1.64E+00	1.79E-01	2.13E-01
Pa-231	(1E-3)	1.1E-02	1.1E-02	1.06E-02	(W)	1.3E+00	1.3E+00	1.28E+00	7.82E+01	9.09E+01
U-232	(0.05)	1.3E-03	1.3E-03	1.31E-03	(Y)	6.7E-01	6.7E-01	6.59E-01	2.61E-01	3.11E-01
U-233	(0.05)	2.9E-04	2.7E-04	2.89E-04	(Y)	1.4E-01	1.3E-01	1.35E-01	4.05E-01	4.80E-01
U-234	(0.05)	2.9E-04	2.6E-04	2.83E-04	(Y)	1.3E-01	1.3E-01	1.32E-01	1.58E-01	1.89E-01
U-235	(0.05)	2.7E-04	2.5E-04	2.67E-04	(Y)	1.2E-01	1.2E-01	1.23E-01	2.13E+02	2.52E+02
U-236	(0.05)	2.7E-04	2.5E-04	2.69E-04	(Y)	1.3E-01	1.2E-01	1.25E-01	8.22E-02	9.83E-02
U-238	(0.05)	2.7E-04	2.4E-04	2.68E-04	(Y)	1.2E-01	1.2E-01	1.18E-01	6.32E+01	7.26E+01
Np-237	(1E-3)	5.3E-03	3.9E-03	4.44E-03	(W)	6.4E-01	4.9E-01	5.40E-01	6.16E+02	7.13E+02
Pu-238	(1E-3)	3.2E-03	3.8E-03	3.20E-03	(W)	3.9E-01	4.6E-01	3.92E-01	5.26E-02	6.30E-02
Pu-239	(1E-3)	3.6E-03	4.3E-03	3.54E-03	(W)	4.3E-01	5.1E-01	4.29E-01	1.16E-01	1.12E-01
Pu-240	(1E-3)	3.6E-03	4.3E-03	3.54E-03	(W)	4.3E-01	5.1E-01	4.29E-01	5.23E-02	7.29E-02
Pu-241	(1E-3)	6.8E-05	8.6E-05	6.85E-05	(W)	8.2E-03	1.0E-02	8.25E-03	6.26E-03	1.04E-02
Pu-242	(1E-3)	3.3E-03	4.1E-03	3.36E-03	(W)	4.1E-01	4.8E-01	4.11E-01	4.36E-02	5.24E-02
Pu-244	(1E-3)	3.3E-03	4.0E-03	3.32E-03	(W)	4.0E-01	4.8E-01	4.03E-01	1.02E+03	1.17E+03
Am-241	(1E-3)	3.6E-03	4.5E-03	3.64E-03	(W)	4.4E-01	5.2E-01	4.44E-01	1.19E+01	1.44E+01
Am-242m	(1E-3)	3.6E-03	4.3E-03	3.61E-03	(W)	4.4E-01	5.3E-01	4.40E-01	3.09E+01	3.64E+01
Am-243	(1E-3)	3.6E-03	4.5E-03	3.62E-03	(W)	4.4E-01	5.2E-01	4.40E-01	3.82E+02	4.49E+02
Cm-243	(1E-3)	2.5E-03	2.9E-03	2.51E-03	(W)	3.1E-01	3.5E-01	3.07E-01	2.46E+02	2.90E+02
Cm-244	(1E-3)	2.0E-03	2.3E-03	2.02E-03	(W)	2.5E-01	2.7E-01	2.48E-01	4.25E-02	5.08E-02
Cm-245	(1E-3)	3.7E-03	4.5E-03	3.74E-03	(W)	4.5E-01	5.4E-01	4.55E-01	1.11E+02	1.32E+02
Cm-246	(1E-3)	3.7E-03	4.5E-03	3.70E-03	(W)	4.6E-01	5.4E-01	4.51E-01	3.49E-02	4.19E-02
Cm-247	(1E-3)	3.4E-03	4.1E-03	3.42E-03	(W)	4.2E-01	4.9E-01	4.14E-01	1.13E+03	1.30E+03
Cm-248	(1E-3)	1.4E-02	1.6E-02	1.36E-02	(W)	1.6E+00	1.9E+00	1.65E+00	3.18E-02	3.82E-02

◂GENII values for these nuclides were obtained by averaging the DOE and EPA values.
★All Po-209 internal dose factors are estimated from Po-210, as described in Section 3.7.1.
♦The External Dose Rate Factors are described in more detail in Section 3.7.1.

Table 10. Ratios of GENII and EPA Internal Dose Factors to DOE Internal Dose Factors
(Differences less than 10 percent not shown)

Nuclide	Inhalation GENII	Inhalation EPA	Ingestion GENII	Ingestion EPA
Be-10			1.11	1.11
Co-60	1.34	1.46		
Se-79		1.11		
Sr-90	0.89			
Nb-94	1.18	1.26	1.42	1.40
Tc-99	1.20	1.11	1.72	1.12
Sn-121m	1.27	1.28	1.12	1.13
Sn-126	1.33	1.34	1.15	1.15
I-129	0.84		0.89	
Ba-133		1.13		
Sm-151			1.14	1.14
Re-187	1.20	1.11	1.75	1.15
Pb-210	1.11			
Bi-207	1.21	1.43		1.12
Po-209	1.20	1.16	1.20	1.19
Ra-226			0.87	1.20
Ra-228		1.13	0.70	1.20
Th-228	1.11		0.77	
U-238			1.12	
Np-237	1.30		1.35	1.14
Pu-238	0.85	0.85	0.84	0.84
Pu-239	0.85	0.84	0.83	0.82
Pu-240	0.85	0.84	0.83	0.82
Pu-241	0.82	0.83	0.79	0.80
Pu-242	0.84	0.86	0.81	0.82
Pu-244	0.84	0.84	0.83	0.83
Am-241	0.85	0.85	0.81	0.81
Am-242m	0.81	0.82	0.83	0.84
Am-243	0.85	0.85	0.81	0.80
Cm-243	0.88	0.88	0.87	0.87
Cm-244			0.87	0.88
Cm-245	0.84	0.84	0.82	0.83
Cm-246	0.84	0.84	0.83	0.82
Cm-247	0.86	0.85	0.84	0.83
Cm-248	0.86	0.87	0.84	0.85

$$\frac{\text{Po-209 Dose Factor}}{\text{Po-210 Dose Factor}} = \frac{4.882 \text{ Mev} * 0.01889 \text{ per day}}{5.3045 \text{ Mev} * 0.01388 \text{ per day}} = 1.252$$

3.7.2 Internal Exposure from Ingested Activity

The ingestion dose is calculated from the ingestion dose factor and the quantity of radioactivity consumed in food, soil and water. The ingestion dose is calculated using the general equation below.

$$H_{ing} = (Q^h_w\ C_w\ +\ Q^h_s\ W\ +\ \sum_p Q^h_p\ C_p)\ D_{ing}\ (1.0\text{x}10^{12}\ \text{pCi/Ci})$$

where,

H_{ing}= the ingestion dose, in mrem

Q^h_w= amount of drinking water consumed annually by the human, in liters per year. The value 730 L/yr is used.

Q^h_s= amount of soil consumed annually by the human, in kilograms per year. The value 0.0365 kg/yr is used.

Q^h_p= amount of produce type p the human consumes each year, in kilograms (or liters for milk) per year. Values are listed in Table 2. Note that p refers to meat and milk as well as vegetables.

C_p= radionuclide concentration in plant or animal type p at the time it is consumed by the human, in curies per kilogram (or curies per liter for milk). Includes an insignificant amount of decay during holdup prior to consumption.

D_{ing}= internal dose factor for ingestion, in mrem per picocurie ingested. Values are shown on Table 9.

Note that for the intruder scenarios, the ingested activity comes from the soil and vegetation only, since the drinking water concentration is zero. For the All Pathways scenario, the person not only eats garden produce (and soil), but also ingests contaminated meat, milk and water. The Columbia River Population doses include fish as well.

3.7.3 Internal Exposure from Inhaled Activity

The activity inhaled in the course of a year depends on the volume of air inhaled during the year, as well as the average air concentration. The average air concentration is estimated from an average mass loading of particulate material in the air. The material in the air is assumed to have the same concentration as the soil. Thus the equation for inhaled activity is shown below.

$$H_{inh} = M_a\ V_a\ D_{inh}\ (1.0\text{x}10^{12}\ \text{pCi/Ci})\ W\{1 - \text{Exp}[-(\lambda_s+\lambda_r)T_h]\}/(\lambda_s+\lambda_r)$$

where,

H_{inh}= inhalation dose, in mrem

D_{inh}= internal dose factor for inhalation, in mrem per picocurie inhaled. Values are shown on Table 9.

M_a= average mass concentration in the air during the year, in kilograms per cubic meter. The GENII value (1E-07 kg/m³) is used for the inhalation dose calculation.

V_a= daily average breathing rate, in cubic meters per hour. The value for Reference Man (0.95 m³/hr, in ICRP 23) is used.

T_h= inhalation time, in hours. This is the number of hours per year that the individual is breathing the average air concentration. The 4680 hour value for maximum individuals was derived using Table 1.

Note that the nuclide intake is accumulated over the time T_h. The equation shows how leaching from the surface layer is included. This portion of the calculation differs from GENII in that GENII does no decay or leaching when computing inhalation dose. GENII assumes the air concentration remains constant during the year.

In reality, the respirable dust loading of the air is lower than the assumed 100 $\mu g/m^3$. The EPA air quality standard is 50 $\mu g/m^3$, which is normally attainable. However, the soil contaminants are found with the small diameter fraction of the surface soil. Hence the concentration of nuclides in the airborne dust is higher than the concentration in the bulk soil. These two effects are assumed to offset one another, so that 100 $\mu g/m^3$ adequately represents the resuspended activity concentration.

For populations, the inhalation exposure time was increased from 4680 hours per year to 8766 hours per year. This increase is related to the broader distribution of radioactivity in the environment from widespread use of the Columbia River for irrigation.

3.7.4 External Exposure

The GENII program calculates external dose from surface contamination using unit dose factors computed by the EXTDF program. The EXTDF program uses parts of the ISOSHLD program to calculate dose equivalent rates from external sources for user entered geometry data. Values from the GENII library (GRDF.DAT) are shown in Table 9. These values have been converted from the SI units to mrem/hr per Ci/m^2. The values for the added nuclides were calculated using EXTDF and the new values are shown on Table 9. External dose to the intruder and the irrigator is calculated using the formula shown below.

$$H_{ext} = \rho\ d\ D_{ext}\ W\ \{1 - Exp[-(\lambda_s+\lambda_r)T_e]\}/(\lambda_s+\lambda_r)$$

where,

H_{ext}= total external dose, in mrem

D_{ext}= external dose rate factor for exposure to radiation from contaminated soil, in mrem/hr per Ci/m^2. Values are shown on Table 9.

d = thickness of soil from which nuclides migrate, in centimeters. The GENII value for this is 15 centimeter.

ρ = bulk density of the surface soil, in grams per cubic centimeter. In GENII this is 1.5 g/cc.

T_e= time exposed to external radiation sources in the soil, in hours. The effective exposure time for maximum individuals is 3260 hours, from Section 1.1.

Note that the dose is accumulated over the time T_h. The equation shows how leaching from the surface layer is included. For the intruder scenario this portion of the calculation differs from GENII in that GENII does no decay or leaching when computing inhalation dose. GENII assumes the soil concentration remains constant during the year.

For populations, the external exposure time was increased from 3260 hours per year to 4383 hours per year. This increase is related to the broader distribution of radioactivity in the environment from widespread use of the Columbia River for irrigation.

External dose to the Columbia River population from recreational activities was computed using GENII for several radionuclides. The average person spends 10 hours swimming and 17 hours on the river shoreline each year (Kincaid 1993). These recreational activities increase the average external dose by approximately four percent. Therefore, the external dose from recreational activities is not explicitly included in the population dose estimates.

4.0 DOSE RESULTS FOR UNIT CONCENTRATIONS

The spreadsheet is used to calculate all doses. GENII was used to verify the calculations. The comparison between GENII and the spreadsheet is the subject of Appendix D. The comparison is for each pathway, but GENII internal dose factors had to be used.

Dose results for the intruders are shown in Tables 11 through 14. The results show the doses to the intruder which would be produced by an initial concentration of 1 Ci/m^3 in the waste. Tables of doses by pathway are shown in Appendix A. The dose for an intruder depends on the volume of waste exhumed. For the Drilling intruder the exhumed waste volume is 0.35 m^3, while for the Excavation intruder this is 75 m^3. The dominant pathway for each nuclide is the same in all cases, except for Cm-243, which changes from "Extern" to "Inhale" after 100 years of decay which produces Pu-239.

Tables 11 and 12 show the intruder doses for the NUREG/CR-5512 transfer factors. Tables 13 and 14 show the intruder doses for the ORNL-5785 concentration ratios in Table 6. The waste concentration in all cases was 1 Ci/m^3. The surface soil concentration was 0.622 μCi/kg for the Post-Drilling Scenario. The Post-Excavation Scenario leads to a surface concentration of 133 μCi/kg (214 time larger).

Tables 15 and 16 show the All Pathways Irrigator and Columbia River Population doses for a water concentration of 1 pCi/L. Appendix B and Appendix C show the doses by pathway. The drinking water pathway is the most common dominant pathway. Thus, the doses in all columns are nearly the same.

Scenario dose factors were computed with no leaching from the surface layer of soil to discover what effect the leaching coefficients have. Both sets of dose factors are shown in the tables. Comparisons are found in Table 18.

Table 17 compares the doses using the NUREG/CR-5512 concentration factors with the doses using the ORNL-5785 factors by using ratios of the NUREG dose to the ORNL dose. Nuclides with dose differences less than 10 percent are not listed in the table.

Table 18 compares the doses using soil leaching with those without leaching by using ratios. The effect that leaching removal has on total dose is small for most nuclides. Thus the values for retardation in the surface layer have little effect on the dose factors for nearly every nuclide considered. Nuclides with dose factor differences less than 10 percent were not listed in the table.

Table 11. Total Doses (mrem/yr per Ci/m³) for the Post-Drilling Scenario Using NUREG/CR-5512 Concentration Ratios

Nuclide	With Soil Leaching 100 yr	With Soil Leaching 300 yr	With Soil Leaching 500 yr	Without Soil Leaching 100 yr	Without Soil Leaching 300 yr	Without Soil Leaching 500 yr	Dominant Pathway
H-3	1.91E-06	2.38E-11	2.98E-16	5.11E-06	6.39E-11	7.99E-16	Soil Ing
Be-10	4.24E-01	4.24E-01	4.24E-01	4.24E-01	4.24E-01	4.24E-01	Extern
C-14	5.00E+00	4.88E+00	4.76E+00	5.13E+00	5.01E+00	4.89E+00	Veggie
Cl-36	6.70E+02	6.69E+02	6.69E+02	7.35E+02	7.34E+02	7.34E+02	Veggie
K-40	2.57E+02	2.57E+02	2.57E+02	2.61E+02	2.61E+02	2.61E+02	Extern
Co-60	6.22E-03	2.35E-14	8.91E-26	6.26E-03	2.37E-14	8.96E-26	Extern
Ni-59	1.18E-01	1.18E-01	1.18E-01	1.19E-01	1.18E-01	1.18E-01	Extern
Ni-63	7.85E-02	1.97E-02	4.92E-03	7.85E-02	1.97E-02	4.92E-03	Veggie
Se-79	9.20E-01	9.19E-01	9.17E-01	9.22E-01	9.20E-01	9.18E-01	Veggie
Sr-90	2.96E+01	2.33E-01	1.83E-03	3.00E+01	2.36E-01	1.85E-03	Veggie
Zr-93	1.85E-01	1.85E-01	1.85E-01	1.85E-01	1.85E-01	1.85E-01	Inhale
Nb-93m	4.70E-04	3.54E-08	2.66E-12	4.71E-04	3.54E-08	2.66E-12	Extern
Nb-94	2.12E+03	2.10E+03	2.09E+03	2.12E+03	2.11E+03	2.09E+03	Extern
Mo-93	5.24E-01	5.04E-01	4.85E-01	5.35E-01	5.14E-01	4.95E-01	Veggie
Tc-99	1.21E+01	1.21E+01	1.21E+01	2.00E+01	1.99E+01	1.99E+01	Veggie
Pd-107	3.03E-02	3.03E-02	3.03E-02	3.04E-02	3.04E-02	3.04E-02	Veggie
Cd-113m	6.12E-01	2.47E-05	9.94E-10	6.15E-01	2.48E-05	9.98E-10	Veggie
Sn-121m	6.91E-01	5.56E-02	4.47E-03	6.93E-01	5.57E-02	4.48E-03	Extern
Sn-126	2.99E+03	2.98E+03	2.98E+03	2.99E+03	2.99E+03	2.98E+03	Extern
I-129	4.66E+01	4.66E+01	4.66E+01	5.47E+01	5.47E+01	5.47E+01	Veggie
Cs-135	2.84E+00	2.84E+00	2.84E+00	2.84E+00	2.84E+00	2.84E+00	Veggie
Cs-137	8.44E+01	8.53E-01	8.62E-03	8.45E+01	8.54E-01	8.63E-03	Extern
Ba-133	6.56E-01	1.21E-06	2.24E-12	6.60E-01	1.22E-06	2.25E-12	Extern
Sm-147	2.68E+01	2.68E+01	2.68E+01	2.68E+01	2.68E+01	2.68E+01	Inhale
Sm-151	1.02E-02	2.19E-03	4.69E-04	1.02E-02	2.19E-03	4.69E-04	Inhale
Eu-150	3.31E+02	7.05E+00	1.50E-01	3.32E+02	7.06E+00	1.50E-01	Extern
Eu-152	9.75E+00	3.65E-04	1.37E-08	9.76E+00	3.65E-04	1.37E-08	Extern
Eu-154	6.21E-01	8.94E-08	1.29E-14	6.22E-01	8.96E-08	1.29E-14	Extern
Gd-152	7.27E+01	7.27E+01	7.27E+01	7.28E+01	7.28E+01	7.28E+01	Inhale
Re-187	1.27E-02	1.27E-02	1.27E-02	1.28E-02	1.28E-02	1.28E-02	Veggie
Pb-210	1.25E+01	2.47E-02	4.88E-05	1.25E+01	2.47E-02	4.88E-05	Soil Ing
Bi-207	2.79E+02	4.39E+00	6.92E-02	2.80E+02	4.41E+00	6.94E-02	Extern
Po-209	4.76E+01	1.22E+01	3.14E+00	4.77E+01	1.22E+01	3.15E+00	Soil Ing
Ra-226	2.77E+03	2.55E+03	2.34E+03	2.77E+03	2.56E+03	2.34E+03	Extern
Ra-228	2.72E-02	9.22E-13	3.12E-23	2.73E-02	9.22E-13	3.12E-23	Extern
Ac-227	1.11E+02	1.91E-01	3.29E-04	1.12E+02	1.92E-01	3.29E-04	Inhale
Th-228	3.63E-13	1.23E-44	4.19E-76	3.63E-13	1.23E-44	4.19E-76	Extern
Th-229	1.06E+03	1.04E+03	1.02E+03	1.06E+03	1.04E+03	1.02E+03	Inhale
Th-230	2.23E+02	4.53E+02	6.64E+02	2.23E+02	4.53E+02	6.64E+02	Extern
Th-232	4.30E+03	4.30E+03	4.30E+03	4.30E+03	4.30E+03	4.30E+03	Extern
Pa-231	3.29E+03	3.39E+03	3.37E+03	3.29E+03	3.39E+03	3.38E+03	Inhale
U-232	1.01E+03	1.48E+02	2.15E+01	1.02E+03	1.48E+02	2.16E+01	Extern
U-233	6.24E+01	8.22E+01	1.02E+02	6.34E+01	8.32E+01	1.03E+02	Inhale
U-234	5.15E+01	5.15E+01	5.14E+01	5.25E+01	5.25E+01	5.25E+01	Inhale
U-235	1.66E+02	1.80E+02	1.95E+02	1.70E+02	1.84E+02	1.98E+02	Extern
U-236	4.81E+01	4.81E+01	4.81E+01	4.91E+01	4.91E+01	4.91E+01	Inhale
U-238	8.01E+01	8.01E+01	8.01E+01	8.18E+01	8.18E+01	8.18E+01	Inhale
Np-237	6.49E+02	6.49E+02	6.49E+02	6.87E+02	6.87E+02	6.87E+02	Extern
Pu-238	9.88E+01	2.04E+01	4.21E+00	9.89E+01	2.04E+01	4.21E+00	Inhale
Pu-239	2.44E+02	2.42E+02	2.41E+02	2.44E+02	2.42E+02	2.41E+02	Inhale
Pu-240	2.42E+02	2.37E+02	2.32E+02	2.42E+02	2.37E+02	2.32E+02	Inhale
Pu-241	7.65E+00	5.57E+00	4.05E+00	7.65E+00	5.57E+00	4.05E+00	Inhale
Pu-242	2.31E+02	2.31E+02	2.31E+02	2.31E+02	2.31E+02	2.31E+02	Inhale
Pu-244	7.64E+02	7.69E+02	7.73E+02	7.64E+02	7.69E+02	7.74E+02	Extern
Am-241	2.23E+02	1.62E+02	1.17E+02	2.23E+02	1.62E+02	1.17E+02	Inhale
Am-242m	2.48E+02	1.38E+02	6.31E+01	2.48E+02	1.38E+02	6.31E+01	Inhale
Am-243	4.57E+02	4.50E+02	4.43E+02	4.57E+02	4.50E+02	4.43E+02	Extern
Cm-243	2.62E+01	4.91E-01	2.90E-01	2.62E+01	4.91E-01	2.91E-01	Extern*
Cm-244	3.43E+00	6.56E-01	6.41E-01	3.43E+00	6.56E-01	6.41E-01	Inhale
Cm-245	3.51E+02	4.08E+02	4.47E+02	3.51E+02	4.08E+02	4.47E+02	Inhale
Cm-246	2.54E+02	2.47E+02	2.40E+02	2.54E+02	2.47E+02	2.40E+02	Inhale
Cm-247	8.31E+02	8.37E+02	8.42E+02	8.31E+02	8.37E+02	8.42E+02	Extern
Cm-248	9.11E+02	9.10E+02	9.10E+02	9.11E+02	9.10E+02	9.10E+02	Inhale

*The dominant pathway for Cm-243 changes to "Inhale" at times greater than 100 years due to the ingrowth of Pu-239.

Table 12. Total Doses (mrem/yr per Ci/m³) for the Post-Excavation Scenario Using NUREG/CR-5512 Concentration Ratios

Nuclide	With Soil Leaching 100 yr	With Soil Leaching 300 yr	With Soil Leaching 500 yr	Without Soil Leaching 100 yr	Without Soil Leaching 300 yr	Without Soil Leaching 500 yr	Dominant Pathway
H-3	4.09E-04	5.11E-09	6.39E-14	1.09E-03	1.37E-08	1.71E-13	Soil Ing
Be-10	9.08E+01	9.08E+01	9.08E+01	9.09E+01	9.09E+01	9.09E+01	Extern
C-14	1.07E+03	1.05E+03	1.02E+03	1.10E+03	1.07E+03	1.05E+03	Veggie
Cl-36	1.43E+05	1.43E+05	1.43E+05	1.57E+05	1.57E+05	1.57E+05	Veggie
K-40	5.51E+04	5.51E+04	5.51E+04	5.60E+04	5.60E+04	5.60E+04	Extern
Co-60	1.33E+00	5.05E-12	1.91E-23	1.34E+00	5.07E-12	1.92E-23	Extern
Ni-59	2.54E+01	2.53E+01	2.53E+01	2.54E+01	2.53E+01	2.53E+01	Extern
Ni-63	1.68E+01	4.21E+00	1.05E+00	1.68E+01	4.21E+00	1.05E+00	Veggie
Se-79	1.97E+02	1.97E+02	1.96E+02	1.98E+02	1.97E+02	1.97E+02	Veggie
Sr-90	6.35E+03	4.99E+01	3.91E-01	6.43E+03	5.05E+01	3.96E-01	Veggie
Zr-93	3.96E+01	3.97E+01	3.97E+01	3.96E+01	3.97E+01	3.97E+01	Inhale
Nb-93m	1.01E-01	7.58E-06	5.70E-10	1.01E-01	7.59E-06	5.71E-10	Extern
Nb-94	4.54E+05	4.50E+05	4.47E+05	4.54E+05	4.51E+05	4.48E+05	Extern
Mo-93	1.12E+02	1.08E+02	1.04E+02	1.15E+02	1.10E+02	1.06E+02	Veggie
Tc-99	2.60E+03	2.60E+03	2.59E+03	4.28E+03	4.27E+03	4.27E+03	Veggie
Pd-107	6.49E+00	6.49E+00	6.49E+00	6.52E+00	6.52E+00	6.52E+00	Veggie
Cd-113m	1.31E+02	5.28E-03	2.13E-07	1.32E+02	5.31E-03	2.14E-07	Veggie
Sn-121m	1.48E+02	1.19E+01	9.58E-01	1.48E+02	1.19E+01	9.60E-01	Extern
Sn-126	6.40E+05	6.39E+05	6.38E+05	6.41E+05	6.40E+05	6.40E+05	Extern
I-129	9.98E+03	9.98E+03	9.98E+03	1.17E+04	1.17E+04	1.17E+04	Veggie
Cs-135	6.09E+02	6.09E+02	6.09E+02	6.09E+02	6.09E+02	6.09E+02	Veggie
Cs-137	1.81E+04	1.83E+02	1.85E+00	1.81E+04	1.83E+02	1.85E+00	Extern
Ba-133	1.41E+02	2.60E-04	4.79E-10	1.42E+02	2.61E-04	4.82E-10	Extern
Sm-147	5.73E+03	5.73E+03	5.73E+03	5.74E+03	5.74E+03	5.74E+03	Inhale
Sm-151	2.19E+00	4.69E-01	1.00E-01	2.19E+00	4.69E-01	1.01E-01	Inhale
Eu-150	7.10E+04	1.51E+03	3.21E+01	7.11E+04	1.51E+03	3.21E+01	Extern
Eu-152	2.09E+03	7.82E-02	2.93E-06	2.09E+03	7.83E-02	2.93E-06	Extern
Eu-154	1.33E+02	1.92E-05	2.76E-12	1.33E+02	1.92E-05	2.76E-12	Extern
Gd-152	1.56E+04	1.56E+04	1.56E+04	1.56E+04	1.56E+04	1.56E+04	Inhale
Re-187	2.71E+00	2.71E+00	2.71E+00	2.75E+00	2.75E+00	2.75E+00	Veggie
Pb-210	2.68E+03	5.29E+00	1.05E-02	2.69E+03	5.30E+00	1.05E-02	Soil Ing
Bi-207	5.98E+04	9.42E+02	1.48E+01	5.99E+04	9.44E+02	1.49E+01	Extern
Po-209	1.02E+04	2.62E+03	6.73E+02	1.02E+04	2.62E+03	6.74E+02	Soil Ing
Ra-226	5.94E+05	5.47E+05	5.02E+05	5.94E+05	5.48E+05	5.02E+05	Extern
Ra-228	5.84E+00	1.98E-10	6.68E-21	5.84E+00	1.98E-10	6.69E-21	Extern
Ac-227	2.39E+04	4.10E+01	7.04E-02	2.39E+04	4.11E+01	7.05E-02	Inhale
Th-228	7.77E-11	2.64E-42	8.98E-74	7.77E-11	2.64E-42	8.98E-74	Extern
Th-229	2.28E+05	2.24E+05	2.19E+05	2.28E+05	2.24E+05	2.19E+05	Inhale
Th-230	4.77E+04	9.71E+04	1.42E+05	4.78E+04	9.71E+04	1.42E+05	Extern
Th-232	9.22E+05	9.22E+05	9.22E+05	9.22E+05	9.22E+05	9.22E+05	Extern
Pa-231	7.05E+05	7.26E+05	7.23E+05	7.06E+05	7.26E+05	7.23E+05	Inhale
U-232	2.17E+05	3.17E+04	4.62E+03	2.18E+05	3.18E+04	4.64E+03	Extern
U-233	1.34E+04	1.76E+04	2.18E+04	1.36E+04	1.78E+04	2.20E+04	Inhale
U-234	1.10E+04	1.10E+04	1.10E+04	1.13E+04	1.12E+04	1.12E+04	Inhale
U-235	3.56E+04	3.87E+04	4.17E+04	3.63E+04	3.94E+04	4.25E+04	Extern
U-236	1.03E+04	1.03E+04	1.03E+04	1.05E+04	1.05E+04	1.05E+04	Inhale
U-238	1.72E+04	1.72E+04	1.72E+04	1.75E+04	1.75E+04	1.75E+04	Inhale
Np-237	1.39E+05	1.39E+05	1.39E+05	1.47E+05	1.47E+05	1.47E+05	Extern
Pu-238	2.12E+04	4.37E+03	9.02E+02	2.12E+04	4.37E+03	9.03E+02	Inhale
Pu-239	5.22E+04	5.19E+04	5.16E+04	5.22E+04	5.19E+04	5.16E+04	Inhale
Pu-240	5.18E+04	5.07E+04	4.97E+04	5.18E+04	5.08E+04	4.97E+04	Inhale
Pu-241	1.64E+03	1.19E+03	8.67E+02	1.64E+03	1.19E+03	8.67E+02	Inhale
Pu-242	4.95E+04	4.95E+04	4.95E+04	4.96E+04	4.96E+04	4.95E+04	Inhale
Pu-244	1.64E+05	1.65E+05	1.66E+05	1.64E+05	1.65E+05	1.66E+05	Extern
Am-241	4.77E+04	3.47E+04	2.52E+04	4.78E+04	3.47E+04	2.52E+04	Inhale
Am-242m	5.32E+04	2.95E+04	1.35E+04	5.32E+04	2.95E+04	1.35E+04	Inhale
Am-243	9.79E+04	9.63E+04	9.48E+04	9.79E+04	9.64E+04	9.49E+04	Extern
Cm-243	5.62E+03	1.05E+02	6.22E+01	5.62E+03	1.05E+02	6.23E+01	Extern*
Cm-244	7.35E+02	1.41E+02	1.37E+02	7.36E+02	1.41E+02	1.37E+02	Inhale
Cm-245	7.53E+04	8.75E+04	9.59E+04	7.53E+04	8.75E+04	9.59E+04	Inhale
Cm-246	5.44E+04	5.29E+04	5.13E+04	5.44E+04	5.29E+04	5.13E+04	Inhale
Cm-247	1.78E+05	1.79E+05	1.80E+05	1.78E+05	1.79E+05	1.80E+05	Extern
Cm-248	1.95E+05	1.95E+05	1.95E+05	1.95E+05	1.95E+05	1.95E+05	Inhale

*The dominant pathway for Cm-243 changes to "Inhale" at times greater than 100 years due to the ingrowth of Pu-239.

Table 13. Total Doses (mrem/yr per Ci/m³) for the Post-Drilling Scenario Using ORNL-5785 Concentration Ratios

Nuclide	With Soil Leaching 100 yr	300 yr	500 yr	Without Soil Leaching 100 yr	300 yr	500 yr	Dominant Pathway
H-3	1.91E-06	2.38E-11	2.98E-16	5.11E-06	6.39E-11	7.99E-16	Soil Ing
Be-10	4.24E-01	4.24E-01	4.24E-01	4.24E-01	4.24E-01	4.24E-01	Extern
C-14	5.00E+00	4.88E+00	4.76E+00	5.13E+00	5.01E+00	4.89E+00	Veggie
Cl-36	5.16E+02	5.16E+02	5.16E+02	7.35E+02	7.34E+02	7.34E+02	Veggie
K-40	2.48E+02	2.48E+02	2.48E+02	2.61E+02	2.61E+02	2.61E+02	Extern
Co-60	6.21E-03	2.35E-14	8.89E-26	6.25E-03	2.37E-14	8.95E-26	Extern
Ni-59	1.07E-01	1.07E-01	1.07E-01	1.07E-01	1.07E-01	1.07E-01	Extern
Ni-63	6.32E-02	1.58E-02	3.96E-03	6.33E-02	1.58E-02	3.97E-03	Veggie
Se-79	9.21E-01	9.19E-01	9.17E-01	9.22E-01	9.20E-01	9.18E-01	Veggie
Sr-90	1.89E+01	1.48E-01	1.16E-03	1.90E+01	1.49E-01	1.17E-03	Veggie
Zr-93	1.85E-01	1.85E-01	1.85E-01	1.85E-01	1.85E-01	1.85E-01	Inhale
Nb-93m	4.71E-04	3.54E-08	2.66E-12	4.71E-04	3.54E-08	2.66E-12	Extern
Nb-94	2.12E+03	2.10E+03	2.09E+03	2.12E+03	2.11E+03	2.09E+03	Extern
Mo-93	5.29E-01	5.09E-01	4.89E-01	5.35E-01	5.14E-01	4.95E-01	Veggie
Tc-99	8.61E+00	8.60E+00	8.60E+00	9.55E+00	9.54E+00	9.53E+00	Veggie
Pd-107	3.03E-02	3.03E-02	3.03E-02	3.04E-02	3.04E-02	3.04E-02	Veggie
Cd-113m	5.98E-01	2.41E-05	9.71E-10	6.15E-01	2.48E-05	9.98E-10	Veggie
Sn-121m	6.92E-01	5.56E-02	4.47E-03	6.93E-01	5.57E-02	4.48E-03	Extern
Sn-126	2.99E+03	2.99E+03	2.98E+03	2.99E+03	2.99E+03	2.98E+03	Extern
I-129	6.50E+01	6.50E+01	6.50E+01	6.53E+01	6.52E+01	6.52E+01	Veggie
Cs-135	1.01E+00	1.01E+00	1.01E+00	1.01E+00	1.01E+00	1.01E+00	Veggie
Cs-137	8.32E+01	8.41E-01	8.49E-03	8.32E+01	8.41E-01	8.50E-03	Extern
Ba-133	6.57E-01	1.21E-06	2.24E-12	6.60E-01	1.22E-06	2.25E-12	Extern
Sm-147	2.68E+01	2.68E+01	2.68E+01	2.68E+01	2.68E+01	2.68E+01	Inhale
Sm-151	1.02E-02	2.19E-03	4.69E-04	1.02E-02	2.19E-03	4.69E-04	Inhale
Eu-150	3.32E+02	7.05E+00	1.50E-01	3.32E+02	7.06E+00	1.50E-01	Extern
Eu-152	9.76E+00	3.65E-04	1.37E-08	9.76E+00	3.65E-04	1.37E-08	Extern
Eu-154	6.22E-01	8.95E-08	1.29E-14	6.22E-01	8.96E-08	1.29E-14	Extern
Gd-152	7.28E+01	7.28E+01	7.28E+01	7.28E+01	7.28E+01	7.28E+01	Inhale
Re-187	1.25E-02	1.25E-02	1.25E-02	1.28E-02	1.28E-02	1.28E-02	Veggie
Pb-210	1.92E+01	3.80E-02	7.50E-05	1.92E+01	3.80E-02	7.50E-05	Veggie
Bi-207	2.79E+02	4.40E+00	6.93E-02	2.80E+02	4.41E+00	6.94E-02	Extern
Po-209	2.88E+01	7.40E+00	1.90E+00	2.88E+01	7.41E+00	1.90E+00	Soil Ing
Ra-226	2.89E+03	2.67E+03	2.44E+03	2.89E+03	2.67E+03	2.45E+03	Extern
Ra-228	2.71E-02	9.16E-13	3.10E-23	2.71E-02	9.16E-13	3.10E-23	Extern
Ac-227	1.12E+02	1.92E-01	3.29E-04	1.12E+02	1.92E-01	3.29E-04	Inhale
Th-228	3.63E-13	1.23E-44	4.19E-76	3.63E-13	1.23E-44	4.19E-76	Extern
Th-229	1.06E+03	1.04E+03	1.02E+03	1.06E+03	1.04E+03	1.02E+03	Inhale
Th-230	2.25E+02	4.66E+02	6.86E+02	2.25E+02	4.66E+02	6.86E+02	Extern
Th-232	4.27E+03	4.27E+03	4.27E+03	4.27E+03	4.27E+03	4.27E+03	Extern
Pa-231	3.29E+03	3.39E+03	3.38E+03	3.29E+03	3.39E+03	3.38E+03	Inhale
U-232	1.01E+03	1.47E+02	2.14E+01	1.01E+03	1.47E+02	2.14E+01	Extern
U-233	5.69E+01	7.66E+01	9.59E+01	5.69E+01	7.66E+01	9.60E+01	Inhale
U-234	4.63E+01	4.63E+01	4.62E+01	4.63E+01	4.63E+01	4.63E+01	Inhale
U-235	1.64E+02	1.78E+02	1.92E+02	1.64E+02	1.78E+02	1.92E+02	Extern
U-236	4.31E+01	4.31E+01	4.31E+01	4.31E+01	4.31E+01	4.31E+01	Inhale
U-238	7.59E+01	7.59E+01	7.59E+01	7.60E+01	7.60E+01	7.60E+01	Inhale
Np-237	7.72E+02	7.72E+02	7.71E+02	7.79E+02	7.79E+02	7.79E+02	Extern
Pu-238	9.83E+01	2.03E+01	4.19E+00	9.83E+01	2.03E+01	4.19E+00	Inhale
Pu-239	2.42E+02	2.41E+02	2.40E+02	2.42E+02	2.41E+02	2.40E+02	Inhale
Pu-240	2.41E+02	2.36E+02	2.31E+02	2.41E+02	2.36E+02	2.31E+02	Inhale
Pu-241	7.76E+00	5.66E+00	4.11E+00	7.77E+00	5.66E+00	4.11E+00	Inhale
Pu-242	2.30E+02	2.30E+02	2.30E+02	2.30E+02	2.30E+02	2.30E+02	Inhale
Pu-244	7.63E+02	7.68E+02	7.73E+02	7.63E+02	7.68E+02	7.73E+02	Extern
Am-241	2.26E+02	1.64E+02	1.19E+02	2.26E+02	1.64E+02	1.19E+02	Inhale
Am-242m	2.50E+02	1.38E+02	6.33E+01	2.50E+02	1.38E+02	6.33E+01	Inhale
Am-243	4.61E+02	4.53E+02	4.46E+02	4.61E+02	4.54E+02	4.47E+02	Extern
Cm-243	2.61E+01	4.88E-01	2.89E-01	2.61E+01	4.89E-01	2.89E-01	Extern*
Cm-244	3.41E+00	6.52E-01	6.37E-01	3.41E+00	6.52E-01	6.38E-01	Inhale
Cm-245	3.50E+02	4.08E+02	4.47E+02	3.50E+02	4.08E+02	4.48E+02	Inhale
Cm-246	2.52E+02	2.45E+02	2.38E+02	2.52E+02	2.45E+02	2.38E+02	Inhale
Cm-247	8.29E+02	8.34E+02	8.39E+02	8.30E+02	8.35E+02	8.41E+02	Extern
Cm-248	9.04E+02	9.03E+02	9.03E+02	9.05E+02	9.05E+02	9.04E+02	Inhale

*The dominant pathway for Cm-243 changes to "Inhale" at times greater than 100 years due to the ingrowth of Pu-239.

Table 14. Total Doses (mrem/yr per Ci/m³) for the Post-Excavation Scenario Using ORNL-5785 Concentration Ratios

Nuclide	With Soil Leaching 100 yr	With Soil Leaching 300 yr	With Soil Leaching 500 yr	Without Soil Leaching 100 yr	Without Soil Leaching 300 yr	Without Soil Leaching 500 yr	Dominant Pathway
H-3	4.09E-04	5.11E-09	6.39E-14	1.09E-03	1.37E-08	1.71E-13	Soil Ing
Be-10	9.09E+01	9.09E+01	9.08E+01	9.09E+01	9.09E+01	9.09E+01	Extern
C-14	1.07E+03	1.05E+03	1.02E+03	1.10E+03	1.07E+03	1.05E+03	Veggie
Cl-36	1.11E+05	1.11E+05	1.10E+05	1.57E+05	1.57E+05	1.57E+05	Veggie
K-40	5.31E+04	5.31E+04	5.31E+04	5.60E+04	5.60E+04	5.60E+04	Extern
Co-60	1.33E+00	5.03E-12	1.90E-23	1.34E+00	5.07E-12	1.92E-23	Extern
Ni-59	2.29E+01	2.29E+01	2.28E+01	2.30E+01	2.29E+01	2.29E+01	Extern
Ni-63	1.35E+01	3.39E+00	8.49E-01	1.36E+01	3.40E+00	8.50E-01	Veggie
Se-79	1.97E+02	1.97E+02	1.97E+02	1.98E+02	1.97E+02	1.97E+02	Veggie
Sr-90	4.05E+03	3.18E+01	2.49E-01	4.07E+03	3.19E+01	2.51E-01	Veggie
Zr-93	3.96E+01	3.97E+01	3.97E+01	3.96E+01	3.97E+01	3.97E+01	Inhale
Nb-93m	1.01E-01	7.58E-06	5.70E-10	1.01E-01	7.59E-06	5.71E-10	Extern
Nb-94	4.54E+05	4.51E+05	4.48E+05	4.54E+05	4.51E+05	4.48E+05	Extern
Mo-93	1.13E+02	1.09E+02	1.05E+02	1.15E+02	1.10E+02	1.06E+02	Veggie
Tc-99	1.84E+03	1.84E+03	1.84E+03	2.05E+03	2.04E+03	2.04E+03	Veggie
Pd-107	6.50E+00	6.50E+00	6.49E+00	6.52E+00	6.52E+00	6.52E+00	Veggie
Cd-113m	1.28E+02	5.16E-03	2.08E-07	1.32E+02	5.31E-03	2.14E-07	Veggie
Sn-121m	1.48E+02	1.19E+01	9.59E-01	1.48E+02	1.19E+01	9.60E-01	Extern
Sn-126	6.41E+05	6.40E+05	6.39E+05	6.41E+05	6.40E+05	6.40E+05	Extern
I-129	1.39E+04	1.39E+04	1.39E+04	1.40E+04	1.40E+04	1.40E+04	Veggie
Cs-135	2.16E+02	2.16E+02	2.16E+02	2.16E+02	2.16E+02	2.16E+02	Veggie
Cs-137	1.78E+04	1.80E+02	1.82E+00	1.78E+04	1.80E+02	1.82E+00	Extern
Ba-133	1.41E+02	2.60E-04	4.79E-10	1.42E+02	2.61E-04	4.82E-10	Extern
Sm-147	5.74E+03	5.74E+03	5.74E+03	5.74E+03	5.74E+03	5.74E+03	Inhale
Sm-151	2.19E+00	4.69E-01	1.00E-01	2.19E+00	4.69E-01	1.01E-01	Inhale
Eu-150	7.11E+04	1.51E+03	3.21E+01	7.11E+04	1.51E+03	3.21E+01	Extern
Eu-152	2.09E+03	7.83E-02	2.93E-06	2.09E+03	7.83E-02	2.93E-06	Extern
Eu-154	1.33E+02	1.92E-05	2.76E-12	1.33E+02	1.92E-05	2.76E-12	Extern
Gd-152	1.56E+04	1.56E+04	1.56E+04	1.56E+04	1.56E+04	1.56E+04	Inhale
Re-187	2.68E+00	2.68E+00	2.68E+00	2.75E+00	2.75E+00	2.75E+00	Veggie
Pb-210	4.12E+03	8.14E+00	1.61E-02	4.12E+03	8.14E+00	1.61E-02	Veggie
Bi-207	5.98E+04	9.43E+02	1.49E+01	5.99E+04	9.44E+02	1.49E+01	Extern
Po-209	6.18E+03	1.59E+03	4.08E+02	6.18E+03	1.59E+03	4.08E+02	Soil Ing
Ra-226	6.19E+05	5.71E+05	5.24E+05	6.19E+05	5.72E+05	5.24E+05	Extern
Ra-228	5.80E+00	1.96E-10	6.64E-21	5.80E+00	1.96E-10	6.64E-21	Extern
Ac-227	2.39E+04	4.10E+01	7.05E-02	2.39E+04	4.11E+01	7.05E-02	Inhale
Th-228	7.77E-11	2.64E-42	8.97E-74	7.77E-11	2.64E-42	8.97E-74	Extern
Th-229	2.27E+05	2.22E+05	2.18E+05	2.27E+05	2.22E+05	2.18E+05	Inhale
Th-230	4.83E+04	9.98E+04	1.47E+05	4.83E+04	9.99E+04	1.47E+05	Extern
Th-232	9.15E+05	9.15E+05	9.15E+05	9.15E+05	9.15E+05	9.15E+05	Extern
Pa-231	7.06E+05	7.26E+05	7.23E+05	7.06E+05	7.26E+05	7.23E+05	Inhale
U-232	2.15E+05	3.14E+04	4.58E+03	2.15E+05	3.14E+04	4.58E+03	Extern
U-233	1.22E+04	1.64E+04	2.06E+04	1.22E+04	1.64E+04	2.06E+04	Inhale
U-234	9.92E+03	9.92E+03	9.91E+03	9.93E+03	9.92E+03	9.92E+03	Inhale
U-235	3.50E+04	3.81E+04	4.12E+04	3.51E+04	3.81E+04	4.12E+04	Extern
U-236	9.24E+03	9.24E+03	9.24E+03	9.24E+03	9.24E+03	9.24E+03	Inhale
U-238	1.63E+04	1.63E+04	1.63E+04	1.63E+04	1.63E+04	1.63E+04	Inhale
Np-237	1.65E+05	1.65E+05	1.65E+05	1.67E+05	1.67E+05	1.67E+05	Extern
Pu-238	2.11E+04	4.34E+03	8.98E+02	2.11E+04	4.34E+03	8.98E+02	Inhale
Pu-239	5.19E+04	5.17E+04	5.14E+04	5.20E+04	5.17E+04	5.14E+04	Inhale
Pu-240	5.15E+04	5.05E+04	4.94E+04	5.15E+04	5.05E+04	4.94E+04	Inhale
Pu-241	1.66E+03	1.21E+03	8.80E+02	1.66E+03	1.21E+03	8.81E+02	Inhale
Pu-242	4.93E+04	4.93E+04	4.92E+04	4.93E+04	4.93E+04	4.93E+04	Inhale
Pu-244	1.63E+05	1.64E+05	1.66E+05	1.63E+05	1.65E+05	1.66E+05	Extern
Am-241	4.85E+04	3.52E+04	2.55E+04	4.85E+04	3.52E+04	2.56E+04	Inhale
Am-242m	5.36E+04	2.96E+04	1.36E+04	5.37E+04	2.96E+04	1.36E+04	Inhale
Am-243	9.87E+04	9.72E+04	9.57E+04	9.88E+04	9.72E+04	9.57E+04	Extern
Cm-243	5.59E+03	1.05E+02	6.19E+01	5.60E+03	1.05E+02	6.19E+01	Extern*
Cm-244	7.30E+02	1.40E+02	1.37E+02	7.31E+02	1.40E+02	1.37E+02	Inhale
Cm-245	7.50E+04	8.74E+04	9.59E+04	7.51E+04	8.75E+04	9.60E+04	Inhale
Cm-246	5.40E+04	5.25E+04	5.09E+04	5.41E+04	5.25E+04	5.10E+04	Inhale
Cm-247	1.78E+05	1.79E+05	1.80E+05	1.78E+05	1.79E+05	1.80E+05	Extern
Cm-248	1.94E+05	1.94E+05	1.93E+05	1.94E+05	1.94E+05	1.94E+05	Inhale

*The dominant pathway for Cm-243 changes to "Inhale" at times greater than 100 years due to the ingrowth of Pu-239.

Table 15. Total Doses (mrem/yr per pCi/L) for the Irrigation Scenario

Nuclide	NUREG Factors Leaching	NUREG Factors No Leach	ORNL-5785 Factors Leaching	ORNL-5785 Factors No Leach	Dominant Pathway
H-3	5.20E-05	5.20E-05	5.20E-05	5.20E-05	Water
Be-10	3.46E-03	3.46E-03	3.46E-03	3.46E-03	Water
C-14	3.35E-03	3.35E-03	3.35E-03	3.35E-03	Water
Cl-36	3.49E-02	3.74E-02	2.94E-02	3.74E-02	Beef
K-40	3.08E-02	3.08E-02	3.07E-02	3.08E-02	Water
Co-60	5.37E-02	5.38E-02	5.37E-02	5.38E-02	Extern
Ni-59	1.96E-04	1.96E-04	1.96E-04	1.96E-04	Water
Ni-63	5.29E-04	5.29E-04	5.28E-04	5.28E-04	Water
Se-79	1.07E-02	1.07E-02	1.07E-02	1.07E-02	Water
Sr-90	1.22E-01	1.23E-01	1.22E-01	1.22E-01	Water
Zr-93	1.53E-03	1.53E-03	1.53E-03	1.53E-03	Water
Nb-93m	3.93E-03	3.93E-03	3.93E-03	3.93E-03	Beef
Nb-94	5.03E-02	5.04E-02	5.04E-02	5.04E-02	Beef
Mo-93	1.33E-03	1.33E-03	1.33E-03	1.33E-03	Water
Tc-99	2.63E-03	3.14E-03	2.05E-03	2.08E-03	Water*
Pd-107	1.73E-04	1.73E-04	1.73E-04	1.73E-04	Water
Cd-113m	1.28E-01	1.28E-01	1.28E-01	1.28E-01	Water
Sn-121m	5.46E-03	5.46E-03	5.46E-03	5.46E-03	Beef
Sn-126	6.78E-02	6.78E-02	6.78E-02	6.78E-02	Beef
I-129	3.65E-01	3.65E-01	3.66E-01	3.66E-01	Water
Cs-135	1.08E-02	1.08E-02	1.07E-02	1.07E-02	Water
Cs-137	8.06E-02	8.06E-02	8.05E-02	8.05E-02	Water
Ba-133	5.45E-03	5.47E-03	5.45E-03	5.47E-03	Extern
Sm-147	1.66E-01	1.66E-01	1.66E-01	1.66E-01	Water
Sm-151	3.13E-04	3.13E-04	3.13E-04	3.13E-04	Water
Eu-150	1.91E-02	1.91E-02	1.91E-02	1.91E-02	Extern
Eu-152	1.49E-02	1.49E-02	1.49E-02	1.49E-02	Extern
Eu-154	1.80E-02	1.80E-02	1.80E-02	1.80E-02	Extern
Gd-152	1.33E-01	1.33E-01	1.33E-01	1.33E-01	Water
Re-187	8.82E-06	8.82E-06	8.82E-06	8.82E-06	Water
Pb-210	5.49E+00	5.49E+00	5.49E+00	5.49E+00	Water
Bi-207	1.71E-02	1.71E-02	1.71E-02	1.71E-02	Extern
Po-209	1.64E+00	1.64E+00	1.64E+00	1.64E+00	Water
Ra-226	9.19E-01	9.19E-01	9.18E-01	9.18E-01	Water
Ra-228	9.95E-01	9.95E-01	9.95E-01	9.95E-01	Water
Ac-227	1.17E+01	1.17E+01	1.17E+01	1.17E+01	Water
Th-228	6.14E-01	6.14E-01	6.14E-01	6.14E-01	Water
Th-229	3.13E+00	3.13E+00	3.13E+00	3.13E+00	Water
Th-230	4.24E-01	4.24E-01	4.24E-01	4.24E-01	Water
Th-232	2.24E+00	2.24E+00	2.24E+00	2.24E+00	Water
Pa-231	8.80E+00	8.80E+00	8.80E+00	8.80E+00	Water

*The Dominant Pathway for Tc-99 with the NUREG concentration ratios and no leaching is "Milk".

Table 15 Continued, Total Doses (mrem/yr per pCi/L) for the Irrigation Scenario

	NUREG Factors		ORNL-5785 Factors		Dominant
Nuclide	Leaching	No Leach	Leaching	No Leach	Pathway
U-232	1.08E+00	1.08E+00	1.08E+00	1.08E+00	Water
U-233	2.23E-01	2.23E-01	2.23E-01	2.23E-01	Water
U-234	2.15E-01	2.15E-01	2.15E-01	2.15E-01	Water
U-235	2.07E-01	2.07E-01	2.07E-01	2.07E-01	Water
U-236	2.06E-01	2.06E-01	2.06E-01	2.06E-01	Water
U-238	2.01E-01	2.01E-01	2.01E-01	2.01E-01	Water
Np-237	3.13E+00	3.13E+00	3.13E+00	3.13E+00	Water
Pu-238	3.04E+00	3.04E+00	3.04E+00	3.04E+00	Water
Pu-239	3.44E+00	3.44E+00	3.44E+00	3.44E+00	Water
Pu-240	3.44E+00	3.44E+00	3.44E+00	3.44E+00	Water
Pu-241	6.88E-02	6.88E-02	6.88E-02	6.88E-02	Water
Pu-242	3.28E+00	3.28E+00	3.28E+00	3.28E+00	Water
Pu-244	3.20E+00	3.20E+00	3.20E+00	3.20E+00	Water
Am-241	3.60E+00	3.60E+00	3.60E+00	3.60E+00	Water
Am-242m	3.43E+00	3.43E+00	3.43E+00	3.43E+00	Water
Am-243	3.60E+00	3.60E+00	3.60E+00	3.60E+00	Water
Cm-243	2.32E+00	2.32E+00	2.32E+00	2.32E+00	Water
Cm-244	1.84E+00	1.84E+00	1.84E+00	1.84E+00	Water
Cm-245	3.60E+00	3.60E+00	3.60E+00	3.60E+00	Water
Cm-246	3.60E+00	3.60E+00	3.60E+00	3.60E+00	Water
Cm-247	3.29E+00	3.29E+00	3.29E+00	3.29E+00	Water
Cm-248	1.28E+01	1.28E+01	1.28E+01	1.28E+01	Water

Table 16. Total Doses (person-rem/yr per pCi/L) for the Columbia River Population Scenario

Nuclide	NUREG Factors Leaching	NUREG Factors No Leach	ORNL-5785 Factors Leaching	ORNL-5785 Factors No Leach	Dominant Pathway
H-3	3.20E-01	3.20E-01	3.20E-01	3.20E-01	Water
Be-10	2.40E+01	2.40E+01	2.40E+01	2.40E+01	Water
C-14	2.53E+01	2.54E+01	2.53E+01	2.54E+01	Beef
Cl-36	3.30E+02	3.61E+02	2.66E+02	3.61E+02	Beef
K-40	2.28E+02	2.28E+02	2.27E+02	2.28E+02	Beef
Co-60	3.52E+02	3.53E+02	3.52E+02	3.52E+02	Extern
Ni-59	1.39E+00	1.39E+00	1.39E+00	1.39E+00	Water
Ni-63	3.75E+00	3.75E+00	3.75E+00	3.75E+00	Water
Se-79	7.80E+01	7.80E+01	7.80E+01	7.80E+01	Water
Sr-90	8.74E+02	8.75E+02	8.69E+02	8.69E+02	Water
Zr-93	1.08E+01	1.08E+01	1.08E+01	1.08E+01	Water
Nb-93m	3.04E+01	3.04E+01	3.04E+01	3.04E+01	Beef
Nb-94	3.57E+02	3.57E+02	3.57E+02	3.57E+02	Beef
Mo-93	9.51E+00	9.52E+00	9.52E+00	9.52E+00	Water
Tc-99	2.01E+01	2.46E+01	1.57E+01	1.61E+01	Milk
Pd-107	1.26E+00	1.26E+00	1.26E+00	1.26E+00	Water
Cd-113m	8.98E+02	8.98E+02	8.97E+02	8.98E+02	Water
Sn-121m	4.13E+01	4.13E+01	4.13E+01	4.13E+01	Beef
Sn-126	4.71E+02	4.71E+02	4.71E+02	4.71E+02	Beef
I-129	2.66E+03	2.67E+03	2.67E+03	2.67E+03	Water
Cs-135	7.95E+01	7.95E+01	7.93E+01	7.93E+01	Beef
Cs-137	5.85E+02	5.85E+02	5.84E+02	5.84E+02	Beef
Ba-133	3.28E+01	3.29E+01	3.28E+01	3.29E+01	Extern
Sm-147	1.16E+03	1.16E+03	1.16E+03	1.16E+03	Water
Sm-151	2.20E+00	2.20E+00	2.20E+00	2.20E+00	Water
Eu-150	1.09E+02	1.09E+02	1.09E+02	1.09E+02	Extern
Eu-152	8.74E+01	8.74E+01	8.74E+01	8.74E+01	Extern
Eu-154	1.09E+02	1.09E+02	1.09E+02	1.09E+02	Extern
Gd-152	9.30E+02	9.30E+02	9.30E+02	9.30E+02	Water
Re-187	6.40E-02	6.41E-02	6.40E-02	6.41E-02	Water
Pb-210	3.80E+04	3.80E+04	3.81E+04	3.81E+04	Water
Bi-207	9.58E+01	9.60E+01	9.59E+01	9.60E+01	Extern
Po-209	1.14E+04	1.14E+04	1.14E+04	1.14E+04	Water
Ra-226	6.35E+03	6.35E+03	6.34E+03	6.34E+03	Water
Ra-228	6.88E+03	6.88E+03	6.88E+03	6.88E+03	Water
Ac-227	8.08E+04	8.08E+04	8.08E+04	8.08E+04	Water
Th-228	4.23E+03	4.23E+03	4.23E+03	4.23E+03	Water
Th-229	2.16E+04	2.16E+04	2.16E+04	2.16E+04	Water
Th-230	2.93E+03	2.93E+03	2.93E+03	2.93E+03	Water
Th-232	1.55E+04	1.55E+04	1.55E+04	1.55E+04	Water
Pa-231	6.08E+04	6.08E+04	6.08E+04	6.08E+04	Water

Table 16 Continued, Total Doses (person-rem/yr per pCi/L) for the Columbia River Population Scenario

Nuclide	NUREG Factors Leaching	NUREG Factors No Leach	ORNL-5785 Factors Leaching	ORNL-5785 Factors No Leach	Dominant Pathway
U-232	7.46E+03	7.46E+03	7.46E+03	7.46E+03	Water
U-233	1.55E+03	1.55E+03	1.55E+03	1.55E+03	Water
U-234	1.49E+03	1.49E+03	1.49E+03	1.49E+03	Water
U-235	1.44E+03	1.44E+03	1.44E+03	1.44E+03	Water
U-236	1.43E+03	1.43E+03	1.43E+03	1.43E+03	Water
U-238	1.39E+03	1.39E+03	1.39E+03	1.39E+03	Water
Np-237	2.16E+04	2.16E+04	2.16E+04	2.16E+04	Water
Pu-238	2.10E+04	2.10E+04	2.10E+04	2.10E+04	Water
Pu-239	2.38E+04	2.38E+04	2.38E+04	2.38E+04	Water
Pu-240	2.38E+04	2.38E+04	2.38E+04	2.38E+04	Water
Pu-241	4.75E+02	4.75E+02	4.75E+02	4.75E+02	Water
Pu-242	2.27E+04	2.27E+04	2.27E+04	2.27E+04	Water
Pu-244	2.21E+04	2.21E+04	2.21E+04	2.21E+04	Water
Am-241	2.49E+04	2.49E+04	2.49E+04	2.49E+04	Water
Am-242m	2.37E+04	2.37E+04	2.37E+04	2.37E+04	Water
Am-243	2.49E+04	2.49E+04	2.49E+04	2.49E+04	Water
Cm-243	1.61E+04	1.61E+04	1.61E+04	1.61E+04	Water
Cm-244	1.27E+04	1.27E+04	1.27E+04	1.27E+04	Water
Cm-245	2.49E+04	2.49E+04	2.49E+04	2.49E+04	Water
Cm-246	2.49E+04	2.49E+04	2.49E+04	2.49E+04	Water
Cm-247	2.27E+04	2.27E+04	2.27E+04	2.27E+04	Water
Cm-248	8.85E+04	8.85E+04	8.85E+04	8.85E+04	Water

Table 17. Ratio of Total Doses: NUREG/CR-5512 / ORNL-5785

Nuclide	With Soil Leaching 100 yr	With Soil Leaching 300 yr	With Soil Leaching 500 yr	With Soil Leaching AllPath	Without Soil Leaching 100 yr	Without Soil Leaching 300 yr	Without Soil Leaching 500 yr	Without Soil Leaching AllPath
Cl-36	1.30	1.30	1.30	1.24				
Ni-63	1.24	1.24	1.24		1.24	1.24	1.24	
Sr-90	1.57	1.57	1.57		1.58	1.58	1.58	
Tc-99	1.41	1.41	1.41	1.28	2.09	2.09	2.09	1.52
I-129	0.72	0.72	0.72		0.84	0.84	0.84	
Cs-135	2.82	2.82	2.82		2.82	2.82	2.82	
Pb-210	0.65	0.65	0.65		0.65	0.65	0.65	
Po-209	1.65	1.65	1.65		1.65	1.65	1.65	
U-233					1.11			
U-234	1.11	1.11	1.11		1.13	1.13	1.13	
U-236	1.12	1.12	1.12		1.14	1.14	1.14	
Np-237	0.84	0.84	0.84		0.88	0.88	0.88	

Notes: Differences less than 10 percent are not shown.
Post-Drilling and Post-Excavation have the same ratios.

Table 18. Ratio of Total Doses: Non-Leaching / Leaching

Nuclide	NUREG/CR-5512 Transfer Factors 100 yr	NUREG/CR-5512 Transfer Factors 300 yr	NUREG/CR-5512 Transfer Factors 500 yr	NUREG/CR-5512 Transfer Factors AllPath	ORNL-5785 Transfer Factors 100 yr	ORNL-5785 Transfer Factors 300 yr	ORNL-5785 Transfer Factors 500 yr	ORNL-5785 Transfer Factors AllPath
H-3	2.68	2.68	2.68		2.68	2.68	2.68	
Cl-36					1.42	1.42	1.42	1.35
Tc-99	1.65	1.65	1.65	1.22				
I-129	1.17	1.17	1.17					

Notes: Differences less than 10 percent are not shown.
Post-Drilling and Post-Excavation have the same ratios.

5.0 MEDIA CONCENTRATION LIMITS

The scenario dose factors shown in Section 4.0 can be used to compute waste and ground water concentration limits from the appropriate dose equivalent limits. The equation used to compute these concentration limits is shown below.

$$\text{Concentration Limit} = \frac{\text{Performance Objective}}{\text{Scenario Dose Factor}}$$

The performance objectives shown below determine the waste concentration limits. The value for the annual population dose is from DOE-RL 5620.2A to indicate when ALARA requirements are satisfied.

Intruder - 100 mrem/year
Irrigator - 25 mrem/year
Water Only - 4 mrem/year
Population - 500 person-rem/year

For the intruder scenarios, the waste concentration limits shown in Tables 19 through 22, apply to the time of disposal. As time of intrusion increases, the allowable waste concentration also increases due to the decay of the source.

Note that alpha emitting nuclides are limited to 100 nCi per gram of waste matrix. If the waste has a density of 1.5 g/cc then the TRU limit corresponds to 100 nCi/g = 0.15 Ci/m^3 . This TRU limit would be applied to all the alpha emitting nuclides, and the actual limit on waste containing these nuclides would then be the lower of the table value and 100 nCi/g.

For the irrigation scenarios, the water concentration limits shown in Tables 23 and 24 and 25 apply to the time at which the water is used for irrigation or drinking. Models used to estimate ground water concentrations at some future time must include the radioactive decay and, in some cases, ingrowth of progeny.

The Drinking Water concentration limits in Table 24 are lower than the All Pathways Irrigator limits shown in Table 23 for every nuclide except Cl-36, Nb-93m, and Nb-94. The drinking water scenario is more restrictive than the all pathways irrigator, except for a few nuclides which are highly concentrated in food. The dose from drinking water is the major portion of the all pathways irrigator dose, so lowering the limit from 25 mrem/yr to 4 mrem/yr reduces the water concentration limit by a factor of 0.16, the ratio of the dose limits. The last four columns of Table 24 show the ratios of the drinking water limit to the irrigation scenario limit for each nuclide.

With regard to the water concentration limits based on population dose, the All Pathways limits in Table 23 are about three orders of magnitude larger than the Columbia River Population limits in Table 25, suggesting that the population limits would be more restrictive. However, the groundwater concentration decreases by more than 5 orders of magnitude upon entering the Columbia River (Kincaid 1993). Thus the All Pathways Irrigator will always be closer to his limit than the Columbia River Population.

Table 19. Waste Concentration Limits (Ci/m^3 to give 100 mrem/yr) Based on the Post-Drilling Scenario Using NUREG/CR-5512 Transfer Factors

Nuclide	With Soil Leaching 100 yr	With Soil Leaching 300 yr	With Soil Leaching 500 yr	Without Soil Leaching 100 yr	Without Soil Leaching 300 yr	Without Soil Leaching 500 yr
H-3	5.25E+07	4.19E+12	3.35E+17	1.96E+07	1.56E+12	1.25E+17
Be-10	2.36E+02	2.36E+02	2.36E+02	2.36E+02	2.36E+02	2.36E+02
C-14	2.00E+01	2.05E+01	2.10E+01	1.95E+01	2.00E+01	2.05E+01
Cl-36	1.49E-01	1.49E-01	1.49E-01	1.36E-01	1.36E-01	1.36E-01
K-40	3.89E-01	3.89E-01	3.89E-01	3.83E-01	3.83E-01	3.83E-01
Co-60	1.61E+04	4.25E+15	1.12E+27	1.60E+04	4.22E+15	1.12E+27
Ni-59	8.44E+02	8.46E+02	8.48E+02	8.44E+02	8.45E+02	8.47E+02
Ni-63	1.27E+03	5.09E+03	2.03E+04	1.27E+03	5.09E+03	2.03E+04
Se-79	1.09E+02	1.09E+02	1.09E+02	1.08E+02	1.09E+02	1.09E+02
Sr-90	3.37E+00	4.30E+02	5.47E+04	3.33E+00	4.25E+02	5.41E+04
Zr-93	5.41E+02	5.40E+02	5.40E+02	5.41E+02	5.40E+02	5.40E+02
Nb-93m	2.13E+05	2.83E+09	3.76E+13	2.12E+05	2.82E+09	3.75E+13
Nb-94	4.73E-02	4.76E-02	4.79E-02	4.72E-02	4.75E-02	4.78E-02
Mo-93	1.91E+02	1.98E+02	2.06E+02	1.87E+02	1.94E+02	2.02E+02
Tc-99	8.25E+00	8.26E+00	8.26E+00	5.01E+00	5.02E+00	5.02E+00
Pd-107	3.30E+03	3.30E+03	3.30E+03	3.29E+03	3.29E+03	3.29E+03
Cd-113m	1.63E+02	4.06E+06	1.01E+11	1.63E+02	4.04E+06	1.00E+11
Sn-121m	1.45E+02	1.80E+03	2.24E+04	1.44E+02	1.79E+03	2.23E+04
Sn-126	3.35E-02	3.35E-02	3.36E-02	3.34E-02	3.35E-02	3.35E-02
I-129	2.15E+00	2.15E+00	2.15E+00	1.83E+00	1.83E+00	1.83E+00
Cs-135	3.52E+01	3.52E+01	3.52E+01	3.52E+01	3.52E+01	3.52E+01
Cs-137	1.18E+00	1.17E+02	1.16E+04	1.18E+00	1.17E+02	1.16E+04
Ba-133	1.52E+02	8.26E+07	4.47E+13	1.51E+02	8.20E+07	4.45E+13
Sm-147	3.74E+00	3.74E+00	3.74E+00	3.73E+00	3.73E+00	3.73E+00
Sm-151	9.80E+03	4.57E+04	2.13E+05	9.79E+03	4.57E+04	2.13E+05
Eu-150	3.02E-01	1.42E+01	6.68E+02	3.01E-01	1.42E+01	6.67E+02
Eu-152	1.03E+01	2.74E+05	7.32E+09	1.02E+01	2.74E+05	7.31E+09
Eu-154	1.61E+02	1.12E+09	7.76E+15	1.61E+02	1.12E+09	7.75E+15
Gd-152	1.38E+00	1.38E+00	1.38E+00	1.37E+00	1.37E+00	1.37E+00
Re-187	7.90E+03	7.90E+03	7.90E+03	7.80E+03	7.80E+03	7.80E+03
Pb-210	7.99E+00	4.05E+03	2.05E+06	7.98E+00	4.04E+03	2.05E+06
Bi-207	3.59E-01	2.28E+01	1.44E+03	3.58E-01	2.27E+01	1.44E+03
Po-209	2.10E+00	8.18E+00	3.18E+01	2.10E+00	8.17E+00	3.18E+01
Ra-226	3.61E-02	3.92E-02	4.27E-02	3.61E-02	3.91E-02	4.27E-02
Ra-228	3.67E+03	1.08E+14	3.21E+24	3.67E+03	1.08E+14	3.21E+24
Ac-227	8.97E-01	5.22E+02	3.04E+05	8.96E-01	5.22E+02	3.04E+05
Th-228	2.76E+14	8.11E+45	2.39E+77	2.76E+14	8.11E+45	2.39E+77
Th-229	9.41E-02	9.59E-02	9.77E-02	9.41E-02	9.59E-02	9.77E-02
Th-230	4.49E-01	2.21E-01	1.51E-01	4.49E-01	2.21E-01	1.51E-01
Th-232	2.32E-02	2.32E-02	2.32E-02	2.32E-02	2.32E-02	2.32E-02
Pa-231	3.04E-02	2.95E-02	2.96E-02	3.04E-02	2.95E-02	2.96E-02
U-232	9.87E-02	6.77E-01	4.64E+00	9.83E-02	6.74E-01	4.62E+00
U-233	1.60E+00	1.22E+00	9.84E-01	1.58E+00	1.20E+00	9.74E-01
U-234	1.94E+00	1.94E+00	1.94E+00	1.90E+00	1.90E+00	1.91E+00
U-235	6.02E-01	5.54E-01	5.13E-01	5.90E-01	5.44E-01	5.04E-01
U-236	2.08E+00	2.08E+00	2.08E+00	2.04E+00	2.04E+00	2.04E+00
U-238	1.25E+00	1.25E+00	1.25E+00	1.22E+00	1.22E+00	1.22E+00
Np-237	1.54E-01	1.54E-01	1.54E-01	1.46E-01	1.46E-01	1.46E-01
Pu-238	1.01E+00	4.91E+00	2.37E+01	1.01E+00	4.91E+00	2.37E+01
Pu-239	4.10E-01	4.13E-01	4.15E-01	4.10E-01	4.13E-01	4.15E-01
Pu-240	4.14E-01	4.22E-01	4.31E-01	4.13E-01	4.22E-01	4.31E-01
Pu-241	1.31E+01	1.79E+01	2.47E+01	1.31E+01	1.79E+01	2.47E+01
Pu-242	4.33E-01	4.33E-01	4.33E-01	4.32E-01	4.32E-01	4.33E-01
Pu-244	1.31E-01	1.30E-01	1.29E-01	1.31E-01	1.30E-01	1.29E-01
Am-241	4.49E-01	6.18E-01	8.52E-01	4.49E-01	6.18E-01	8.52E-01
Am-242m	4.03E-01	7.27E-01	1.59E+00	4.03E-01	7.27E-01	1.58E+00
Am-243	2.19E-01	2.22E-01	2.26E-01	2.19E-01	2.22E-01	2.26E-01
Cm-243	3.81E+00	2.04E+02	3.44E+02	3.81E+00	2.04E+02	3.44E+02
Cm-244	2.91E+01	1.52E+02	1.56E+02	2.91E+01	1.52E+02	1.56E+02
Cm-245	2.85E-01	2.45E-01	2.24E-01	2.85E-01	2.45E-01	2.24E-01
Cm-246	3.94E-01	4.05E-01	4.17E-01	3.94E-01	4.05E-01	4.17E-01
Cm-247	1.20E-01	1.20E-01	1.19E-01	1.20E-01	1.19E-01	1.19E-01
Cm-248	1.10E-01	1.10E-01	1.10E-01	1.10E-01	1.10E-01	1.10E-01

Table 20. Waste Concentration Limits (Ci/m^3 to give 100 mrem/yr) Based on the Post-Excavation Scenario Using NUREG/CR-5512 Transfer Factors

Nuclide	With Soil Leaching 100 yr	With Soil Leaching 300 yr	With Soil Leaching 500 yr	Without Soil Leaching 100 yr	Without Soil Leaching 300 yr	Without Soil Leaching 500 yr
H-3	2.45E+05	1.96E+10	1.56E+15	9.13E+04	7.30E+09	5.84E+14
Be-10	1.10E+00	1.10E+00	1.10E+00	1.10E+00	1.10E+00	1.10E+00
C-14	9.34E-02	9.57E-02	9.80E-02	9.09E-02	9.32E-02	9.54E-02
Cl-36	6.97E-04	6.97E-04	6.98E-04	6.35E-04	6.35E-04	6.36E-04
K-40	1.82E-03	1.82E-03	1.82E-03	1.79E-03	1.79E-03	1.79E-03
Co-60	7.50E+01	1.98E+13	5.24E+24	7.46E+01	1.97E+13	5.21E+24
Ni-59	3.94E+00	3.95E+00	3.96E+00	3.94E+00	3.95E+00	3.95E+00
Ni-63	5.94E+00	2.37E+01	9.48E+01	5.94E+00	2.37E+01	9.48E+01
Se-79	5.07E-01	5.08E-01	5.09E-01	5.06E-01	5.07E-01	5.08E-01
Sr-90	1.57E-02	2.01E+00	2.55E+02	1.56E-02	1.98E+00	2.52E+02
Zr-93	2.53E+00	2.52E+00	2.52E+00	2.52E+00	2.52E+00	2.52E+00
Nb-93m	9.93E+02	1.32E+07	1.75E+11	9.91E+02	1.32E+07	1.75E+11
Nb-94	2.21E-04	2.22E-04	2.24E-04	2.20E-04	2.22E-04	2.23E-04
Mo-93	8.90E-01	9.26E-01	9.63E-01	8.73E-01	9.07E-01	9.44E-01
Tc-99	3.85E-02	3.85E-02	3.86E-02	2.34E-02	2.34E-02	2.34E-02
Pd-107	1.54E+01	1.54E+01	1.54E+01	1.53E+01	1.53E+01	1.53E+01
Cd-113m	7.63E-01	1.89E+04	4.70E+08	7.59E-01	1.88E+04	4.67E+08
Sn-121m	6.75E-01	8.40E+00	1.04E+02	6.74E-01	8.38E+00	1.04E+02
Sn-126	1.56E-04	1.57E-04	1.57E-04	1.56E-04	1.56E-04	1.56E-04
I-129	1.00E-02	1.00E-02	1.00E-02	8.53E-03	8.53E-03	8.53E-03
Cs-135	1.64E-01	1.64E-01	1.64E-01	1.64E-01	1.64E-01	1.64E-01
Cs-137	5.53E-03	5.47E-01	5.42E+01	5.52E-03	5.46E-01	5.41E+01
Ba-133	7.11E-01	3.85E+05	2.09E+11	7.07E-01	3.83E+05	2.07E+11
Sm-147	1.74E-02	1.74E-02	1.74E-02	1.74E-02	1.74E-02	1.74E-02
Sm-151	4.57E+01	2.13E+02	9.96E+02	4.57E+01	2.13E+02	9.95E+02
Eu-150	1.41E-03	6.62E-02	3.12E+00	1.41E-03	6.61E-02	3.11E+00
Eu-152	4.79E-02	1.28E+03	3.42E+07	4.78E-02	1.28E+03	3.41E+07
Eu-154	7.51E-01	5.22E+06	3.62E+13	7.50E-01	5.21E+06	3.62E+13
Gd-152	6.42E-03	6.42E-03	6.42E-03	6.41E-03	6.41E-03	6.41E-03
Re-187	3.69E+01	3.69E+01	3.69E+01	3.64E+01	3.64E+01	3.64E+01
Pb-210	3.73E-02	1.89E+01	9.57E+03	3.72E-02	1.89E+01	9.56E+03
Bi-207	1.67E-03	1.06E-01	6.74E+00	1.67E-03	1.06E-01	6.72E+00
Po-209	9.81E-03	3.82E-02	1.49E-01	9.79E-03	3.81E-02	1.48E-01
Ra-226	1.68E-04	1.83E-04	1.99E-04	1.68E-04	1.83E-04	1.99E-04
Ra-228	1.71E+01	5.06E+11	1.50E+22	1.71E+01	5.06E+11	1.50E+22
Ac-227	4.19E-03	2.44E+00	1.42E+03	4.18E-03	2.44E+00	1.42E+03
Th-228	1.29E+12	3.79E+43	1.11E+75	1.29E+12	3.79E+43	1.11E+75
Th-229	4.39E-04	4.47E-04	4.56E-04	4.39E-04	4.47E-04	4.56E-04
Th-230	2.09E-03	1.03E-03	7.03E-04	2.09E-03	1.03E-03	7.02E-04
Th-232	1.08E-04	1.08E-04	1.08E-04	1.08E-04	1.08E-04	1.08E-04
Pa-231	1.42E-04	1.38E-04	1.38E-04	1.42E-04	1.38E-04	1.38E-04
U-232	4.60E-04	3.16E-03	2.17E-02	4.59E-04	3.14E-03	2.16E-02
U-233	7.48E-03	5.68E-03	4.59E-03	7.36E-03	5.61E-03	4.55E-03
U-234	9.06E-03	9.07E-03	9.07E-03	8.88E-03	8.89E-03	8.89E-03
U-235	2.81E-03	2.59E-03	2.40E-03	2.75E-03	2.54E-03	2.35E-03
U-236	9.70E-03	9.70E-03	9.70E-03	9.51E-03	9.51E-03	9.51E-03
U-238	5.83E-03	5.83E-03	5.83E-03	5.71E-03	5.71E-03	5.71E-03
Np-237	7.19E-04	7.20E-04	7.20E-04	6.80E-04	6.80E-04	6.80E-04
Pu-238	4.72E-03	2.29E-02	1.11E-01	4.72E-03	2.29E-02	1.11E-01
Pu-239	1.92E-03	1.93E-03	1.94E-03	1.91E-03	1.93E-03	1.94E-03
Pu-240	1.93E-03	1.97E-03	2.01E-03	1.93E-03	1.97E-03	2.01E-03
Pu-241	6.10E-02	8.37E-02	1.15E-01	6.10E-02	8.37E-02	1.15E-01
Pu-242	2.02E-03	2.02E-03	2.02E-03	2.02E-03	2.02E-03	2.02E-03
Pu-244	6.11E-04	6.07E-04	6.03E-04	6.11E-04	6.07E-04	6.03E-04
Am-241	2.09E-03	2.89E-03	3.98E-03	2.09E-03	2.89E-03	3.97E-03
Am-242m	1.88E-03	3.39E-03	7.40E-03	1.88E-03	3.39E-03	7.39E-03
Am-243	1.02E-03	1.04E-03	1.05E-03	1.02E-03	1.04E-03	1.05E-03
Cm-243	1.78E-02	9.51E-01	1.61E+00	1.78E-02	9.51E-01	1.61E+00
Cm-244	1.36E-01	7.12E-01	7.28E-01	1.36E-01	7.11E-01	7.28E-01
Cm-245	1.33E-03	1.14E-03	1.04E-03	1.33E-03	1.14E-03	1.04E-03
Cm-246	1.84E-03	1.89E-03	1.95E-03	1.84E-03	1.89E-03	1.95E-03
Cm-247	5.61E-04	5.58E-04	5.54E-04	5.61E-04	5.58E-04	5.54E-04
Cm-248	5.13E-04	5.13E-04	5.13E-04	5.12E-04	5.13E-04	5.13E-04

Table 21. Waste Concentration Limits (Ci/m^3 to give 100 mrem/yr) Based on the Post-Drilling Scenario Using ORNL-5785 Transfer Factors

	With Soil Leaching			Without Soil Leaching		
Nuclide	100 yr	300 yr	500 yr	100 yr	300 yr	500 yr
H-3	5.25E+07	4.19E+12	3.35E+17	1.96E+07	1.56E+12	1.25E+17
Be-10	2.36E+02	2.36E+02	2.36E+02	2.36E+02	2.36E+02	2.36E+02
C-14	2.00E+01	2.05E+01	2.10E+01	1.95E+01	2.00E+01	2.05E+01
Cl-36	1.94E-01	1.94E-01	1.94E-01	1.36E-01	1.36E-01	1.36E-01
K-40	4.04E-01	4.04E-01	4.04E-01	3.83E-01	3.83E-01	3.83E-01
Co-60	1.61E+04	4.26E+15	1.13E+27	1.60E+04	4.23E+15	1.12E+27
Ni-59	9.35E+02	9.36E+02	9.38E+02	9.33E+02	9.35E+02	9.36E+02
Ni-63	1.58E+03	6.32E+03	2.52E+04	1.58E+03	6.31E+03	2.52E+04
Se-79	1.09E+02	1.09E+02	1.09E+02	1.08E+02	1.09E+02	1.09E+02
Sr-90	5.30E+00	6.75E+02	8.59E+04	5.27E+00	6.71E+02	8.55E+04
Zr-93	5.41E+02	5.40E+02	5.40E+02	5.41E+02	5.40E+02	5.40E+02
Nb-93m	2.13E+05	2.83E+09	3.76E+13	2.12E+05	2.82E+09	3.75E+13
Nb-94	4.72E-02	4.75E-02	4.78E-02	4.72E-02	4.75E-02	4.78E-02
Mo-93	1.89E+02	1.96E+02	2.04E+02	1.87E+02	1.94E+02	2.02E+02
Tc-99	1.16E+01	1.16E+01	1.16E+01	1.05E+01	1.05E+01	1.05E+01
Pd-107	3.30E+03	3.30E+03	3.30E+03	3.29E+03	3.29E+03	3.29E+03
Cd-113m	1.67E+02	4.15E+06	1.03E+11	1.63E+02	4.04E+06	1.00E+11
Sn-121m	1.45E+02	1.80E+03	2.23E+04	1.44E+02	1.79E+03	2.23E+04
Sn-126	3.35E-02	3.35E-02	3.35E-02	3.34E-02	3.35E-02	3.35E-02
I-129	1.54E+00	1.54E+00	1.54E+00	1.53E+00	1.53E+00	1.53E+00
Cs-135	9.92E+01	9.92E+01	9.92E+01	9.92E+01	9.92E+01	9.92E+01
Cs-137	1.20E+00	1.19E+02	1.18E+04	1.20E+00	1.19E+02	1.18E+04
Ba-133	1.52E+02	8.25E+07	4.47E+13	1.51E+02	8.20E+07	4.45E+13
Sm-147	3.73E+00	3.73E+00	3.73E+00	3.73E+00	3.73E+00	3.73E+00
Sm-151	9.79E+03	4.57E+04	2.13E+05	9.79E+03	4.57E+04	2.13E+05
Eu-150	3.02E-01	1.42E+01	6.67E+02	3.01E-01	1.42E+01	6.67E+02
Eu-152	1.02E+01	2.74E+05	7.32E+09	1.02E+01	2.74E+05	7.31E+09
Eu-154	1.61E+02	1.12E+09	7.76E+15	1.61E+02	1.12E+09	7.75E+15
Gd-152	1.37E+00	1.37E+00	1.37E+00	1.37E+00	1.37E+00	1.37E+00
Re-187	7.99E+03	7.99E+03	7.99E+03	7.80E+03	7.80E+03	7.80E+03
Pb-210	5.20E+00	2.63E+03	1.33E+06	5.20E+00	2.63E+03	1.33E+06
Bi-207	3.58E-01	2.27E+01	1.44E+03	3.58E-01	2.27E+01	1.44E+03
Po-209	3.47E+00	1.35E+01	5.26E+01	3.47E+00	1.35E+01	5.25E+01
Ra-226	3.46E-02	3.75E-02	4.09E-02	3.46E-02	3.75E-02	4.09E-02
Ra-228	3.69E+03	1.09E+14	3.23E+24	3.69E+03	1.09E+14	3.23E+24
Ac-227	8.97E-01	5.22E+02	3.04E+05	8.96E-01	5.22E+02	3.04E+05
Th-228	2.76E+14	8.12E+45	2.39E+77	2.76E+14	8.12E+45	2.39E+77
Th-229	9.46E-02	9.64E-02	9.82E-02	9.46E-02	9.64E-02	9.82E-02
Th-230	4.44E-01	2.15E-01	1.46E-01	4.44E-01	2.15E-01	1.46E-01
Th-232	2.34E-02	2.34E-02	2.34E-02	2.34E-02	2.34E-02	2.34E-02
Pa-231	3.04E-02	2.95E-02	2.96E-02	3.04E-02	2.95E-02	2.96E-02
U-232	9.95E-02	6.82E-01	4.68E+00	9.95E-02	6.82E-01	4.68E+00
U-233	1.76E+00	1.31E+00	1.04E+00	1.76E+00	1.30E+00	1.04E+00
U-234	2.16E+00	2.16E+00	2.16E+00	2.16E+00	2.16E+00	2.16E+00
U-235	6.11E-01	5.62E-01	5.20E-01	6.11E-01	5.62E-01	5.20E-01
U-236	2.32E+00	2.32E+00	2.32E+00	2.32E+00	2.32E+00	2.32E+00
U-238	1.32E+00	1.32E+00	1.32E+00	1.32E+00	1.32E+00	1.32E+00
Np-237	1.30E-01	1.30E-01	1.30E-01	1.28E-01	1.28E-01	1.28E-01
Pu-238	1.02E+00	4.93E+00	2.39E+01	1.02E+00	4.93E+00	2.39E+01
Pu-239	4.13E-01	4.15E-01	4.17E-01	4.12E-01	4.15E-01	4.17E-01
Pu-240	4.16E-01	4.25E-01	4.34E-01	4.16E-01	4.25E-01	4.34E-01
Pu-241	1.29E+01	1.77E+01	2.43E+01	1.29E+01	1.77E+01	2.43E+01
Pu-242	4.35E-01	4.35E-01	4.35E-01	4.35E-01	4.35E-01	4.35E-01
Pu-244	1.31E-01	1.30E-01	1.29E-01	1.31E-01	1.30E-01	1.29E-01
Am-241	4.42E-01	6.09E-01	8.39E-01	4.42E-01	6.09E-01	8.38E-01
Am-242m	4.00E-01	7.24E-01	1.58E+00	3.99E-01	7.23E-01	1.58E+00
Am-243	2.17E-01	2.21E-01	2.24E-01	2.17E-01	2.20E-01	2.24E-01
Cm-243	3.83E+00	2.05E+02	3.46E+02	3.83E+00	2.05E+02	3.46E+02
Cm-244	2.94E+01	1.53E+02	1.57E+02	2.93E+01	1.53E+02	1.57E+02
Cm-245	2.86E-01	2.45E-01	2.23E-01	2.85E-01	2.45E-01	2.23E-01
Cm-246	3.97E-01	4.09E-01	4.21E-01	3.96E-01	4.08E-01	4.20E-01
Cm-247	1.21E-01	1.20E-01	1.19E-01	1.20E-01	1.20E-01	1.19E-01
Cm-248	1.11E-01	1.11E-01	1.11E-01	1.10E-01	1.11E-01	1.11E-01

Table 22. Waste Concentration Limits (Ci/m³ to give 100 mrem/yr) Based on the Post-Excavation Scenario Using ORNL-5785 Transfer Factors

Nuclide	With Soil Leaching 100 yr	300 yr	500 yr	Without Soil Leaching 100 yr	300 yr	500 yr
H-3	2.45E+05	1.96E+10	1.56E+15	9.13E+04	7.30E+09	5.84E+14
Be-10	1.10E+00	1.10E+00	1.10E+00	1.10E+00	1.10E+00	1.10E+00
C-14	9.34E-02	9.57E-02	9.80E-02	9.09E-02	9.32E-02	9.54E-02
Cl-36	9.04E-04	9.05E-04	9.05E-04	6.35E-04	6.35E-04	6.36E-04
K-40	1.88E-03	1.88E-03	1.88E-03	1.79E-03	1.79E-03	1.79E-03
Co-60	7.52E+01	1.99E+13	5.25E+24	7.46E+01	1.97E+13	5.21E+24
Ni-59	4.36E+00	4.37E+00	4.38E+00	4.35E+00	4.36E+00	4.37E+00
Ni-63	7.38E+00	2.95E+01	1.18E+02	7.37E+00	2.95E+01	1.18E+02
Se-79	5.07E-01	5.08E-01	5.09E-01	5.06E-01	5.07E-01	5.08E-01
Sr-90	2.47E-02	3.15E+00	4.01E+02	2.46E-02	3.13E+00	3.99E+02
Zr-93	2.53E+00	2.52E+00	2.52E+00	2.52E+00	2.52E+00	2.52E+00
Nb-93m	9.92E+02	1.32E+07	1.75E+11	9.91E+02	1.32E+07	1.75E+11
Nb-94	2.20E-04	2.22E-04	2.23E-04	2.20E-04	2.22E-04	2.23E-04
Mo-93	8.82E-01	9.16E-01	9.53E-01	8.73E-01	9.07E-01	9.44E-01
Tc-99	5.42E-02	5.43E-02	5.43E-02	4.89E-02	4.89E-02	4.89E-02
Pd-107	1.54E+01	1.54E+01	1.54E+01	1.53E+01	1.53E+01	1.53E+01
Cd-113m	7.81E-01	1.94E+04	4.81E+08	7.59E-01	1.88E+04	4.67E+08
Sn-121m	6.74E-01	8.39E+00	1.04E+02	6.74E-01	8.38E+00	1.04E+02
Sn-126	1.56E-04	1.56E-04	1.57E-04	1.56E-04	1.56E-04	1.56E-04
I-129	7.18E-03	7.18E-03	7.18E-03	7.15E-03	7.15E-03	7.15E-03
Cs-135	4.63E-01	4.63E-01	4.63E-01	4.63E-01	4.63E-01	4.63E-01
Cs-137	5.61E-03	5.55E-01	5.49E+01	5.61E-03	5.55E-01	5.49E+01
Ba-133	7.10E-01	3.85E+05	2.09E+11	7.07E-01	3.83E+05	2.07E+11
Sm-147	1.74E-02	1.74E-02	1.74E-02	1.74E-02	1.74E-02	1.74E-02
Sm-151	4.57E+01	2.13E+02	9.95E+02	4.57E+01	2.13E+02	9.95E+02
Eu-150	1.41E-03	6.62E-02	3.11E+00	1.41E-03	6.61E-02	3.11E+00
Eu-152	4.78E-02	1.28E+03	3.42E+07	4.78E-02	1.28E+03	3.41E+07
Eu-154	7.51E-01	5.21E+06	3.62E+13	7.50E-01	5.21E+06	3.62E+13
Gd-152	6.41E-03	6.41E-03	6.41E-03	6.41E-03	6.41E-03	6.41E-03
Re-187	3.73E+01	3.73E+01	3.73E+01	3.64E+01	3.64E+01	3.64E+01
Pb-210	2.43E-02	1.23E+01	6.23E+03	2.42E-02	1.23E+01	6.22E+03
Bi-207	1.67E-03	1.06E-01	6.73E+00	1.67E-03	1.06E-01	6.72E+00
Po-209	1.62E-02	6.30E-02	2.45E-01	1.62E-02	6.30E-02	2.45E-01
Ra-226	1.62E-04	1.75E-04	1.91E-04	1.62E-04	1.75E-04	1.91E-04
Ra-228	1.72E+01	5.09E+11	1.51E+22	1.72E+01	5.09E+11	1.51E+22
Ac-227	4.18E-03	2.44E+00	1.42E+03	4.18E-03	2.44E+00	1.42E+03
Th-228	1.29E+12	3.79E+43	1.11E+75	1.29E+12	3.79E+43	1.11E+75
Th-229	4.41E-04	4.50E-04	4.58E-04	4.41E-04	4.50E-04	4.58E-04
Th-230	2.07E-03	1.00E-03	6.80E-04	2.07E-03	1.00E-03	6.80E-04
Th-232	1.09E-04	1.09E-04	1.09E-04	1.09E-04	1.09E-04	1.09E-04
Pa-231	1.42E-04	1.38E-04	1.38E-04	1.42E-04	1.38E-04	1.38E-04
U-232	4.64E-04	3.18E-03	2.18E-02	4.64E-04	3.18E-03	2.18E-02
U-233	8.20E-03	6.09E-03	4.86E-03	8.20E-03	6.09E-03	4.86E-03
U-234	1.01E-02	1.01E-02	1.01E-02	1.01E-02	1.01E-02	1.01E-02
U-235	2.85E-03	2.62E-03	2.43E-03	2.85E-03	2.62E-03	2.43E-03
U-236	1.08E-02	1.08E-02	1.08E-02	1.08E-02	1.08E-02	1.08E-02
U-238	6.15E-03	6.15E-03	6.15E-03	6.14E-03	6.14E-03	6.14E-03
Np-237	6.05E-04	6.05E-04	6.05E-04	5.99E-04	5.99E-04	5.99E-04
Pu-238	4.75E-03	2.30E-02	1.11E-01	4.75E-03	2.30E-02	1.11E-01
Pu-239	1.93E-03	1.94E-03	1.95E-03	1.92E-03	1.94E-03	1.95E-03
Pu-240	1.94E-03	1.98E-03	2.02E-03	1.94E-03	1.98E-03	2.02E-03
Pu-241	6.01E-02	8.24E-02	1.14E-01	6.01E-02	8.24E-02	1.14E-01
Pu-242	2.03E-03	2.03E-03	2.03E-03	2.03E-03	2.03E-03	2.03E-03
Pu-244	6.12E-04	6.08E-04	6.04E-04	6.12E-04	6.08E-04	6.04E-04
Am-241	2.06E-03	2.84E-03	3.91E-03	2.06E-03	2.84E-03	3.91E-03
Am-242m	1.86E-03	3.38E-03	7.37E-03	1.86E-03	3.38E-03	7.37E-03
Am-243	1.01E-03	1.03E-03	1.05E-03	1.01E-03	1.03E-03	1.04E-03
Cm-243	1.79E-02	9.56E-01	1.61E+00	1.79E-02	9.55E-01	1.61E+00
Cm-244	1.37E-01	7.15E-01	7.32E-01	1.37E-01	7.15E-01	7.32E-01
Cm-245	1.33E-03	1.14E-03	1.04E-03	1.33E-03	1.14E-03	1.04E-03
Cm-246	1.85E-03	1.91E-03	1.96E-03	1.85E-03	1.90E-03	1.96E-03
Cm-247	5.63E-04	5.60E-04	5.56E-04	5.62E-04	5.59E-04	5.55E-04
Cm-248	5.16E-04	5.17E-04	5.17E-04	5.16E-04	5.16E-04	5.16E-04

Table 23. Ground Water Concentration Limits (pCi/L to give 25 mrem/yr) for the Irrigation Scenario

Nuclide	NUREG Factors Leaching	NUREG Factors No Leach	ORNL-5785 Factors Leaching	ORNL-5785 Factors No Leach
H-3	4.81E+05	4.81E+05	4.81E+05	4.81E+05
Be-10	7.23E+03	7.23E+03	7.23E+03	7.23E+03
C-14	7.46E+03	7.46E+03	7.46E+03	7.46E+03
Cl-36	7.16E+02	6.68E+02	8.51E+02	6.68E+02
K-40	8.12E+02	8.11E+02	8.14E+02	8.11E+02
Co-60	4.65E+02	4.64E+02	4.66E+02	4.65E+02
Ni-59	1.27E+05	1.27E+05	1.28E+05	1.28E+05
Ni-63	4.73E+04	4.73E+04	4.74E+04	4.74E+04
Se-79	2.33E+03	2.33E+03	2.33E+03	2.33E+03
Sr-90	2.04E+02	2.04E+02	2.05E+02	2.05E+02
Zr-93	1.63E+04	1.63E+04	1.63E+04	1.63E+04
Nb-93m	6.35E+03	6.35E+03	6.35E+03	6.35E+03
Nb-94	4.97E+02	4.96E+02	4.96E+02	4.96E+02
Mo-93	1.87E+04	1.87E+04	1.87E+04	1.87E+04
Tc-99	9.49E+03	7.97E+03	1.22E+04	1.20E+04
Pd-107	1.45E+05	1.45E+05	1.45E+05	1.45E+05
Cd-113m	1.96E+02	1.96E+02	1.96E+02	1.96E+02
Sn-121m	4.57E+03	4.57E+03	4.57E+03	4.57E+03
Sn-126	3.69E+02	3.69E+02	3.69E+02	3.69E+02
I-129	6.85E+01	6.85E+01	6.83E+01	6.83E+01
Cs-135	2.32E+03	2.32E+03	2.33E+03	2.33E+03
Cs-137	3.10E+02	3.10E+02	3.11E+02	3.11E+02
Ba-133	4.59E+03	4.57E+03	4.59E+03	4.57E+03
Sm-147	1.51E+02	1.51E+02	1.51E+02	1.51E+02
Sm-151	8.00E+04	8.00E+04	8.00E+04	8.00E+04
Eu-150	1.31E+03	1.31E+03	1.31E+03	1.31E+03
Eu-152	1.68E+03	1.68E+03	1.68E+03	1.68E+03
Eu-154	1.39E+03	1.39E+03	1.39E+03	1.39E+03
Gd-152	1.88E+02	1.88E+02	1.88E+02	1.88E+02
Re-187	2.83E+06	2.83E+06	2.84E+06	2.83E+06
Pb-210	4.55E+00	4.55E+00	4.55E+00	4.55E+00
Bi-207	1.46E+03	1.46E+03	1.46E+03	1.46E+03
Po-209	1.53E+01	1.53E+01	1.53E+01	1.53E+01
Ra-226	2.72E+01	2.72E+01	2.72E+01	2.72E+01
Ra-228	2.51E+01	2.51E+01	2.51E+01	2.51E+01
Ac-227	2.14E+00	2.14E+00	2.14E+00	2.14E+00
Th-228	4.07E+01	4.07E+01	4.07E+01	4.07E+01
Th-229	7.99E+00	7.99E+00	7.99E+00	7.99E+00
Th-230	5.89E+01	5.89E+01	5.89E+01	5.89E+01
Th-232	1.11E+01	1.11E+01	1.11E+01	1.11E+01
Pa-231	2.84E+00	2.84E+00	2.84E+00	2.84E+00
U-232	2.33E+01	2.32E+01	2.33E+01	2.33E+01
U-233	1.12E+02	1.12E+02	1.12E+02	1.12E+02
U-234	1.16E+02	1.16E+02	1.17E+02	1.17E+02

Table 23 Continued, Ground Water Concentration Limits (pCi/L to give 25 mrem/yr) for the Irrigation Scenario

Nuclide	NUREG Factors Leaching	NUREG Factors No Leach	ORNL-5785 Factors Leaching	ORNL-5785 Factors No Leach
U-235	1.21E+02	1.21E+02	1.21E+02	1.21E+02
U-236	1.21E+02	1.21E+02	1.21E+02	1.21E+02
U-238	1.25E+02	1.25E+02	1.25E+02	1.25E+02
Np-237	8.00E+00	7.99E+00	7.99E+00	7.99E+00
Pu-238	8.23E+00	8.23E+00	8.23E+00	8.23E+00
Pu-239	7.27E+00	7.27E+00	7.27E+00	7.27E+00
Pu-240	7.27E+00	7.27E+00	7.27E+00	7.27E+00
Pu-241	3.64E+02	3.64E+02	3.64E+02	3.64E+02
Pu-242	7.63E+00	7.63E+00	7.63E+00	7.63E+00
Pu-244	7.81E+00	7.81E+00	7.81E+00	7.81E+00
Am-241	6.95E+00	6.95E+00	6.95E+00	6.95E+00
Am-242m	7.28E+00	7.28E+00	7.28E+00	7.28E+00
Am-243	6.94E+00	6.94E+00	6.94E+00	6.94E+00
Cm-243	1.08E+01	1.08E+01	1.08E+01	1.08E+01
Cm-244	1.36E+01	1.36E+01	1.36E+01	1.36E+01
Cm-245	6.94E+00	6.94E+00	6.94E+00	6.94E+00
Cm-246	6.94E+00	6.94E+00	6.94E+00	6.94E+00
Cm-247	7.61E+00	7.61E+00	7.61E+00	7.61E+00
Cm-248	1.95E+00	1.95E+00	1.95E+00	1.95E+00

Table 24. Drinking Water Concentration Limits (pCi/L to give 4 mrem/yr) and Comparison with the Irrigation Limits

Nuclide	Water Limits pCi/L	Water to Irrigation Limit Ratio NUREG/CR-5512 Leach	None	ORNL-5785 Leach	None
H-3	8.70E+04	0.18	0.18	0.18	0.18
Be-10	1.30E+03	0.18	0.18	0.18	0.18
C-14	2.61E+03	0.35	0.35	0.35	0.35
Cl-36	1.83E+03	2.55	2.73	2.15	2.73
K-40	2.88E+02	0.36	0.36	0.35	0.36
Co-60	2.11E+02	0.45	0.45	0.45	0.45
Ni-59	2.74E+04	0.21	0.21	0.21	0.21
Ni-63	1.01E+04	0.21	0.21	0.21	0.21
Se-79	6.60E+02	0.28	0.28	0.28	0.28
Sr-90	3.91E+01	0.19	0.19	0.19	0.19
Zr-93	3.42E+03	0.21	0.21	0.21	0.21
Nb-93m	1.03E+04	1.63	1.63	1.63	1.63
Nb-94	1.07E+03	2.16	2.16	2.16	2.16
Mo-93	4.21E+03	0.22	0.23	0.22	0.23
Tc-99	4.21E+03	0.44	0.53	0.35	0.35
Pd-107	3.91E+04	0.27	0.27	0.27	0.27
Cd-113m	3.65E+01	0.19	0.19	0.19	0.19
Sn-121m	2.75E+03	0.60	0.60	0.60	0.60
Sn-126	2.99E+02	0.81	0.81	0.81	0.81
I-129	1.96E+01	0.29	0.29	0.29	0.29
Cs-135	7.72E+02	0.33	0.33	0.33	0.33
Cs-137	1.10E+02	0.35	0.35	0.35	0.35
Ba-133	1.71E+03	0.37	0.37	0.37	0.37
Sm-147	3.04E+01	0.20	0.20	0.20	0.20
Sm-151	1.61E+04	0.20	0.20	0.20	0.20
Eu-150	8.84E+02	0.67	0.67	0.67	0.67
Eu-152	9.13E+02	0.54	0.54	0.54	0.54
Eu-154	6.02E+02	0.43	0.43	0.43	0.43
Gd-152	3.65E+01	0.19	0.19	0.19	0.19
Re-187	6.60E+05	0.23	0.23	0.23	0.23
Pb-210	8.14E-01	0.18	0.18	0.18	0.18
Bi-207	1.12E+03	0.77	0.77	0.77	0.77
Po-209	2.74E+00	0.18	0.18	0.18	0.18
Ra-226	4.98E+00	0.18	0.18	0.18	0.18
Ra-228	4.57E+00	0.18	0.18	0.18	0.18
Ac-227	3.76E-01	0.18	0.18	0.18	0.18
Th-228	7.27E+00	0.18	0.18	0.18	0.18
Th-229	1.40E+00	0.18	0.18	0.18	0.18
Th-230	1.03E+01	0.18	0.18	0.18	0.18
Th-232	1.96E+00	0.18	0.18	0.18	0.18
Pa-231	4.98E-01	0.18	0.18	0.18	0.18
U-232	4.21E+00	0.18	0.18	0.18	0.18
U-233	2.03E+01	0.18	0.18	0.18	0.18
U-234	2.11E+01	0.18	0.18	0.18	0.18

Table 24 Continued, Drinking Water Concentration Limits (pCi/L to give 4 mrem/yr) and Comparison with the Irrigation Limits

Nuclide	Water Limits pCi/L	Water to Irrigation Limit Ratio NUREG/CR-5512 Leach	NUREG/CR-5512 None	ORNL-5785 Leach	ORNL-5785 None
U-235	2.19E+01	0.18	0.18	0.18	0.18
U-236	2.19E+01	0.18	0.18	0.18	0.18
U-238	2.25E+01	0.18	0.18	0.18	0.18
Np-237	1.40E+00	0.18	0.18	0.18	0.18
Pu-238	1.44E+00	0.18	0.18	0.18	0.18
Pu-239	1.27E+00	0.18	0.18	0.18	0.18
Pu-240	1.27E+00	0.18	0.18	0.18	0.18
Pu-241	6.37E+01	0.18	0.18	0.18	0.18
Pu-242	1.34E+00	0.18	0.18	0.18	0.18
Pu-244	1.37E+00	0.18	0.18	0.18	0.18
Am-241	1.22E+00	0.18	0.18	0.18	0.18
Am-242m	1.28E+00	0.18	0.18	0.18	0.18
Am-243	1.22E+00	0.18	0.18	0.18	0.18
Cm-243	1.89E+00	0.18	0.18	0.18	0.18
Cm-244	2.38E+00	0.18	0.18	0.18	0.18
Cm-245	1.22E+00	0.18	0.18	0.18	0.18
Cm-246	1.22E+00	0.18	0.18	0.18	0.18
Cm-247	1.34E+00	0.18	0.18	0.18	0.18
Cm-248	3.42E-01	0.18	0.18	0.18	0.18

Table 25. Columbia River Water Concentration Limits (pCi/L to give 500 person-rem/yr)

Nuclide	NUREG Factors Leaching	NUREG Factors No Leach	ORNL-5785 Factors Leaching	ORNL-5785 Factors No Leach
H-3	1.56E+03	1.56E+03	1.56E+03	1.56E+03
Be-10	2.08E+01	2.08E+01	2.08E+01	2.08E+01
C-14	1.97E+01	1.97E+01	1.97E+01	1.97E+01
Cl-36	1.52E+00	1.39E+00	1.88E+00	1.39E+00
K-40	2.19E+00	2.19E+00	2.20E+00	2.19E+00
Co-60	1.42E+00	1.42E+00	1.42E+00	1.42E+00
Ni-59	3.59E+02	3.59E+02	3.60E+02	3.60E+02
Ni-63	1.33E+02	1.33E+02	1.33E+02	1.33E+02
Se-79	6.41E+00	6.41E+00	6.41E+00	6.41E+00
Sr-90	5.72E-01	5.72E-01	5.75E-01	5.75E-01
Zr-93	4.63E+01	4.63E+01	4.63E+01	4.63E+01
Nb-93m	1.64E+01	1.64E+01	1.64E+01	1.64E+01
Nb-94	1.40E+00	1.40E+00	1.40E+00	1.40E+00
Mo-93	5.25E+01	5.25E+01	5.25E+01	5.25E+01
Tc-99	2.49E+01	2.04E+01	3.18E+01	3.10E+01
Pd-107	3.98E+02	3.98E+02	3.98E+02	3.98E+02
Cd-113m	5.57E-01	5.57E-01	5.57E-01	5.57E-01
Sn-121m	1.21E+01	1.21E+01	1.21E+01	1.21E+01
Sn-126	1.06E+00	1.06E+00	1.06E+00	1.06E+00
I-129	1.88E-01	1.88E-01	1.87E-01	1.87E-01
Cs-135	6.29E+00	6.29E+00	6.30E+00	6.30E+00
Cs-137	8.55E-01	8.55E-01	8.57E-01	8.57E-01
Ba-133	1.52E+01	1.52E+01	1.52E+01	1.52E+01
Sm-147	4.30E-01	4.30E-01	4.30E-01	4.30E-01
Sm-151	2.28E+02	2.28E+02	2.28E+02	2.28E+02
Eu-150	4.57E+00	4.57E+00	4.57E+00	4.57E+00
Eu-152	5.72E+00	5.72E+00	5.72E+00	5.72E+00
Eu-154	4.60E+00	4.60E+00	4.60E+00	4.60E+00
Gd-152	5.38E-01	5.38E-01	5.38E-01	5.38E-01
Re-187	7.81E+03	7.80E+03	7.81E+03	7.80E+03
Pb-210	1.31E-02	1.31E-02	1.31E-02	1.31E-02
Bi-207	5.22E+00	5.21E+00	5.21E+00	5.21E+00
Po-209	4.40E-02	4.40E-02	4.40E-02	4.40E-02
Ra-226	7.88E-02	7.88E-02	7.88E-02	7.88E-02
Ra-228	7.26E-02	7.26E-02	7.27E-02	7.27E-02
Ac-227	6.19E-03	6.19E-03	6.19E-03	6.19E-03
Th-228	1.18E-01	1.18E-01	1.18E-01	1.18E-01
Th-229	2.31E-02	2.31E-02	2.31E-02	2.31E-02
Th-230	1.70E-01	1.70E-01	1.70E-01	1.70E-01
Th-232	3.23E-02	3.23E-02	3.23E-02	3.23E-02
Pa-231	8.22E-03	8.22E-03	8.22E-03	8.22E-03
U-232	6.70E-02	6.70E-02	6.70E-02	6.70E-02
U-233	3.23E-01	3.23E-01	3.23E-01	3.23E-01
U-234	3.36E-01	3.36E-01	3.36E-01	3.36E-01

Table 25 Continued, Columbia River Water Concentration Limits (pCi/L to give 500 person-rem/yr)

Nuclide	NUREG Factors Leaching	NUREG Factors No Leach	ORNL-5785 Factors Leaching	ORNL-5785 Factors No Leach
U-235	3.48E-01	3.48E-01	3.48E-01	3.48E-01
U-236	3.49E-01	3.49E-01	3.49E-01	3.49E-01
U-238	3.59E-01	3.59E-01	3.59E-01	3.59E-01
Np-237	2.31E-02	2.31E-02	2.31E-02	2.31E-02
Pu-238	2.38E-02	2.38E-02	2.38E-02	2.38E-02
Pu-239	2.10E-02	2.10E-02	2.10E-02	2.10E-02
Pu-240	2.10E-02	2.10E-02	2.10E-02	2.10E-02
Pu-241	1.05E+00	1.05E+00	1.05E+00	1.05E+00
Pu-242	2.21E-02	2.21E-02	2.21E-02	2.21E-02
Pu-244	2.26E-02	2.26E-02	2.26E-02	2.26E-02
Am-241	2.01E-02	2.01E-02	2.01E-02	2.01E-02
Am-242m	2.11E-02	2.11E-02	2.11E-02	2.11E-02
Am-243	2.01E-02	2.01E-02	2.01E-02	2.01E-02
Cm-243	3.12E-02	3.12E-02	3.12E-02	3.12E-02
Cm-244	3.93E-02	3.93E-02	3.93E-02	3.93E-02
Cm-245	2.01E-02	2.01E-02	2.01E-02	2.01E-02
Cm-246	2.01E-02	2.01E-02	2.01E-02	2.01E-02
Cm-247	2.20E-02	2.20E-02	2.20E-02	2.20E-02
Cm-248	5.65E-03	5.65E-03	5.65E-03	5.65E-03

6.0 AIR TRANSPORT OF BURIAL GROUND EMISSIONS

The atmospheric dispersion of both acute and chronic airborne emissions from the surface of a burial ground to a nearby resident was estimated using the ISC2 programs from the U.S. Environmental Protection Agency. The only nuclides which can diffuse through the soil cover over the waste are H-3, C-14, and Rn-222. Doses are only computed from the ISC2 results for the first two nuclides, since Rn-222 is limited by its surface emanation rate rather than the projected dose downwind.

The inhalation dose is the product shown in the equation below.

$$H_{inh}^{vol} = Q\ (X/Q)\ V_a\ D_{inh}\ (1.0x10^{12}\ pCi/Ci)$$

where,

H_{inh}^{vol} = inhalation dose from the volatile emissions, in mrem

Q = annual curies released into the air from the burial ground

X/Q = normalized integrated exposure, in seconds per cubic meter

D_{inh} = internal dose factor for inhalation, in mrem per picocurie inhaled. Values are shown on Table 9. The values for H-3 and C-14 are 9.5E-08 and 2.1E-06 mrem/pCi respectively.

V = inhalation rate for Reference Man (ICRP 23), 3.33E-04 m³/second for light activity, and 2.67E-04 m³/second averaged over 24 hours.

The ISC2 programs were used two ways, as a check. The first was to treat the air emissions source as a point. The second approach was the more realistic treatment as an extended source. The extended source was assumed to be a square 316 meters by 316 meters, with a total area of 10 hectare, representative of the burial ground. Hanford Site wind data collected at the Hanford Meteorological Station for the years 1983 to 1991 was used. Note that the source was divided into 36 smaller squares to improve accuracy at small distances. All input files used in the calculations are listed in Appendix E.

6.1 Chronic Releases (Annual Average)

Results for the chronic release case (ISCLT) are shown on Table 26 below. The release occurs over the better part of one year. The wind direction ESE had the largest concentrations for most of the distances. The normalized integrated exposure (X/Q) is the final air concentration divided by the total release rate from the source.

Table 26. Air Concentrations and Normalized Integrated Exposures (X/Q) from Chronic Releases (Release rate is 1.0 gram/second)

Distance meters	Air Conc, μg/m³ Point	Air Conc, μg/m³ Area	X/Q, sec/m³ Point	X/Q, sec/m³ Area
221	71.047	62.088	7.10E-05	6.21E-05
241	61.644	53.525	6.16E-05	5.35E-05
271	50.730	44.308	5.07E-05	4.43E-05
321	38.183	33.959	3.82E-05	3.40E-05
371	29.921	26.815	2.99E-05	2.68E-05
421	24.128	21.599	2.41E-05	2.16E-05
471	19.900	17.811	1.99E-05	1.78E-05
521	16.718	15.000	1.67E-05	1.50E-05
671	10.763	9.823	1.08E-05	9.82E-06
871	6.882	6.384	6.88E-06	6.38E-06
1171	4.204	3.971	4.20E-06	3.97E-06
2171	1.549	1.500	1.55E-06	1.50E-06
5171	0.411	0.405	4.11E-07	4.05E-07
10000	0.155	0.154	1.55E-07	1.54E-07

Note: The air transport direction is ESE in each case.

Distance is measured from the center of the square source. The distances from the outer edge of the square are found by subtracting 171 meters from the table distance. The 171 meters is the distance from the center of the square to the edge at an angle of 22.5° from perpendicular, corresponding to the ESE transport direction. As the distance from the burial site increases, the average air concentration decreases.

The largest annual average integrated exposure will not exceed 1.0E-04 seconds per cubic meter at the boundary in the ESE direction. Thus, the combination of all the factors to the right of Q in the inhalation dose equation leads to the following scenario dose factors: for tritium, 0.0025 mrem/Ci released; for C-14, 0.056 mrem/Ci released. As an example of how these numbers are used, suppose a burial ground is projected to release 10 curies of C-14 over the course of a year. Then the largest inhalation dose near the burial ground would be 0.56 mrem from C-14.

6.2 Acute Releases (less than 8 hours)

Actions by an intruder might somehow release much of the volatiles in the space of one day. If the burial ground release were of short duration, then the maximum integrated exposure would be larger, since the wind can be assumed to drift slowly in that direction with a high stability. Table 27 below summarizes ISCST results. The assumed averaging time is one hour. Stability class F at a wind speed of 1 meter/second is used in the table. The values in the table provide an upper bound on the possible dispersion factors.

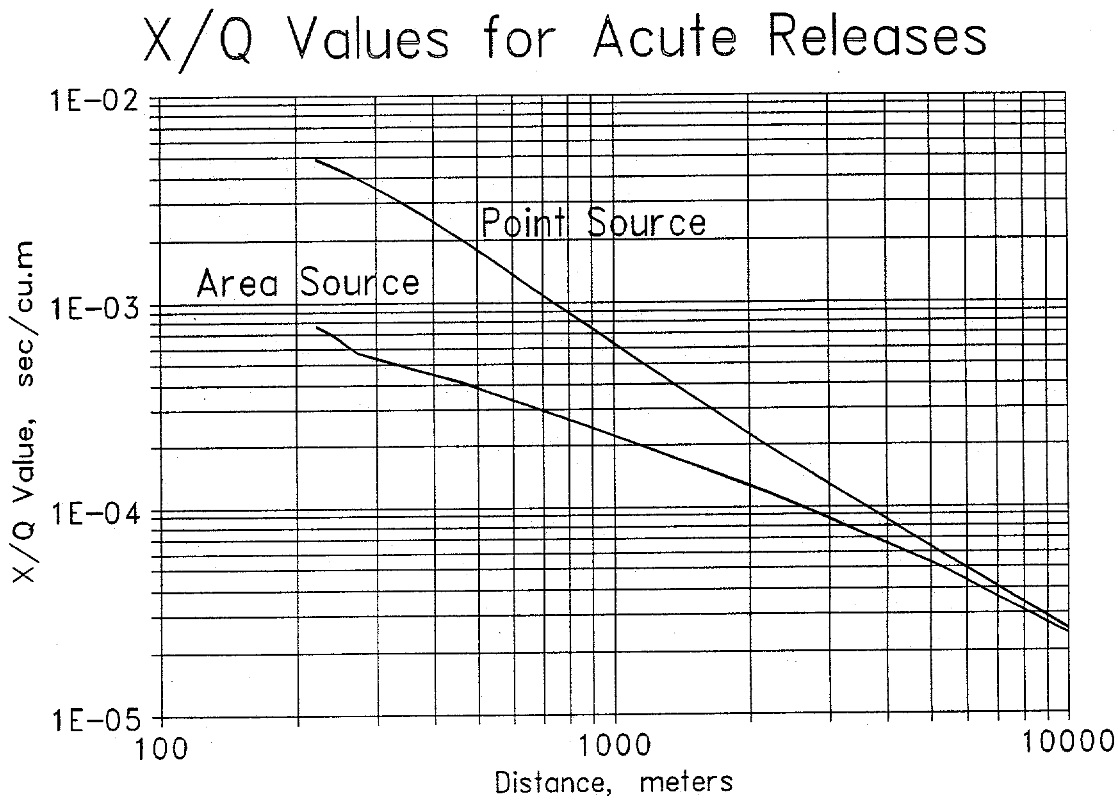
Table 27. Air Concentrations and Normalized Integrated Exposures (X/Q) from Acute Releases (Release rate is 1.0 gram/second)

Distance	Air Conc, μg/m³		X/Q, sec/m³	
meters	Point	Area	Point	Area
221	4872.4	769.8	4.87E-03	7.70E-04
241	4489.2	687.6	4.49E-03	6.88E-04
271	3971.8	571.9	3.97E-03	5.72E-04
321	3262.2	514.8	3.26E-03	5.15E-04
371	2713.9	471.8	2.71E-03	4.72E-04
421	2288.6	435.4	2.29E-03	4.35E-04
471	1954.7	403.3	1.95E-03	4.03E-04
521	1689.0	374.7	1.69E-03	3.75E-04
671	1154.0	307.1	1.15E-03	3.07E-04
871	781.3	248.9	7.81E-04	2.49E-04
1171	502.5	197.6	5.02E-04	1.98E-04
2171	200.6	118.8	2.01E-04	1.19E-04
5171	60.4	51.8	6.04E-05	5.18E-05
10000	25.2	24.0	2.52E-05	2.40E-05

Note: Stability Class F at 1 m/sec has been used.

For the acute case, the difference between the point and area source is more pronounced. The graph illustrates the relationship between the point and area source air concentrations. Judging by the sharp increase at the smallest distance, it appears that the source should be divided even further, to perhaps 49 or 64 or 81 pieces.

The scenario dose factors for the acute release use the larger breathing rate for light activity. Assuming the acute X/Q will not exceed 8.0E-04 seconds per cubic meter, then the scenario dose factors for the acute case turn out to be a factor of 10 larger than the dose factors for the chronic case. The acute scenario dose factors are 0.025 mrem/Ci of tritium released, and 0.56 mrem/Ci of C-14 released.



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8.0 LIST OF VARIABLES

B_f= bioaccumulation factor for a given radionuclide in fish, in liters per kilogram.

B_p= soil to plant concentration ratio, as Ci/kg dry weight of vegetables to Ci/kg of soil.

C_p= radionuclide concentration in plant type p at the time it is consumed, in curies per kilogram. Includes the decay during holdup.

C_p^c= concentration of carbon in animal feed type p, in kg carbon per kilogram (wet) of plant. In this equation p refers to fresh forage, stored hay, stored grain, and drinking water. The carbon concentration of drinking water is small enough that it can be ignored.

C_p^d= radionuclide concentration in plant type p due to direct deposition of irrigation water. The units for C_p^d are Ci/kg.

C_f= radionuclide concentration in fish, in curies per kilogram.

C_p^f= radionuclide concentration in plant type p due to foliar deposition from soil resuspension. The units for C_p^f are Ci/kg.

C_p^r= radionuclide concentration in plant type p due to absorption from the soil through the roots. The units for C_p^f are Ci/kg.

C_q^{C14}= concentration of ^{14}C in animal product q (beef or milk) consumed by the human, in Ci/kg

C_q^c= concentration of carbon in animal product q consumed by the human, in kg carbon per kilogram (wet) of animal product q (beef or milk)

C_q= radionuclide concentration in beef or milk (q), in curies per kilogram

C_l^q= radionuclide concentration in forage (leafy vegetables) the cattle eat, in curies per kilogram. This includes the decay during holdup.

C_g^q= radionuclide concentration in stored feed (grain) the cattle eat, in curies per kilogram. This includes the decay during holdup.

C_w= irrigation water concentration, in curies per liter (Ci/L)

D_{ext}= external dose rate factor for exposure to radiation from contaminated soil, in mrem/hr per Ci/m²

D_{ing}= internal dose factor for ingestion, in mrem per picocurie ingested

D_{inh}= internal dose factor for inhalation, in mrem per picocurie inhaled

D_p= activity deposition rate due to irrigation of soils growing plant type p, in curies per square meter per year (Ci/yr/m²)

E = total evapo-transpiration, in centimeters per year

$E\alpha$= total alpha energy per decay. For Po-209 this is 4.882 Mev per decay, while for Po-210 this is 5.3045 Mev per decay.

F_p^f= interception fraction for plant type p. The fraction of what falls to the earth that lands on the plant. For direct deposition on plants by irrigating water, the value F_p^f = 0.25 is assigned for all plant types.

F_i= fraction of the year that irrigation water is applied. The value 0.5 is used since the irrigation is assumed to take place 6 months per year.

F_q= ratio of the equilibrium concentration of a nuclide in the animal product (beef or milk) to the daily intake by cattle. For beef the units are Ci/kg(beef) per Ci/day, while for milk the units are Ci/L(milk) per Ci/day.

F_f^q= fraction of cattle diet which is forage. In GENII this is 0.75, and forage (grass & hay) is treated as a leafy vegetable for both types of cattle.

F_s^q= fraction of cattle diet which is stored feed. In GENII this is 0.25, and stored feed is treated as a grain.

F_p^w= fraction of water in produce type p, where p refers to meat and milk as well as vegetables. The dry to wet ratio (R_p) can be calculated from this since $R_p = 1 - F_p^w$.

F_p^{w2}= effective water fraction in produce type p, where p refers to meat and milk as well as vegetables. This water fraction includes hydrogen which is not in the form of water. It is used in place of F_p^w.

F_p^H= fraction of hydrogen in the dry produce. A scale factor of 9 converts this to an effective water fraction.

H_{ext}= total external dose, in mrem

H_{ing}= total ingestion dose, in mrem

H_{inh}= total inhalation dose, in mrem

H_{inh}^{vol}= inhalation dose from the volatile emissions, in mrem

I = total irrigation water applied, in centimeters per year (for calculating λ_s)

I_p= inches of irrigation water applied each year to plant type p (for calculating D_p)

K_d= distribution coefficient in surface soil for an element, in milliliters per gram

K_p^f= constant used to relate the standing biomass (dry) and the interception fraction for plant type p, in square meters per kilogram

M_a= average mass concentration in the air during the year, in kilograms per cubic meter. The GENII value (1E-07 kg/m³) is used for the inhalation dose calculation.

P = total precipitation, in centimeters per year

Q_w^h= amount of drinking water consumed annually by the human, in liters per year. The value 730 L/yr is used.

Q_s^h= amount of soil consumed annually by the human, in kilograms per year. The value 0.0365 kg/yr is used.

Q_p^h= amount of produce type p the human consumes each year, in kilograms (or liters for milk) per year. Values are listed in Table 2. Note that p refers to meat and milk as well as vegetables.

Q_v^q= amount of vegetation consumed by beef or milk cattle on an average day, in kilograms per day. In GENII the beef cattle eat 68 kg/day while the milk cows eat 55 kg/day.

Q_w^q= amount of drinking water consumed by cattle, in liters per day. In GENII the beef cattle drink 50 L/day, while the milk cows drink 60 L/day.

R^a= resuspension factor, i.e. the ratio of the air concentration to the surface contamination causing it. In GENII this is used to calculate the rain splash onto plants, and has the value 1E-9 per meter.

R_p= dry to wet ratio for plant type p

T = soil leaching time, in years

T_d= dose commitment period used in the dose factor collections shown in Table 9, namely, 50 years.

T_e= time exposed to external radiation sources in the soil, in hours. The effective exposure time for maximum individuals is 3260 hours, from Section 1.1.

T_h= inhalation time, in hours. This is the number of hours per year that the individual is breathing the average air concentration. The 4680 hour value for maximum individuals was derived using Table 1.

T_p^f= exposure time of the plant type p to the airborne contamination depositing on the foliage, in days (also called growing period)

T_p^h= holdup time, i.e. the time between harvest and consumption of plant type p, in days

T_v= translocation factor, i.e. the fraction of what deposits on the foliage that ends up in the edible portions of the plant.

V_a= daily average breathing rate, in cubic meters per hour. The value for Reference Man (0.95 m^3/hr, in ICRP 23) is used.

V_d= diffusion attachment speed, or ground deposition speed, in meters per second. The GENII value of 0.001 m/s is used for every nuclide.

W = soil concentration at the time of harvest, in Ci/kg (either W^s or W_p^i)

W_o= initial soil concentration in the intruder scenarios, in curies per kilogram of soil

W_p^i= soil concentration due to irrigation, in curies per kilogram of soil

W^s= soil concentration after time T, in curies per kilogram of soil

X/Q = normalized integrated exposure, in seconds per cubic meter

Y_p= yield of crop type p, in kilograms per square meter (wet weight). Also called the standing biomass.

d = thickness of soil from which nuclides migrate, in centimeters. This is assumed to be 15 cm (5.9 inches).

λ_{eff}= effective removal constant, which combines both the biological elimination and the radioactive decay of the nuclide.

λ_r= radioactive decay constant, namely, the natural logarithm of 2 divided by the radioactive decay halflife in years or days

λ_s= annual average soil leaching coefficient, fraction removed from a soil layer of thickness "d" per year

λ_w= weathering removal coefficient, 0.0495105 per day, or 18.0713 per year, which corresponds to a 14 day half time

ρ = bulk density of the soil, in grams per cubic centimeter. In GENII this is 1.5 g/cc.

θ = volumetric water content of soil, milliliters of water per cubic centimeter of soil

θ_w= moisture content of soil assumed for the tritium model, in liters per kilogram of soil. The value 0.1 L/kg (Kennedy and Strenge, 1992) is used for this parameter.

Appendix A.

Intruder Scenario Doses by Pathway

Intruder Scenarios after 100 Years -- NUREG/CR-5512 -- LEACHING
Effective Dose Equivalent, mrem/yr per Ci exhumed

Nuclide	Inhale	Extern	Soil Ing	Root Up	Rain Sp	Case Totals	Maximum Pathway
H-3	9.6E-08	5.8E-11	5.2E-06	0.0E+00	1.3E-07	5.42E-06	Soil Ing
Be-10	2.8E-01	5.7E-01	2.7E-01	8.9E-02	5.1E-03	1.21E+00	Extern
C-14	1.6E-03	9.2E-03	1.3E-01	1.4E+01	2.5E-03	1.43E+01	Veggie
Cl-36	1.4E-02	9.5E-01	1.7E-01	1.9E+03	3.3E-03	1.91E+03	Veggie
K-40	9.4E-03	6.2E+02	1.2E+00	1.1E+02	2.3E-02	7.34E+02	Extern
Co-60	2.2E-07	1.8E-02	3.1E-06	1.6E-05	5.9E-08	1.78E-02	Extern
Ni-59	1.0E-03	1.7E-01	1.3E-02	1.5E-01	2.4E-04	3.38E-01	Extern
Ni-63	1.2E-03	1.2E-04	1.7E-02	2.1E-01	3.3E-04	2.24E-01	Veggie
Se-79	7.1E-03	7.0E-03	5.4E-01	2.1E+00	1.0E-02	2.63E+00	Veggie
Sr-90	1.6E-02	2.2E+00	7.8E-01	8.2E+01	1.5E-02	8.47E+01	Veggie
Zr-93	2.8E-01	6.8E-02	1.4E-01	4.2E-02	2.6E-03	5.28E-01	Inhale
Nb-93m	1.9E-04	5.8E-04	2.9E-04	2.8E-04	5.5E-06	1.34E-03	Extern
Nb-94	2.6E-01	6.0E+03	3.3E-01	3.1E-01	6.2E-03	6.05E+03	Extern
Mo-93	4.3E-02	3.8E-01	1.1E-01	9.6E-01	2.2E-03	1.50E+00	Veggie
Tc-99	2.8E-03	3.0E-02	3.9E-02	3.5E+01	9.6E-04	3.46E+01	Veggie
Pd-107	1.0E-02	5.4E-06	9.0E-03	6.7E-02	1.7E-04	8.66E-02	Veggie
Cd-113m	6.9E-03	3.4E-03	6.0E-02	1.7E+00	1.1E-03	1.75E+00	Veggie
Sn-121m	2.1E-03	1.9E+00	3.6E-02	4.4E-02	6.8E-04	1.97E+00	Extern
Sn-126	6.0E-02	8.5E+03	1.2E+00	1.4E+00	2.2E-02	8.53E+03	Extern
I-129	1.1E-01	5.7E+00	1.4E+01	1.1E+02	3.0E-01	1.33E+02	Veggie
Cs-135	3.6E-03	1.9E-02	4.6E-01	7.6E+00	8.6E-03	8.12E+00	Veggie
Cs-137	2.5E-03	2.4E+02	3.2E-01	5.4E+00	6.1E-03	2.41E+02	Extern
Ba-133	7.2E-06	1.9E+00	2.7E-04	1.1E-03	5.2E-06	1.88E+00	Extern
Sm-147	5.7E+01	0.0E+00	1.2E+01	8.0E+00	2.2E-01	7.64E+01	Inhale
Sm-151	1.1E-02	1.2E-03	1.0E-02	7.0E-03	1.9E-04	2.92E-02	Inhale
Eu-150	3.1E-02	9.5E+02	5.8E-02	4.0E-02	1.1E-03	9.47E+02	Extern
Eu-152	1.0E-03	2.8E+01	2.3E-03	1.6E-03	4.4E-05	2.79E+01	Extern
Eu-154	7.6E-05	1.8E+00	2.2E-04	1.5E-04	4.1E-06	1.77E+00	Extern
Gd-152	1.9E+02	0.0E+00	9.7E+00	6.7E+00	1.8E-01	2.08E+02	Inhale
Re-187	3.8E-05	0.0E+00	5.3E-04	3.6E-02	1.0E-05	3.62E-02	Veggie
Pb-210	7.4E-01	2.2E-01	1.9E+01	1.5E+01	3.6E-01	3.58E+01	Soil Ing
Bi-207	1.4E-03	8.0E+02	3.9E-02	4.4E-02	7.4E-04	7.97E+02	Extern
Po-209	4.1E+00	5.9E+00	6.5E+01	5.9E+01	1.2E+00	1.36E+02	Soil Ing
Ra-226	2.2E+01	7.0E+03	4.7E+02	4.2E+02	8.9E+00	7.92E+03	Extern
Ra-228	2.1E-03	7.4E-02	8.3E-04	6.7E-04	1.6E-05	7.78E-02	Extern
Ac-227	2.2E+02	5.7E+01	3.9E+01	3.5E+00	7.3E-01	3.19E+02	Inhale
Th-228	3.9E-14	9.9E-13	7.6E-15	7.4E-16	1.5E-16	1.04E-12	Extern
Th-229	1.6E+03	1.2E+03	2.5E+02	2.3E+01	4.7E+00	3.04E+03	Inhale
Th-230	2.6E+02	3.1E+02	5.0E+01	1.8E+01	9.4E-01	6.37E+02	Extern
Th-232	1.5E+03	1.0E+04	3.1E+02	1.3E+02	5.8E+00	1.23E+04	Extern
Pa-231	6.2E+03	1.5E+03	1.6E+03	1.3E+02	3.0E+01	9.40E+03	Inhale
U-232	3.0E+02	2.5E+03	5.0E+01	5.6E+01	9.5E-01	2.90E+03	Extern
U-233	1.2E+02	1.2E+01	2.0E+01	3.0E+01	3.7E-01	1.78E+02	Inhale
U-234	1.0E+02	2.4E-01	1.7E+01	2.9E+01	3.1E-01	1.47E+02	Inhale
U-235	1.0E+02	3.2E+02	1.9E+01	2.8E+01	3.6E-01	4.75E+02	Extern
U-236	9.4E+01	1.3E-01	1.6E+01	2.8E+01	3.0E-01	1.37E+02	Inhale
U-238	9.4E+01	9.3E+01	1.5E+01	2.7E+01	2.9E-01	2.29E+02	Inhale
Np-237	3.7E+02	8.7E+02	2.4E+02	3.7E+02	4.6E+00	1.85E+03	Extern
Pu-238	1.7E+02	3.7E-02	1.1E+02	2.9E+00	2.1E+00	2.82E+02	Inhale
Pu-239	4.1E+02	1.5E-01	2.8E+02	7.1E+00	5.2E+00	6.96E+02	Inhale
Pu-240	4.0E+02	9.4E-02	2.8E+02	7.1E+00	5.2E+00	6.91E+02	Inhale
Pu-241	1.2E+01	5.4E-01	8.5E+00	4.9E-01	1.6E-01	2.18E+01	Inhale
Pu-242	3.8E+02	6.8E-02	2.7E+02	6.8E+00	5.0E+00	6.61E+02	Inhale
Pu-244	3.9E+02	1.5E+03	2.6E+02	6.7E+00	4.9E+00	2.18E+03	Extern
Am-241	3.5E+02	1.6E+01	2.5E+02	1.4E+01	4.7E+00	6.37E+02	Inhale
Am-242m	4.0E+02	3.0E+01	2.6E+02	1.2E+01	4.9E+00	7.09E+02	Inhale
Am-243	4.1E+02	5.8E+02	2.9E+02	1.7E+01	5.4E+00	1.30E+03	Extern
Cm-243	2.5E+01	3.3E+01	1.7E+01	4.5E-01	3.1E-01	7.49E+01	Extern
Cm-244	5.7E+00	1.7E-03	3.9E+00	1.1E-01	7.4E-02	9.81E+00	Inhale
Cm-245	4.8E+02	1.7E+02	3.3E+02	1.0E+01	6.2E+00	1.00E+03	Inhale
Cm-246	4.2E+02	5.4E-02	2.9E+02	7.8E+00	5.4E+00	7.26E+02	Inhale
Cm-247	3.9E+02	1.7E+03	2.7E+02	7.2E+00	5.0E+00	2.38E+03	Extern
Cm-248	1.5E+03	5.0E-02	1.0E+03	2.8E+01	1.9E+01	2.60E+03	Inhale

Note: The above values must be multiplied by the volume of waste exhumed.

Intruder Scenarios after 100 Years -- ORNL-5785 -- LEACHING
Effective Dose Equivalent, mrem/yr per Ci exhumed

Nuclide	Inhale	Extern	Soil Ing	Root Up	Rain Sp	Case Totals	Maximum Pathway
H-3	9.6E-08	5.8E-11	5.2E-06	0.0E+00	1.3E-07	5.42E-06	Soil Ing
Be-10	2.8E-01	5.7E-01	2.7E-01	8.9E-02	5.1E-03	1.21E+00	Extern
C-14	1.6E-03	9.2E-03	1.3E-01	1.4E+01	2.5E-03	1.43E+01	Veggie
Cl-36	9.0E-03	6.3E-01	1.1E-01	1.5E+03	2.6E-03	1.47E+03	Veggie
K-40	9.0E-03	6.0E+02	1.2E+00	1.1E+02	2.2E-02	7.08E+02	Extern
Co-60	2.2E-07	1.8E-02	3.1E-06	3.9E-06	5.9E-08	1.77E-02	Extern
Ni-59	1.0E-03	1.7E-01	1.3E-02	1.2E-01	2.4E-04	3.06E-01	Extern
Ni-63	1.2E-03	1.2E-04	1.7E-02	1.6E-01	3.3E-04	1.81E-01	Veggie
Se-79	7.1E-03	7.0E-03	5.4E-01	2.1E+00	1.0E-02	2.63E+00	Veggie
Sr-90	1.6E-02	2.2E+00	7.9E-01	5.1E+01	1.5E-02	5.39E+01	Veggie
Zr-93	2.8E-01	6.8E-02	1.4E-01	4.2E-02	2.6E-03	5.28E-01	Inhale
Nb-93m	1.9E-04	5.8E-04	2.9E-04	2.8E-04	5.5E-06	1.34E-03	Extern
Nb-94	2.6E-01	6.1E+03	3.3E-01	3.1E-01	6.2E-03	6.05E+03	Extern
Mo-93	4.3E-02	3.9E-01	1.1E-01	9.7E-01	2.2E-03	1.51E+00	Veggie
Tc-99	5.0E-03	5.5E-02	7.0E-02	2.4E+01	1.4E-03	2.46E+01	Veggie
Pd-107	1.0E-02	5.4E-06	9.0E-03	6.7E-02	1.7E-04	8.66E-02	Veggie
Cd-113m	6.6E-03	3.3E-03	5.7E-02	1.6E+00	1.1E-03	1.71E+00	Veggie
Sn-121m	2.1E-03	1.9E+00	3.6E-02	4.4E-02	6.8E-04	1.98E+00	Extern
Sn-126	6.0E-02	8.5E+03	1.2E+00	1.4E+00	2.2E-02	8.54E+03	Extern
I-129	1.4E-01	7.2E+00	1.8E+01	1.6E+02	3.4E-01	1.86E+02	Veggie
Cs-135	3.6E-03	1.9E-02	4.6E-01	2.4E+00	8.6E-03	2.88E+00	Veggie
Cs-137	2.5E-03	2.4E+02	3.2E-01	1.7E+00	6.1E-03	2.38E+02	Extern
Ba-133	7.2E-06	1.9E+00	2.7E-04	1.1E-03	5.2E-06	1.88E+00	Extern
Sm-147	5.7E+01	0.0E+00	1.2E+01	8.0E+00	2.2E-01	7.65E+01	Inhale
Sm-151	1.1E-02	1.2E-03	1.0E-02	7.0E-03	1.9E-04	2.92E-02	Inhale
Eu-150	3.1E-02	9.5E+02	5.8E-02	4.0E-02	1.1E-03	9.48E+02	Extern
Eu-152	1.0E-03	2.8E+01	2.3E-03	1.6E-03	4.4E-05	2.79E+01	Extern
Eu-154	7.6E-05	1.8E+00	2.2E-04	1.5E-04	4.1E-06	1.78E+00	Extern
Gd-152	1.9E+02	0.0E+00	9.7E+00	6.7E+00	1.8E-01	2.08E+02	Inhale
Re-187	3.7E-05	0.0E+00	5.2E-04	3.5E-02	9.9E-06	3.58E-02	Veggie
Pb-210	7.4E-01	2.2E-01	1.9E+01	3.5E+01	3.6E-01	5.50E+01	Veggie
Bi-207	1.4E-03	8.0E+02	3.9E-02	4.4E-02	7.4E-04	7.98E+02	Extern
Po-209	4.1E+00	5.9E+00	6.6E+01	5.6E+00	1.2E+00	8.23E+01	Soil Ing
Ra-226	2.2E+01	7.0E+03	4.7E+02	7.5E+02	8.9E+00	8.25E+03	Extern
Ra-228	2.1E-03	7.4E-02	8.3E-04	1.8E-04	1.6E-05	7.73E-02	Extern
Ac-227	2.2E+02	5.7E+01	3.9E+01	3.5E+00	7.3E-01	3.19E+02	Inhale
Th-228	3.9E-14	9.9E-13	7.6E-15	1.8E-16	1.5E-16	1.04E-12	Extern
Th-229	1.6E+03	1.2E+03	2.5E+02	5.5E+00	4.7E+00	3.02E+03	Inhale
Th-230	2.6E+02	3.1E+02	5.0E+01	2.5E+01	9.4E-01	6.44E+02	Extern
Th-232	1.5E+03	1.0E+04	3.1E+02	3.5E+01	5.8E+00	1.22E+04	Extern
Pa-231	6.2E+03	1.5E+03	1.6E+03	1.3E+02	3.0E+01	9.41E+03	Inhale
U-232	3.0E+02	2.5E+03	5.1E+01	2.2E+01	9.6E-01	2.87E+03	Extern
U-233	1.2E+02	1.2E+01	2.0E+01	1.2E+01	3.7E-01	1.63E+02	Inhale
U-234	1.0E+02	2.5E-01	1.7E+01	1.1E+01	3.2E-01	1.32E+02	Inhale
U-235	1.1E+02	3.3E+02	1.9E+01	1.1E+01	3.6E-01	4.67E+02	Extern
U-236	9.6E+01	1.3E-01	1.6E+01	1.1E+01	3.0E-01	1.23E+02	Inhale
U-238	9.6E+01	9.5E+01	1.6E+01	1.1E+01	3.0E-01	2.17E+02	Inhale
Np-237	3.9E+02	9.2E+02	2.5E+02	6.4E+02	4.7E+00	2.20E+03	Extern
Pu-238	1.7E+02	3.7E-02	1.1E+02	1.3E+00	2.1E+00	2.81E+02	Inhale
Pu-239	4.1E+02	1.5E-01	2.8E+02	3.2E+00	5.2E+00	6.93E+02	Inhale
Pu-240	4.0E+02	9.4E-02	2.8E+02	3.2E+00	5.2E+00	6.87E+02	Inhale
Pu-241	1.2E+01	5.4E-01	8.5E+00	8.3E-01	1.6E-01	2.22E+01	Inhale
Pu-242	3.8E+02	6.8E-02	2.7E+02	3.1E+00	5.0E+00	6.57E+02	Inhale
Pu-244	3.9E+02	1.5E+03	2.6E+02	3.0E+00	4.9E+00	2.18E+03	Extern
Am-241	3.5E+02	1.6E+01	2.5E+02	2.4E+01	4.7E+00	6.47E+02	Inhale
Am-242m	4.0E+02	3.0E+01	2.6E+02	1.8E+01	4.9E+00	7.15E+02	Inhale
Am-243	4.1E+02	5.8E+02	2.9E+02	2.8E+01	5.4E+00	1.32E+03	Extern
Cm-243	2.5E+01	3.3E+01	1.7E+01	2.0E-01	3.1E-01	7.45E+01	Extern
Cm-244	5.7E+00	1.7E-03	3.9E+00	4.6E-02	7.4E-02	9.73E+00	Inhale
Cm-245	4.8E+02	1.7E+02	3.3E+02	6.9E+00	6.2E+00	1.00E+03	Inhale
Cm-246	4.2E+02	5.4E-02	2.9E+02	3.4E+00	5.4E+00	7.20E+02	Inhale
Cm-247	3.9E+02	1.7E+03	2.7E+02	3.1E+00	5.0E+00	2.37E+03	Extern
Cm-248	1.5E+03	5.0E-02	1.0E+03	1.2E+01	1.9E+01	2.58E+03	Inhale

Note: The above values must be multiplied by the volume of waste exhumed.

Intruder Scenarios after 300 Years -- NUREG/CR-5512 -- LEACHING
Effective Dose Equivalent, mrem/yr per Ci exhumed

Nuclide	Inhale	Extern	Soil Ing	Root Up	Rain Sp	Case Totals	Maximum Pathway
H-3	1.2E-12	7.3E-16	6.5E-11	0.0E+00	1.6E-12	6.77E-11	Soil Ing
Be-10	2.8E-01	5.7E-01	2.7E-01	8.9E-02	5.1E-03	1.21E+00	Extern
C-14	1.5E-03	9.0E-03	1.3E-01	1.4E+01	2.4E-03	1.39E+01	Veggie
Cl-36	1.4E-02	9.5E-01	1.7E-01	1.9E+03	3.3E-03	1.91E+03	Veggie
K-40	9.4E-03	6.2E+02	1.2E+00	1.1E+02	2.3E-02	7.34E+02	Extern
Co-60	8.2E-19	6.7E-14	1.2E-17	6.0E-17	2.2E-19	6.73E-14	Extern
Ni-59	1.0E-03	1.7E-01	1.3E-02	1.5E-01	2.4E-04	3.38E-01	Extern
Ni-63	3.0E-04	3.1E-05	4.4E-03	5.1E-02	8.2E-05	5.62E-02	Veggie
Se-79	7.1E-03	7.0E-03	5.4E-01	2.1E+00	1.0E-02	2.62E+00	Veggie
Sr-90	1.3E-04	1.7E-02	6.1E-03	6.4E-01	1.2E-04	6.65E-01	Veggie
Zr-93	2.8E-01	6.9E-02	1.4E-01	4.2E-02	2.6E-03	5.29E-01	Inhale
Nb-93m	1.4E-08	4.4E-08	2.2E-08	2.1E-08	4.1E-10	1.01E-07	Extern
Nb-94	2.6E-01	6.0E+03	3.3E-01	3.1E-01	6.1E-03	6.01E+03	Extern
Mo-93	4.1E-02	3.7E-01	1.1E-01	9.2E-01	2.1E-03	1.44E+00	Veggie
Tc-99	2.8E-03	3.0E-02	3.9E-02	3.5E+01	9.6E-04	3.46E+01	Veggie
Pd-107	1.0E-02	5.4E-06	9.0E-03	6.7E-02	1.7E-04	8.66E-02	Veggie
Cd-113m	2.8E-07	1.4E-07	2.4E-06	6.8E-05	4.6E-08	7.04E-05	Veggie
Sn-121m	1.7E-04	1.5E-01	2.9E-03	3.5E-03	5.5E-05	1.59E-01	Extern
Sn-126	6.0E-02	8.5E+03	1.2E+00	1.4E+00	2.2E-02	8.52E+03	Extern
I-129	1.1E-01	5.7E+00	1.4E+01	1.1E+02	3.0E-01	1.33E+02	Veggie
Cs-135	3.6E-03	1.9E-02	4.6E-01	7.6E+00	8.6E-03	8.12E+00	Veggie
Cs-137	2.6E-05	2.4E+00	3.3E-03	5.4E-02	6.1E-05	2.44E+00	Extern
Ba-133	1.3E-11	3.5E-06	5.0E-10	2.0E-09	9.6E-12	3.46E-06	Extern
Sm-147	5.7E+01	0.0E+00	1.2E+01	8.0E+00	2.2E-01	7.64E+01	Inhale
Sm-151	2.3E-03	2.5E-04	2.2E-03	1.5E-03	4.1E-05	6.25E-03	Inhale
Eu-150	6.6E-04	2.0E+01	1.2E-03	8.5E-04	2.3E-05	2.01E+01	Extern
Eu-152	3.9E-08	1.0E-03	8.7E-08	6.0E-08	1.6E-09	1.04E-03	Extern
Eu-154	1.1E-11	2.6E-07	3.1E-11	2.2E-11	5.9E-13	2.56E-07	Extern
Gd-152	1.9E+02	0.0E+00	9.7E+00	6.7E+00	1.8E-01	2.08E+02	Inhale
Re-187	3.8E-05	0.0E+00	5.3E-04	3.6E-02	1.0E-05	3.62E-02	Veggie
Pb-210	1.5E-03	4.4E-04	3.8E-02	3.0E-02	7.1E-04	7.06E-02	Soil Ing
Bi-207	2.2E-05	1.3E+01	6.2E-04	6.9E-04	1.2E-05	1.26E+01	Extern
Po-209	1.0E+00	1.5E+00	1.7E+01	1.5E+01	3.2E-01	3.49E+01	Soil Ing
Ra-226	2.1E+01	6.4E+03	4.5E+02	4.0E+02	8.5E+00	7.30E+03	Extern
Ra-228	7.0E-14	2.5E-12	2.8E-14	2.3E-14	5.4E-16	2.63E-12	Extern
Ac-227	3.8E-01	9.8E-02	6.6E-02	6.0E-03	1.3E-03	5.47E-01	Inhale
Th-228	1.3E-45	3.4E-44	2.6E-46	2.5E-47	5.2E-48	3.52E-44	Extern
Th-229	1.6E+03	1.1E+03	2.5E+02	2.2E+01	4.6E+00	2.98E+03	Inhale
Th-230	2.6E+02	8.9E+02	9.1E+01	5.4E+01	1.7E+00	1.29E+03	Extern
Th-232	1.5E+03	1.0E+04	3.1E+02	1.3E+02	5.8E+00	1.23E+04	Extern
Pa-231	6.4E+03	1.5E+03	1.7E+03	1.3E+02	3.1E+01	9.68E+03	Inhale
U-232	4.3E+01	3.6E+02	7.4E+00	8.2E+00	1.4E-01	4.22E+02	Extern
U-233	1.5E+02	3.4E+01	2.4E+01	3.0E+01	4.6E-01	2.35E+02	Inhale
U-234	1.0E+02	2.4E-01	1.7E+01	2.9E+01	3.1E-01	1.47E+02	Inhale
U-235	1.3E+02	3.3E+02	2.6E+01	2.8E+01	4.9E-01	5.16E+02	Extern
U-236	9.4E+01	1.3E-01	1.6E+01	2.8E+01	3.0E-01	1.37E+02	Inhale
U-238	9.4E+01	9.3E+01	1.5E+01	2.7E+01	2.9E-01	2.29E+02	Inhale
Np-237	3.7E+02	8.7E+02	2.4E+02	3.7E+02	4.6E+00	1.85E+03	Extern
Pu-238	3.4E+01	7.7E-03	2.3E+01	6.0E-01	4.3E-01	5.82E+01	Inhale
Pu-239	4.0E+02	1.5E-01	2.8E+02	7.1E+00	5.2E+00	6.92E+02	Inhale
Pu-240	3.9E+02	9.2E-02	2.7E+02	6.9E+00	5.1E+00	6.76E+02	Inhale
Pu-241	8.8E+00	4.0E-01	6.2E+00	3.6E-01	1.2E-01	1.59E+01	Inhale
Pu-242	3.8E+02	6.8E-02	2.7E+02	6.8E+00	5.0E+00	6.60E+02	Inhale
Pu-244	4.0E+02	1.5E+03	2.7E+02	6.9E+00	5.0E+00	2.20E+03	Extern
Am-241	2.6E+02	1.2E+01	1.8E+02	1.0E+01	3.4E+00	4.62E+02	Inhale
Am-242m	2.2E+02	1.2E+01	1.5E+02	6.1E+00	2.8E+00	3.93E+02	Inhale
Am-243	4.1E+02	5.7E+02	2.9E+02	1.6E+01	5.4E+00	1.28E+03	Extern
Cm-243	6.7E-01	2.6E-01	4.6E-01	1.2E-02	8.6E-03	1.40E+00	Inhale
Cm-244	1.1E+00	2.5E-04	7.5E-01	1.9E-02	1.4E-02	1.87E+00	Inhale
Cm-245	5.8E+02	1.7E+02	3.9E+02	1.4E+01	7.4E+00	1.17E+03	Inhale
Cm-246	4.1E+02	5.2E-02	2.8E+02	7.5E+00	5.2E+00	7.05E+02	Inhale
Cm-247	4.0E+02	1.7E+03	2.7E+02	7.3E+00	5.1E+00	2.39E+03	Extern
Cm-248	1.5E+03	5.0E-02	1.0E+03	2.8E+01	1.9E+01	2.60E+03	Inhale

Note: The above values must be multiplied by the volume of waste exhumed.

Intruder Scenarios after 300 Years -- ORNL-5785 -- LEACHING
Effective Dose Equivalent, mrem/yr per Ci exhumed

Nuclide	Inhale	Extern	Soil Ing	Root Up	Rain Sp	Case Totals	Maximum Pathway
H-3	1.2E-12	7.3E-16	6.5E-11	0.0E+00	1.6E-12	6.77E-11	Soil Ing
Be-10	2.8E-01	5.7E-01	2.7E-01	8.9E-02	5.1E-03	1.21E+00	Extern
C-14	1.5E-03	9.0E-03	1.3E-01	1.4E+01	2.4E-03	1.39E+01	Veggie
Cl-36	9.0E-03	6.3E-01	1.1E-01	1.5E+03	2.6E-03	1.47E+03	Veggie
K-40	9.0E-03	6.0E+02	1.2E+00	1.1E+02	2.2E-02	7.08E+02	Extern
Co-60	8.2E-19	6.7E-14	1.2E-17	1.5E-17	2.2E-19	6.71E-14	Extern
Ni-59	1.0E-03	1.7E-01	1.3E-02	1.2E-01	2.4E-04	3.05E-01	Extern
Ni-63	3.0E-04	3.1E-05	4.4E-03	4.0E-02	8.2E-05	4.52E-02	Veggie
Se-79	7.1E-03	7.0E-03	5.4E-01	2.1E+00	1.0E-02	2.63E+00	Veggie
Sr-90	1.3E-04	1.8E-02	6.2E-03	4.0E-01	1.2E-04	4.23E-01	Veggie
Zr-93	2.8E-01	6.9E-02	1.4E-01	4.2E-02	2.6E-03	5.29E-01	Inhale
Nb-93m	1.4E-08	4.4E-08	2.2E-08	2.1E-08	4.2E-10	1.01E-07	Extern
Nb-94	2.6E-01	6.0E+03	3.3E-01	3.1E-01	6.1E-03	6.01E+03	Extern
Mo-93	4.2E-02	3.7E-01	1.1E-01	9.3E-01	2.1E-03	1.45E+00	Veggie
Tc-99	5.0E-03	5.5E-02	7.0E-02	2.4E+01	1.4E-03	2.46E+01	Veggie
Pd-107	1.0E-02	5.4E-06	9.0E-03	6.7E-02	1.7E-04	8.66E-02	Veggie
Cd-113m	2.7E-07	1.3E-07	2.3E-06	6.6E-05	4.5E-08	6.88E-05	Veggie
Sn-121m	1.7E-04	1.5E-01	2.9E-03	3.5E-03	5.5E-05	1.59E-01	Extern
Sn-126	6.0E-02	8.5E+03	1.2E+00	1.4E+00	2.2E-02	8.53E+03	Extern
I-129	1.4E-01	7.2E+00	1.8E+01	1.6E+02	3.4E-01	1.86E+02	Veggie
Cs-135	3.6E-03	1.9E-02	4.6E-01	2.4E+00	8.6E-03	2.88E+00	Veggie
Cs-137	2.6E-05	2.4E+00	3.3E-03	1.7E-02	6.1E-05	2.40E+00	Extern
Ba-133	1.3E-11	3.5E-06	5.0E-10	2.0E-09	9.6E-12	3.46E-06	Extern
Sm-147	5.7E+01	0.0E+00	1.2E+01	8.0E+00	2.2E-01	7.65E+01	Inhale
Sm-151	2.3E-03	2.5E-04	2.2E-03	1.5E-03	4.1E-05	6.25E-03	Inhale
Eu-150	6.6E-04	2.0E+01	1.2E-03	8.5E-04	2.3E-05	2.01E+01	Extern
Eu-152	3.9E-08	1.0E-03	8.7E-08	6.0E-08	1.6E-09	1.04E-03	Extern
Eu-154	1.1E-11	2.6E-07	3.1E-11	2.2E-11	5.9E-13	2.56E-07	Extern
Gd-152	1.9E+02	0.0E+00	9.7E+00	6.7E+00	1.8E-01	2.08E+02	Inhale
Re-187	3.7E-05	0.0E+00	5.2E-04	3.5E-02	9.9E-06	3.58E-02	Veggie
Pb-210	1.5E-03	4.4E-04	3.8E-02	6.8E-02	7.1E-04	1.09E-01	Veggie
Bi-207	2.2E-05	1.3E+01	6.2E-04	6.9E-04	1.2E-05	1.26E+01	Extern
Po-209	1.0E+00	1.5E+00	1.7E+01	1.4E+00	3.2E-01	2.12E+01	Soil Ing
Ra-226	2.1E+01	6.4E+03	4.5E+02	7.2E+02	8.5E+00	7.62E+03	Extern
Ra-228	7.0E-14	2.5E-12	2.8E-14	6.0E-15	5.4E-16	2.62E-12	Extern
Ac-227	3.8E-01	9.8E-02	6.6E-02	6.0E-03	1.3E-03	5.47E-01	Inhale
Th-228	1.3E-45	3.4E-44	2.6E-46	6.0E-48	5.2E-48	3.52E-44	Extern
Th-229	1.6E+03	1.1E+03	2.5E+02	5.4E+00	4.6E+00	2.96E+03	Inhale
Th-230	2.6E+02	8.9E+02	9.1E+01	9.0E+01	1.7E+00	1.33E+03	Extern
Th-232	1.5E+03	1.0E+04	3.1E+02	3.5E+01	5.8E+00	1.22E+04	Extern
Pa-231	6.4E+03	1.5E+03	1.7E+03	1.3E+02	3.1E+01	9.68E+03	Inhale
U-232	4.4E+01	3.6E+02	7.5E+00	3.2E+00	1.4E-01	4.19E+02	Extern
U-233	1.5E+02	3.4E+01	2.5E+01	1.2E+01	4.6E-01	2.19E+02	Inhale
U-234	1.0E+02	2.5E-01	1.7E+01	1.1E+01	3.2E-01	1.32E+02	Inhale
U-235	1.3E+02	3.4E+02	2.6E+01	1.2E+01	4.9E-01	5.08E+02	Extern
U-236	9.6E+01	1.3E-01	1.6E+01	1.1E+01	3.0E-01	1.23E+02	Inhale
U-238	9.6E+01	9.5E+01	1.6E+01	1.1E+01	3.0E-01	2.17E+02	Inhale
Np-237	3.9E+02	9.2E+02	2.5E+02	6.4E+02	4.7E+00	2.20E+03	Extern
Pu-238	3.4E+01	7.7E-03	2.3E+01	2.7E-01	4.3E-01	5.79E+01	Inhale
Pu-239	4.0E+02	1.5E-01	2.8E+02	3.2E+00	5.2E+00	6.89E+02	Inhale
Pu-240	3.9E+02	9.2E-02	2.7E+02	3.1E+00	5.1E+00	6.73E+02	Inhale
Pu-241	8.8E+00	4.0E-01	6.2E+00	6.1E-01	1.2E-01	1.62E+01	Inhale
Pu-242	3.8E+02	6.8E-02	2.7E+02	3.1E+00	5.0E+00	6.57E+02	Inhale
Pu-244	4.0E+02	1.5E+03	2.7E+02	3.1E+00	5.0E+00	2.19E+03	Extern
Am-241	2.6E+02	1.2E+01	1.8E+02	1.8E+01	3.4E+00	4.69E+02	Inhale
Am-242m	2.2E+02	1.2E+01	1.5E+02	7.8E+00	2.8E+00	3.95E+02	Inhale
Am-243	4.1E+02	5.7E+02	2.9E+02	2.8E+01	5.4E+00	1.30E+03	Extern
Cm-243	6.7E-01	2.6E-01	4.6E-01	5.5E-03	8.6E-03	1.40E+00	Inhale
Cm-244	1.1E+00	2.6E-04	7.5E-01	8.6E-03	1.4E-02	1.86E+00	Inhale
Cm-245	5.8E+02	1.7E+02	3.9E+02	1.4E+01	7.4E+00	1.17E+03	Inhale
Cm-246	4.1E+02	5.2E-02	2.8E+02	3.3E+00	5.2E+00	6.99E+02	Inhale
Cm-247	4.0E+02	1.7E+03	2.7E+02	3.2E+00	5.1E+00	2.38E+03	Extern
Cm-248	1.5E+03	5.0E-02	1.0E+03	1.2E+01	1.9E+01	2.58E+03	Inhale

Note: The above values must be multiplied by the volume of waste exhumed.

Intruder Scenarios after 500 Years -- NUREG/CR-5512 -- LEACHING

Effective Dose Equivalent, mrem/yr per Ci exhumed

Nuclide	Inhale	Extern	Soil Ing	Root Up	Rain Sp	Case Totals	Maximum Pathway
H-3	1.5E-17	9.1E-21	8.2E-16	0.0E+00	2.0E-17	8.47E-16	Soil Ing
Be-10	2.8E-01	5.7E-01	2.7E-01	8.9E-02	5.1E-03	1.21E+00	Extern
C-14	1.5E-03	8.8E-03	1.2E-01	1.3E+01	2.3E-03	1.36E+01	Veggie
Cl-36	1.4E-02	9.5E-01	1.7E-01	1.9E+03	3.3E-03	1.91E+03	Veggie
K-40	9.4E-03	6.2E+02	1.2E+00	1.1E+02	2.3E-02	7.34E+02	Extern
Co-60	3.1E-30	2.5E-25	4.4E-29	2.3E-28	8.5E-31	2.55E-25	Extern
Ni-59	1.0E-03	1.7E-01	1.3E-02	1.5E-01	2.4E-04	3.37E-01	Extern
Ni-63	7.5E-05	7.8E-06	1.1E-03	1.3E-02	2.1E-05	1.41E-02	Veggie
Se-79	7.0E-03	6.9E-03	5.3E-01	2.1E+00	1.0E-02	2.62E+00	Veggie
Sr-90	1.0E-06	1.4E-04	4.8E-05	5.0E-03	9.1E-07	5.22E-03	Veggie
Zr-93	2.8E-01	6.9E-02	1.4E-01	4.2E-02	2.6E-03	5.29E-01	Inhale
Nb-93m	1.1E-12	3.3E-12	1.6E-12	1.6E-12	3.1E-14	7.60E-12	Extern
Nb-94	2.6E-01	6.0E+03	3.2E-01	3.1E-01	6.1E-03	5.96E+03	Extern
Mo-93	4.0E-02	3.5E-01	1.1E-01	8.8E-01	2.0E-03	1.38E+00	Veggie
Tc-99	2.8E-03	3.0E-02	3.9E-02	3.5E+01	9.6E-04	3.46E+01	Veggie
Pd-107	1.0E-02	5.4E-06	9.0E-03	6.7E-02	1.7E-04	8.66E-02	Veggie
Cd-113m	1.1E-11	5.6E-12	9.7E-11	2.7E-09	1.8E-12	2.84E-09	Veggie
Sn-121m	1.3E-05	1.2E-02	2.3E-04	2.8E-04	4.4E-06	1.28E-02	Extern
Sn-126	6.0E-02	8.5E+03	1.2E+00	1.4E+00	2.2E-02	8.51E+03	Extern
I-129	1.1E-01	5.7E+00	1.4E+01	1.1E+02	3.0E-01	1.33E+02	Veggie
Cs-135	3.6E-03	1.9E-02	4.6E-01	7.6E+00	8.6E-03	8.12E+00	Veggie
Cs-137	2.6E-07	2.4E-02	3.3E-05	5.5E-04	6.2E-07	2.46E-02	Extern
Ba-133	2.4E-17	6.4E-12	9.2E-16	3.6E-15	1.8E-17	6.39E-12	Extern
Sm-147	5.7E+01	0.0E+00	1.2E+01	8.0E+00	2.2E-01	7.64E+01	Inhale
Sm-151	4.9E-04	5.4E-05	4.7E-04	3.2E-04	8.8E-06	1.34E-03	Inhale
Eu-150	1.4E-05	4.3E-01	2.6E-05	1.8E-05	4.9E-07	4.28E-01	Extern
Eu-152	1.5E-12	3.9E-08	3.2E-12	2.2E-12	6.2E-14	3.90E-08	Extern
Eu-154	1.6E-18	3.7E-14	4.5E-18	3.1E-18	8.5E-20	3.68E-14	Extern
Gd-152	1.9E+02	0.0E+00	9.7E+00	6.7E+00	1.8E-01	2.08E+02	Inhale
Re-187	3.8E-05	0.0E+00	5.3E-04	3.6E-02	1.0E-05	3.62E-02	Veggie
Pb-210	2.9E-06	8.6E-07	7.4E-05	6.0E-05	1.4E-06	1.39E-04	Soil Ing
Bi-207	3.4E-07	2.0E-01	9.8E-06	1.1E-05	1.8E-07	1.98E-01	Extern
Po-209	2.7E-01	3.9E-01	4.3E+00	3.9E+00	8.1E-02	8.97E+00	Soil Ing
Ra-226	1.9E+01	5.9E+03	4.1E+02	3.7E+02	7.8E+00	6.69E+03	Extern
Ra-228	2.4E-24	8.5E-23	9.5E-25	7.7E-25	1.8E-26	8.91E-23	Extern
Ac-227	6.4E-04	1.7E-04	1.1E-04	1.0E-05	2.2E-06	9.39E-04	Inhale
Th-228	4.5E-77	1.1E-75	8.7E-78	8.5E-79	1.8E-79	1.20E-75	Extern
Th-229	1.5E+03	1.1E+03	2.4E+02	2.2E+01	4.5E+00	2.92E+03	Inhale
Th-230	2.6E+02	1.4E+03	1.3E+02	8.7E+01	2.4E+00	1.90E+03	Extern
Th-232	1.5E+03	1.0E+04	3.1E+02	1.3E+02	5.8E+00	1.23E+04	Extern
Pa-231	6.3E+03	1.5E+03	1.6E+03	1.3E+02	3.1E+01	9.64E+03	Inhale
U-232	6.3E+00	5.3E+01	1.1E+00	1.2E+00	2.0E-02	6.16E+01	Extern
U-233	1.8E+02	5.5E+01	2.9E+01	3.1E+01	5.4E-01	2.90E+02	Inhale
U-234	1.0E+02	2.4E-01	1.6E+01	2.9E+01	3.1E-01	1.47E+02	Inhale
U-235	1.6E+02	3.4E+02	3.3E+01	2.9E+01	6.2E-01	5.56E+02	Extern
U-236	9.4E+01	1.3E-01	1.6E+01	2.8E+01	3.0E-01	1.37E+02	Inhale
U-238	9.4E+01	9.3E+01	1.5E+01	2.7E+01	2.9E-01	2.29E+02	Inhale
Np-237	3.7E+02	8.7E+02	2.4E+02	3.7E+02	4.6E+00	1.85E+03	Extern
Pu-238	7.1E+00	1.7E-03	4.7E+00	1.3E-01	8.9E-02	1.20E+01	Inhale
Pu-239	4.0E+02	1.4E-01	2.8E+02	7.0E+00	5.2E+00	6.88E+02	Inhale
Pu-240	3.9E+02	9.0E-02	2.6E+02	6.8E+00	5.0E+00	6.62E+02	Inhale
Pu-241	6.4E+00	2.9E-01	4.5E+00	2.6E-01	8.5E-02	1.16E+01	Inhale
Pu-242	3.8E+02	6.8E-02	2.7E+02	6.8E+00	5.0E+00	6.60E+02	Inhale
Pu-244	4.0E+02	1.5E+03	2.7E+02	7.0E+00	5.1E+00	2.21E+03	Extern
Am-241	1.9E+02	8.5E+00	1.3E+02	7.6E+00	2.5E+00	3.35E+02	Inhale
Am-242m	1.0E+02	4.9E+00	6.8E+01	2.7E+00	1.3E+00	1.80E+02	Inhale
Am-243	4.0E+02	5.6E+02	2.8E+02	1.6E+01	5.3E+00	1.26E+03	Extern
Cm-243	4.8E-01	7.3E-03	3.3E-01	8.5E-03	6.2E-03	8.30E-01	Inhale
Cm-244	1.1E+00	2.5E-04	7.3E-01	1.9E-02	1.4E-02	1.83E+00	Inhale
Cm-245	6.4E+02	1.8E+02	4.4E+02	1.7E+01	8.2E+00	1.28E+03	Inhale
Cm-246	4.0E+02	5.1E-02	2.7E+02	7.3E+00	5.1E+00	6.85E+02	Inhale
Cm-247	4.0E+02	1.7E+03	2.7E+02	7.4E+00	5.2E+00	2.41E+03	Extern
Cm-248	1.5E+03	5.0E-02	1.0E+03	2.8E+01	1.9E+01	2.60E+03	Inhale

Note: The above values must be multiplied by the volume of waste exhumed.

Intruder Scenarios after 500 Years -- ORNL-5785 -- LEACHING

Effective Dose Equivalent, mrem/yr per Ci exhumed

Nuclide	Inhale	Extern	Soil Ing	Root Up	Rain Sp	Case Totals	Maximum Pathway
H-3	1.5E-17	9.1E-21	8.2E-16	0.0E+00	2.0E-17	8.47E-16	Soil Ing
Be-10	2.8E-01	5.7E-01	2.7E-01	8.9E-02	5.1E-03	1.21E+00	Extern
C-14	1.5E-03	8.8E-03	1.2E-01	1.3E+01	2.3E-03	1.36E+01	Veggie
Cl-36	9.0E-03	6.3E-01	1.1E-01	1.5E+03	2.6E-03	1.47E+03	Veggie
K-40	9.0E-03	6.0E+02	1.2E+00	1.1E+02	2.2E-02	7.08E+02	Extern
Co-60	3.1E-30	2.5E-25	4.4E-29	5.5E-29	8.5E-31	2.54E-25	Extern
Ni-59	1.0E-03	1.7E-01	1.3E-02	1.2E-01	2.4E-04	3.05E-01	Extern
Ni-63	7.5E-05	7.8E-06	1.1E-03	1.0E-02	2.1E-05	1.13E-02	Veggie
Se-79	7.1E-03	6.9E-03	5.4E-01	2.1E+00	1.0E-02	2.62E+00	Veggie
Sr-90	1.0E-06	1.4E-04	4.9E-05	3.1E-03	9.2E-07	3.32E-03	Veggie
Zr-93	2.8E-01	6.9E-02	1.4E-01	4.2E-02	2.6E-03	5.29E-01	Inhale
Nb-93m	1.1E-12	3.3E-12	1.6E-12	1.6E-12	3.1E-14	7.61E-12	Extern
Nb-94	2.6E-01	6.0E+03	3.3E-01	3.1E-01	6.1E-03	5.97E+03	Extern
Mo-93	4.0E-02	3.6E-01	1.1E-01	8.9E-01	2.0E-03	1.40E+00	Veggie
Tc-99	5.0E-03	5.5E-02	7.0E-02	2.4E+01	1.4E-03	2.46E+01	Veggie
Pd-107	1.0E-02	5.4E-06	9.0E-03	6.7E-02	1.7E-04	8.66E-02	Veggie
Cd-113m	1.1E-11	5.3E-12	9.3E-11	2.7E-09	1.8E-12	2.77E-09	Veggie
Sn-121m	1.3E-05	1.2E-02	2.4E-04	2.8E-04	4.4E-06	1.28E-02	Extern
Sn-126	6.0E-02	8.5E+03	1.2E+00	1.4E+00	2.2E-02	8.52E+03	Extern
I-129	1.4E-01	7.2E+00	1.8E+01	1.6E+02	3.4E-01	1.86E+02	Veggie
Cs-135	3.6E-03	1.9E-02	4.6E-01	2.4E+00	8.6E-03	2.88E+00	Veggie
Cs-137	2.6E-07	2.4E-02	3.3E-05	1.7E-04	6.2E-07	2.43E-02	Extern
Ba-133	2.5E-17	6.4E-12	9.3E-16	3.6E-15	1.8E-17	6.39E-12	Extern
Sm-147	5.7E+01	0.0E+00	1.2E+01	8.0E+00	2.2E-01	7.65E+01	Inhale
Sm-151	4.9E-04	5.4E-05	4.7E-04	3.2E-04	8.8E-06	1.34E-03	Inhale
Eu-150	1.4E-05	4.3E-01	2.6E-05	1.8E-05	4.9E-07	4.28E-01	Extern
Eu-152	1.5E-12	3.9E-08	3.3E-12	2.2E-12	6.2E-14	3.90E-08	Extern
Eu-154	1.6E-18	3.7E-14	4.5E-18	3.1E-18	8.5E-20	3.68E-14	Extern
Gd-152	1.9E+02	0.0E+00	9.7E+00	6.7E+00	1.8E-01	2.08E+02	Inhale
Re-187	3.7E-05	0.0E+00	5.2E-04	3.5E-02	9.9E-06	3.58E-02	Veggie
Pb-210	2.9E-06	8.6E-07	7.5E-05	1.3E-04	1.4E-06	2.14E-04	Veggie
Bi-207	3.4E-07	2.0E-01	9.8E-06	1.1E-05	1.8E-07	1.98E-01	Extern
Po-209	2.7E-01	3.9E-01	4.3E+00	3.7E-01	8.1E-02	5.43E+00	Soil Ing
Ra-226	1.9E+01	5.9E+03	4.1E+02	6.6E+02	7.8E+00	6.98E+03	Extern
Ra-228	2.4E-24	8.5E-23	9.5E-25	2.0E-25	1.8E-26	8.86E-23	Extern
Ac-227	6.4E-04	1.7E-04	1.1E-04	1.0E-05	2.2E-06	9.40E-04	Inhale
Th-228	4.5E-77	1.1E-75	8.7E-78	2.1E-79	1.8E-79	1.20E-75	Extern
Th-229	1.5E+03	1.1E+03	2.4E+02	5.3E+00	4.5E+00	2.91E+03	Inhale
Th-230	2.6E+02	1.4E+03	1.3E+02	1.5E+02	2.4E+00	1.96E+03	Extern
Th-232	1.5E+03	1.0E+04	3.1E+02	3.5E+01	5.8E+00	1.22E+04	Extern
Pa-231	6.3E+03	1.5E+03	1.6E+03	1.3E+02	3.1E+01	9.64E+03	Inhale
U-232	6.4E+00	5.3E+01	1.1E+00	4.6E-01	2.0E-02	6.11E+01	Extern
U-233	1.8E+02	5.5E+01	2.9E+01	1.2E+01	5.5E-01	2.74E+02	Inhale
U-234	1.0E+02	2.5E-01	1.7E+01	1.1E+01	3.2E-01	1.32E+02	Inhale
U-235	1.6E+02	3.4E+02	3.3E+01	1.2E+01	6.2E-01	5.49E+02	Extern
U-236	9.6E+01	1.3E-01	1.6E+01	1.1E+01	3.0E-01	1.23E+02	Inhale
U-238	9.6E+01	9.5E+01	1.6E+01	1.1E+01	3.0E-01	2.17E+02	Inhale
Np-237	3.9E+02	9.2E+02	2.5E+02	6.4E+02	4.7E+00	2.20E+03	Extern
Pu-238	7.1E+00	1.7E-03	4.7E+00	5.9E-02	8.9E-02	1.20E+01	Inhale
Pu-239	4.0E+02	1.4E-01	2.8E+02	3.2E+00	5.2E+00	6.85E+02	Inhale
Pu-240	3.9E+02	9.0E-02	2.6E+02	3.0E+00	5.0E+00	6.59E+02	Inhale
Pu-241	6.4E+00	2.9E-01	4.5E+00	4.4E-01	8.5E-02	1.17E+01	Inhale
Pu-242	3.8E+02	6.8E-02	2.7E+02	3.1E+00	5.0E+00	6.57E+02	Inhale
Pu-244	4.0E+02	1.5E+03	2.7E+02	3.2E+00	5.1E+00	2.21E+03	Extern
Am-241	1.9E+02	8.5E+00	1.3E+02	1.3E+01	2.5E+00	3.41E+02	Inhale
Am-242m	1.0E+02	4.9E+00	6.8E+01	3.3E+00	1.3E+00	1.81E+02	Inhale
Am-243	4.0E+02	5.6E+02	2.8E+02	2.7E+01	5.3E+00	1.28E+03	Extern
Cm-243	4.8E-01	7.3E-03	3.3E-01	4.0E-03	6.2E-03	8.26E-01	Inhale
Cm-244	1.1E+00	2.5E-04	7.3E-01	8.4E-03	1.4E-02	1.82E+00	Inhale
Cm-245	6.4E+02	1.8E+02	4.4E+02	1.8E+01	8.2E+00	1.28E+03	Inhale
Cm-246	4.0E+02	5.1E-02	2.7E+02	3.2E+00	5.1E+00	6.79E+02	Inhale
Cm-247	4.0E+02	1.7E+03	2.7E+02	3.2E+00	5.1E+00	2.40E+03	Extern
Cm-248	1.5E+03	5.0E-02	1.0E+03	1.2E+01	1.9E+01	2.58E+03	Inhale

Note: The above values must be multiplied by the volume of waste exhumed.

Intruder Scenarios at 100 Years -- NUREG/CR-5512 -- NO LEACHING
Effective Dose Equivalent, mrem/yr per Ci exhumed

Nuclide	Inhale	Extern	Soil Ing	Root Up	Rain Sp	Case Totals	Maximum Pathway
H-3	2.6E-07	1.6E-10	1.4E-05	0.0E+00	2.7E-07	1.45E-05	Soil Ing
Be-10	2.8E-01	5.7E-01	2.7E-01	8.9E-02	5.1E-03	1.21E+00	Extern
C-14	1.7E-03	9.7E-03	1.3E-01	1.5E+01	2.5E-03	1.47E+01	Veggie
Cl-36	1.6E-02	1.1E+00	1.9E-01	2.1E+03	3.7E-03	2.10E+03	Veggie
K-40	9.6E-03	6.3E+02	1.2E+00	1.1E+02	2.3E-02	7.47E+02	Extern
Co-60	2.2E-07	1.8E-02	3.1E-06	1.6E-05	5.9E-08	1.79E-02	Extern
Ni-59	1.0E-03	1.7E-01	1.3E-02	1.5E-01	2.4E-04	3.39E-01	Extern
Ni-63	1.2E-03	1.2E-04	1.7E-02	2.1E-01	3.3E-04	2.24E-01	Veggie
Se-79	7.1E-03	7.0E-03	5.4E-01	2.1E+00	1.0E-02	2.63E+00	Veggie
Sr-90	1.7E-02	2.3E+00	8.0E-01	8.3E+01	1.5E-02	8.57E+01	Veggie
Zr-93	2.8E-01	6.8E-02	1.4E-01	4.2E-02	2.6E-03	5.28E-01	Inhale
Nb-93m	1.9E-04	5.8E-04	2.9E-04	2.8E-04	5.5E-06	1.35E-03	Extern
Nb-94	2.6E-01	6.1E+03	3.3E-01	3.1E-01	6.2E-03	6.06E+03	Extern
Mo-93	4.4E-02	3.9E-01	1.2E-01	9.7E-01	2.2E-03	1.53E+00	Veggie
Tc-99	6.0E-03	6.6E-02	8.4E-02	5.7E+01	1.6E-03	5.70E+01	Veggie
Pd-107	1.0E-02	5.4E-06	9.1E-03	6.7E-02	1.7E-04	8.69E-02	Veggie
Cd-113m	6.9E-03	3.5E-03	6.0E-02	1.7E+00	1.1E-03	1.76E+00	Veggie
Sn-121m	2.1E-03	1.9E+00	3.6E-02	4.4E-02	6.8E-04	1.98E+00	Extern
Sn-126	6.0E-02	8.5E+03	1.2E+00	1.4E+00	2.2E-02	8.55E+03	Extern
I-129	1.4E-01	7.3E+00	1.8E+01	1.3E+02	3.4E-01	1.56E+02	Veggie
Cs-135	3.6E-03	1.9E-02	4.6E-01	7.6E+00	8.6E-03	8.12E+00	Veggie
Cs-137	2.5E-03	2.4E+02	3.2E-01	5.4E+00	6.1E-03	2.42E+02	Extern
Ba-133	7.2E-06	1.9E+00	2.7E-04	1.1E-03	5.2E-06	1.89E+00	Extern
Sm-147	5.7E+01	0.0E+00	1.2E+01	8.0E+00	2.2E-01	7.65E+01	Inhale
Sm-151	1.1E-02	1.2E-03	1.0E-02	7.0E-03	1.9E-04	2.92E-02	Inhale
Eu-150	3.1E-02	9.5E+02	5.8E-02	4.0E-02	1.1E-03	9.48E+02	Extern
Eu-152	1.0E-03	2.8E+01	2.3E-03	1.6E-03	4.4E-05	2.79E+01	Extern
Eu-154	7.6E-05	1.8E+00	2.2E-04	1.5E-04	4.1E-06	1.78E+00	Extern
Gd-152	1.9E+02	0.0E+00	9.7E+00	6.7E+00	1.8E-01	2.08E+02	Inhale
Re-187	3.9E-05	0.0E+00	5.4E-04	3.6E-02	1.0E-05	3.66E-02	Veggie
Pb-210	7.4E-01	2.2E-01	1.9E+01	1.5E+01	3.6E-01	3.58E+01	Soil Ing
Bi-207	1.4E-03	8.0E+02	4.0E-02	4.4E-02	7.4E-04	7.99E+02	Extern
Po-209	4.1E+00	5.9E+00	6.6E+01	5.9E+01	1.2E+00	1.36E+02	Soil Ing
Ra-226	2.2E+01	7.0E+03	4.7E+02	4.2E+02	8.9E+00	7.92E+03	Extern
Ra-228	2.1E-03	7.4E-02	8.3E-04	6.7E-04	1.6E-05	7.79E-02	Extern
Ac-227	2.2E+02	5.7E+01	3.9E+01	3.5E+00	7.3E-01	3.19E+02	Inhale
Th-228	3.9E-14	9.9E-13	7.6E-15	7.4E-16	1.5E-16	1.04E-12	Extern
Th-229	1.6E+03	1.2E+03	2.5E+02	2.3E+01	4.7E+00	3.04E+03	Inhale
Th-230	2.6E+02	3.1E+02	5.0E+01	1.8E+01	9.4E-01	6.37E+02	Extern
Th-232	1.5E+03	1.0E+04	3.1E+02	1.3E+02	5.8E+00	1.23E+04	Extern
Pa-231	6.2E+03	1.5E+03	1.6E+03	1.3E+02	3.0E+01	9.41E+03	Inhale
U-232	3.0E+02	2.5E+03	5.1E+01	5.7E+01	9.6E-01	2.91E+03	Extern
U-233	1.2E+02	1.2E+01	2.0E+01	3.0E+01	3.7E-01	1.81E+02	Inhale
U-234	1.0E+02	2.5E-01	1.7E+01	2.9E+01	3.2E-01	1.50E+02	Inhale
U-235	1.1E+02	3.3E+02	1.9E+01	2.8E+01	3.6E-01	4.85E+02	Extern
U-236	9.6E+01	1.3E-01	1.6E+01	2.8E+01	3.0E-01	1.40E+02	Inhale
U-238	9.6E+01	9.5E+01	1.6E+01	2.7E+01	3.0E-01	2.34E+02	Inhale
Np-237	3.9E+02	9.3E+02	2.5E+02	3.8E+02	4.7E+00	1.96E+03	Extern
Pu-238	1.7E+02	3.7E-02	1.1E+02	2.9E+00	2.1E+00	2.82E+02	Inhale
Pu-239	4.1E+02	1.5E-01	2.8E+02	7.1E+00	5.2E+00	6.97E+02	Inhale
Pu-240	4.0E+02	9.4E-02	2.8E+02	7.1E+00	5.2E+00	6.91E+02	Inhale
Pu-241	1.2E+01	5.4E-01	8.5E+00	4.9E-01	1.6E-01	2.19E+01	Inhale
Pu-242	3.8E+02	6.8E-02	2.7E+02	6.8E+00	5.0E+00	6.61E+02	Inhale
Pu-244	3.9E+02	1.5E+03	2.6E+02	6.7E+00	4.9E+00	2.18E+03	Extern
Am-241	3.5E+02	1.6E+01	2.5E+02	1.4E+01	4.7E+00	6.37E+02	Inhale
Am-242m	4.0E+02	3.0E+01	2.6E+02	1.2E+01	4.9E+00	7.09E+02	Inhale
Am-243	4.1E+02	5.8E+02	2.9E+02	1.7E+01	5.4E+00	1.31E+03	Extern
Cm-243	2.5E+01	3.3E+01	1.7E+01	4.5E-01	3.1E-01	7.49E+01	Extern
Cm-244	5.7E+00	1.7E-03	3.9E+00	1.1E-01	7.4E-02	9.81E+00	Inhale
Cm-245	4.8E+02	1.7E+02	3.3E+02	1.0E+01	6.2E+00	1.00E+03	Inhale
Cm-246	4.2E+02	5.4E-02	2.9E+02	7.8E+00	5.4E+00	7.26E+02	Inhale
Cm-247	3.9E+02	1.7E+03	2.7E+02	7.2E+00	5.0E+00	2.38E+03	Extern
Cm-248	1.5E+03	5.0E-02	1.0E+03	2.8E+01	1.9E+01	2.60E+03	Inhale

Note: The above values must be multiplied by the volume of waste exhumed.

Intruder Scenarios at 100 Years -- ORNL-5785 -- NO LEACHING
Effective Dose Equivalent, mrem/yr per Ci exhumed

Nuclide	Inhale	Extern	Soil Ing	Root Up	Rain Sp	Case Totals	Maximum Pathway
H-3	2.6E-07	1.6E-10	1.4E-05	0.0E+00	2.7E-07	1.45E-05	Soil Ing
Be-10	2.8E-01	5.7E-01	2.7E-01	8.9E-02	5.1E-03	1.21E+00	Extern
C-14	1.7E-03	9.7E-03	1.3E-01	1.5E+01	2.5E-03	1.47E+01	Veggie
Cl-36	1.6E-02	1.1E+00	1.9E-01	2.1E+03	3.7E-03	2.10E+03	Veggie
K-40	9.6E-03	6.3E+02	1.2E+00	1.1E+02	2.3E-02	7.47E+02	Extern
Co-60	2.2E-07	1.8E-02	3.1E-06	3.9E-06	5.9E-08	1.79E-02	Extern
Ni-59	1.0E-03	1.7E-01	1.3E-02	1.2E-01	2.4E-04	3.06E-01	Extern
Ni-63	1.2E-03	1.2E-04	1.7E-02	1.6E-01	3.3E-04	1.81E-01	Veggie
Se-79	7.1E-03	7.0E-03	5.4E-01	2.1E+00	1.0E-02	2.63E+00	Veggie
Sr-90	1.7E-02	2.3E+00	8.0E-01	5.1E+01	1.5E-02	5.42E+01	Veggie
Zr-93	2.8E-01	6.8E-02	1.4E-01	4.2E-02	2.6E-03	5.28E-01	Inhale
Nb-93m	1.9E-04	5.8E-04	2.9E-04	2.8E-04	5.5E-06	1.35E-03	Extern
Nb-94	2.6E-01	6.1E+03	3.3E-01	3.1E-01	6.2E-03	6.06E+03	Extern
Mo-93	4.4E-02	3.9E-01	1.2E-01	9.7E-01	2.2E-03	1.53E+00	Veggie
Tc-99	6.0E-03	6.6E-02	8.4E-02	2.7E+01	1.6E-03	2.73E+01	Veggie
Pd-107	1.0E-02	5.4E-06	9.1E-03	6.7E-02	1.7E-04	8.69E-02	Veggie
Cd-113m	6.9E-03	3.5E-03	6.0E-02	1.7E+00	1.1E-03	1.76E+00	Veggie
Sn-121m	2.1E-03	1.9E+00	3.6E-02	4.4E-02	6.8E-04	1.98E+00	Extern
Sn-126	6.0E-02	8.5E+03	1.2E+00	1.4E+00	2.2E-02	8.55E+03	Extern
I-129	1.4E-01	7.3E+00	1.8E+01	1.6E+02	3.4E-01	1.86E+02	Veggie
Cs-135	3.6E-03	1.9E-02	4.6E-01	2.4E+00	8.6E-03	2.88E+00	Veggie
Cs-137	2.5E-03	2.4E+02	3.2E-01	1.7E+00	6.1E-03	2.38E+02	Extern
Ba-133	7.2E-06	1.9E+00	2.7E-04	1.1E-03	5.2E-06	1.89E+00	Extern
Sm-147	5.7E+01	0.0E+00	1.2E+01	8.0E+00	2.2E-01	7.65E+01	Inhale
Sm-151	1.1E-02	1.2E-03	1.0E-02	7.0E-03	1.9E-04	2.92E-02	Inhale
Eu-150	3.1E-02	9.5E+02	5.8E-02	4.0E-02	1.1E-03	9.48E+02	Extern
Eu-152	1.0E-03	2.8E+01	2.3E-03	1.6E-03	4.4E-05	2.79E+01	Extern
Eu-154	7.6E-05	1.8E+00	2.2E-04	1.5E-04	4.1E-06	1.78E+00	Extern
Gd-152	1.9E+02	0.0E+00	9.7E+00	6.7E+00	1.8E-01	2.08E+02	Inhale
Re-187	3.9E-05	0.0E+00	5.4E-04	3.6E-02	1.0E-05	3.66E-02	Veggie
Pb-210	7.4E-01	2.2E-01	1.9E+01	3.5E+01	3.6E-01	5.50E+01	Veggie
Bi-207	1.4E-03	8.0E+02	4.0E-02	4.4E-02	7.4E-04	7.99E+02	Extern
Po-209	4.1E+00	5.9E+00	6.6E+01	5.6E+00	1.2E+00	8.24E+01	Soil Ing
Ra-226	2.2E+01	7.0E+03	4.7E+02	7.5E+02	8.9E+00	8.26E+03	Extern
Ra-228	2.1E-03	7.4E-02	8.3E-04	1.8E-04	1.6E-05	7.74E-02	Extern
Ac-227	2.2E+02	5.7E+01	3.9E+01	3.5E+00	7.3E-01	3.19E+02	Inhale
Th-228	3.9E-14	9.9E-13	7.6E-15	1.8E-16	1.5E-16	1.04E-12	Extern
Th-229	1.6E+03	1.2E+03	2.5E+02	5.5E+00	4.7E+00	3.02E+03	Inhale
Th-230	2.6E+02	3.1E+02	5.0E+01	2.5E+01	9.4E-01	6.44E+02	Extern
Th-232	1.5E+03	1.0E+04	3.1E+02	3.5E+01	5.8E+00	1.22E+04	Extern
Pa-231	6.2E+03	1.5E+03	1.6E+03	1.3E+02	3.0E+01	9.41E+03	Inhale
U-232	3.0E+02	2.5E+03	5.1E+01	2.2E+01	9.6E-01	2.87E+03	Extern
U-233	1.2E+02	1.2E+01	2.0E+01	1.2E+01	3.7E-01	1.63E+02	Inhale
U-234	1.0E+02	2.5E-01	1.7E+01	1.1E+01	3.2E-01	1.32E+02	Inhale
U-235	1.1E+02	3.3E+02	1.9E+01	1.1E+01	3.6E-01	4.68E+02	Extern
U-236	9.6E+01	1.3E-01	1.6E+01	1.1E+01	3.0E-01	1.23E+02	Inhale
U-238	9.6E+01	9.5E+01	1.6E+01	1.1E+01	3.0E-01	2.17E+02	Inhale
Np-237	3.9E+02	9.3E+02	2.5E+02	6.5E+02	4.7E+00	2.23E+03	Extern
Pu-238	1.7E+02	3.7E-02	1.1E+02	1.3E+00	2.1E+00	2.81E+02	Inhale
Pu-239	4.1E+02	1.5E-01	2.8E+02	3.2E+00	5.2E+00	6.93E+02	Inhale
Pu-240	4.0E+02	9.4E-02	2.8E+02	3.2E+00	5.2E+00	6.87E+02	Inhale
Pu-241	1.2E+01	5.4E-01	8.5E+00	8.3E-01	1.6E-01	2.22E+01	Inhale
Pu-242	3.8E+02	6.8E-02	2.7E+02	3.1E+00	5.0E+00	6.57E+02	Inhale
Pu-244	3.9E+02	1.5E+03	2.6E+02	3.0E+00	4.9E+00	2.18E+03	Extern
Am-241	3.5E+02	1.6E+01	2.5E+02	2.4E+01	4.7E+00	6.47E+02	Inhale
Am-242m	4.0E+02	3.0E+01	2.6E+02	1.8E+01	4.9E+00	7.15E+02	Inhale
Am-243	4.1E+02	5.8E+02	2.9E+02	2.8E+01	5.4E+00	1.32E+03	Extern
Cm-243	2.5E+01	3.3E+01	1.7E+01	2.0E-01	3.1E-01	7.47E+01	Extern
Cm-244	5.7E+00	1.7E-03	3.9E+00	4.6E-02	7.4E-02	9.75E+00	Inhale
Cm-245	4.8E+02	1.7E+02	3.3E+02	6.9E+00	6.2E+00	1.00E+03	Inhale
Cm-246	4.2E+02	5.4E-02	2.9E+02	3.4E+00	5.4E+00	7.21E+02	Inhale
Cm-247	3.9E+02	1.7E+03	2.7E+02	3.2E+00	5.0E+00	2.37E+03	Extern
Cm-248	1.5E+03	5.0E-02	1.0E+03	1.2E+01	1.9E+01	2.59E+03	Inhale

Note: The above values must be multiplied by the volume of waste exhumed.

Intruder Scenarios at 300 Years -- NUREG/CR-5512 -- NO LEACHING
Effective Dose Equivalent, mrem/yr per Ci exhumed

Nuclide	Inhale	Extern	Soil Ing	Root Up	Rain Sp	Case Totals	Maximum Pathway
H-3	3.2E-12	2.0E-15	1.8E-10	0.0E+00	3.4E-12	1.82E-10	Soil Ing
Be-10	2.8E-01	5.7E-01	2.7E-01	8.9E-02	5.1E-03	1.21E+00	Extern
C-14	1.6E-03	9.4E-03	1.3E-01	1.4E+01	2.5E-03	1.43E+01	Veggie
Cl-36	1.6E-02	1.1E+00	1.9E-01	2.1E+03	3.6E-03	2.10E+03	Veggie
K-40	9.6E-03	6.3E+02	1.2E+00	1.1E+02	2.3E-02	7.47E+02	Extern
Co-60	8.3E-19	6.8E-14	1.2E-17	6.1E-17	2.2E-19	6.76E-14	Extern
Ni-59	1.0E-03	1.7E-01	1.3E-02	1.5E-01	2.4E-04	3.38E-01	Extern
Ni-63	3.0E-04	3.1E-05	4.4E-03	5.1E-02	8.2E-05	5.62E-02	Veggie
Se-79	7.1E-03	7.0E-03	5.4E-01	2.1E+00	1.0E-02	2.63E+00	Veggie
Sr-90	1.3E-04	1.8E-02	6.2E-03	6.5E-01	1.2E-04	6.73E-01	Veggie
Zr-93	2.8E-01	6.9E-02	1.4E-01	4.2E-02	2.6E-03	5.30E-01	Inhale
Nb-93m	1.4E-08	4.4E-08	2.2E-08	2.1E-08	4.2E-10	1.01E-07	Extern
Nb-94	2.6E-01	6.0E+03	3.3E-01	3.1E-01	6.1E-03	6.02E+03	Extern
Mo-93	4.2E-02	3.8E-01	1.1E-01	9.4E-01	2.1E-03	1.47E+00	Veggie
Tc-99	6.0E-03	6.6E-02	8.4E-02	5.7E+01	1.6E-03	5.70E+01	Veggie
Pd-107	1.0E-02	5.4E-06	9.1E-03	6.7E-02	1.7E-04	8.69E-02	Veggie
Cd-113m	2.8E-07	1.4E-07	2.4E-06	6.8E-05	4.6E-08	7.08E-05	Veggie
Sn-121m	1.7E-04	1.5E-01	2.9E-03	3.5E-03	5.5E-05	1.59E-01	Extern
Sn-126	6.0E-02	8.5E+03	1.2E+00	1.4E+00	2.2E-02	8.54E+03	Extern
I-129	1.4E-01	7.3E+00	1.8E+01	1.3E+02	3.4E-01	1.56E+02	Veggie
Cs-135	3.6E-03	1.9E-02	4.6E-01	7.6E+00	8.6E-03	8.12E+00	Veggie
Cs-137	2.6E-05	2.4E+00	3.3E-03	5.4E-02	6.1E-05	2.44E+00	Extern
Ba-133	1.3E-11	3.5E-06	5.0E-10	2.0E-09	9.6E-12	3.48E-06	Extern
Sm-147	5.7E+01	0.0E+00	1.2E+01	8.0E+00	2.2E-01	7.65E+01	Inhale
Sm-151	2.3E-03	2.5E-04	2.2E-03	1.5E-03	4.1E-05	6.26E-03	Inhale
Eu-150	6.6E-04	2.0E+01	1.2E-03	8.5E-04	2.3E-05	2.02E+01	Extern
Eu-152	3.9E-08	1.0E-03	8.7E-08	6.0E-08	1.6E-09	1.04E-03	Extern
Eu-154	1.1E-11	2.6E-07	3.1E-11	2.2E-11	5.9E-13	2.56E-07	Extern
Gd-152	1.9E+02	0.0E+00	9.7E+00	6.7E+00	1.8E-01	2.08E+02	Inhale
Re-187	3.9E-05	0.0E+00	5.4E-04	3.6E-02	1.0E-05	3.66E-02	Veggie
Pb-210	1.5E-03	4.4E-04	3.8E-02	3.0E-02	7.1E-04	7.07E-02	Soil Ing
Bi-207	2.2E-05	1.3E+01	6.2E-04	6.9E-04	1.2E-05	1.26E+01	Extern
Po-209	1.0E+00	1.5E+00	1.7E+01	1.5E+01	3.2E-01	3.50E+01	Soil Ing
Ra-226	2.1E+01	6.4E+03	4.5E+02	4.0E+02	8.5E+00	7.30E+03	Extern
Ra-228	7.0E-14	2.5E-12	2.8E-14	2.3E-14	5.4E-16	2.63E-12	Extern
Ac-227	3.8E-01	9.8E-02	6.6E-02	6.0E-03	1.3E-03	5.47E-01	Inhale
Th-228	1.3E-45	3.4E-44	2.6E-46	2.5E-47	5.2E-48	3.52E-44	Extern
Th-229	1.6E+03	1.1E+03	2.5E+02	2.2E+01	4.6E+00	2.98E+03	Inhale
Th-230	2.6E+02	8.9E+02	9.1E+01	5.4E+01	1.7E+00	1.30E+03	Extern
Th-232	1.5E+03	1.0E+04	3.1E+02	1.3E+02	5.8E+00	1.23E+04	Extern
Pa-231	6.4E+03	1.5E+03	1.7E+03	1.3E+02	3.1E+01	9.69E+03	Inhale
U-232	4.4E+01	3.6E+02	7.5E+00	8.3E+00	1.4E-01	4.24E+02	Extern
U-233	1.5E+02	3.4E+01	2.5E+01	3.1E+01	4.6E-01	2.38E+02	Inhale
U-234	1.0E+02	2.5E-01	1.7E+01	2.9E+01	3.2E-01	1.50E+02	Inhale
U-235	1.3E+02	3.4E+02	2.6E+01	2.9E+01	4.9E-01	5.25E+02	Extern
U-236	9.6E+01	1.3E-01	1.6E+01	2.8E+01	3.0E-01	1.40E+02	Inhale
U-238	9.6E+01	9.5E+01	1.6E+01	2.7E+01	3.0E-01	2.34E+02	Inhale
Np-237	3.9E+02	9.3E+02	2.5E+02	3.8E+02	4.7E+00	1.96E+03	Extern
Pu-238	3.4E+01	7.7E-03	2.3E+01	6.0E-01	4.3E-01	5.82E+01	Inhale
Pu-239	4.0E+02	1.5E-01	2.8E+02	7.1E+00	5.2E+00	6.93E+02	Inhale
Pu-240	3.9E+02	9.2E-02	2.7E+02	6.9E+00	5.1E+00	6.77E+02	Inhale
Pu-241	8.8E+00	4.0E-01	6.2E+00	3.6E-01	1.2E-01	1.59E+01	Inhale
Pu-242	3.8E+02	6.8E-02	2.7E+02	6.8E+00	5.0E+00	6.61E+02	Inhale
Pu-244	4.0E+02	1.5E+03	2.7E+02	6.9E+00	5.0E+00	2.20E+03	Extern
Am-241	2.6E+02	1.2E+01	1.8E+02	1.0E+01	3.4E+00	4.62E+02	Inhale
Am-242m	2.2E+02	1.2E+01	1.5E+02	6.1E+00	2.8E+00	3.93E+02	Inhale
Am-243	4.1E+02	5.7E+02	2.9E+02	1.6E+01	5.4E+00	1.28E+03	Extern
Cm-243	6.7E-01	2.6E-01	4.6E-01	1.2E-02	8.6E-03	1.40E+00	Inhale
Cm-244	1.1E+00	2.6E-04	7.5E-01	1.9E-02	1.4E-02	1.87E+00	Inhale
Cm-245	5.8E+02	1.7E+02	3.9E+02	1.4E+01	7.4E+00	1.17E+03	Inhale
Cm-246	4.1E+02	5.2E-02	2.8E+02	7.5E+00	5.2E+00	7.05E+02	Inhale
Cm-247	4.0E+02	1.7E+03	2.7E+02	7.3E+00	5.1E+00	2.39E+03	Extern
Cm-248	1.5E+03	5.0E-02	1.0E+03	2.8E+01	1.9E+01	2.60E+03	Inhale

Note: The above values must be multiplied by the volume of waste exhumed.

Intruder Scenarios at 300 Years -- ORNL-5785 -- NO LEACHING
Effective Dose Equivalent, mrem/yr per Ci exhumed

Nuclide	Inhale	Extern	Soil Ing	Root Up	Rain Sp	Case Totals	Maximum Pathway
H-3	3.2E-12	2.0E-15	1.8E-10	0.0E+00	3.4E-12	1.82E-10	Soil Ing
Be-10	2.8E-01	5.7E-01	2.7E-01	8.9E-02	5.1E-03	1.21E+00	Extern
C-14	1.6E-03	9.4E-03	1.3E-01	1.4E+01	2.5E-03	1.43E+01	Veggie
Cl-36	1.6E-02	1.1E+00	1.9E-01	2.1E+03	3.6E-03	2.10E+03	Veggie
K-40	9.6E-03	6.3E+02	1.2E+00	1.1E+02	2.3E-02	7.47E+02	Extern
Co-60	8.3E-19	6.8E-14	1.2E-17	1.5E-17	2.2E-19	6.76E-14	Extern
Ni-59	1.0E-03	1.7E-01	1.3E-02	1.2E-01	2.4E-04	3.06E-01	Extern
Ni-63	3.0E-04	3.1E-05	4.4E-03	4.0E-02	8.2E-05	4.53E-02	Veggie
Se-79	7.1E-03	7.0E-03	5.4E-01	2.1E+00	1.0E-02	2.63E+00	Veggie
Sr-90	1.3E-04	1.8E-02	6.2E-03	4.0E-01	1.2E-04	4.26E-01	Veggie
Zr-93	2.8E-01	6.9E-02	1.4E-01	4.2E-02	2.6E-03	5.30E-01	Inhale
Nb-93m	1.4E-08	4.4E-08	2.2E-08	2.1E-08	4.2E-10	1.01E-07	Extern
Nb-94	2.6E-01	6.0E+03	3.3E-01	3.1E-01	6.1E-03	6.02E+03	Extern
Mo-93	4.2E-02	3.8E-01	1.1E-01	9.4E-01	2.1E-03	1.47E+00	Veggie
Tc-99	6.0E-03	6.6E-02	8.4E-02	2.7E+01	1.6E-03	2.73E+01	Veggie
Pd-107	1.0E-02	5.4E-06	9.1E-03	6.7E-02	1.7E-04	8.69E-02	Veggie
Cd-113m	2.8E-07	1.4E-07	2.4E-06	6.8E-05	4.6E-08	7.08E-05	Veggie
Sn-121m	1.7E-04	1.5E-01	2.9E-03	3.5E-03	5.5E-05	1.59E-01	Extern
Sn-126	6.0E-02	8.5E+03	1.2E+00	1.4E+00	2.2E-02	8.54E+03	Extern
I-129	1.4E-01	7.3E+00	1.8E+01	1.6E+02	3.4E-01	1.86E+02	Veggie
Cs-135	3.6E-03	1.9E-02	4.6E-01	2.4E+00	8.6E-03	2.88E+00	Veggie
Cs-137	2.6E-05	2.4E+00	3.3E-03	1.7E-02	6.1E-05	2.40E+00	Extern
Ba-133	1.3E-11	3.5E-06	5.0E-10	2.0E-09	9.6E-12	3.48E-06	Extern
Sm-147	5.7E+01	0.0E+00	1.2E+01	8.0E+00	2.2E-01	7.65E+01	Inhale
Sm-151	2.3E-03	2.5E-04	2.2E-03	1.5E-03	4.1E-05	6.26E-03	Inhale
Eu-150	6.6E-04	2.0E+01	1.2E-03	8.5E-04	2.3E-05	2.02E+01	Extern
Eu-152	3.9E-08	1.0E-03	8.7E-08	6.0E-08	1.6E-09	1.04E-03	Extern
Eu-154	1.1E-11	2.6E-07	3.1E-11	2.2E-11	5.9E-13	2.56E-07	Extern
Gd-152	1.9E+02	0.0E+00	9.7E+00	6.7E+00	1.8E-01	2.08E+02	Inhale
Re-187	3.9E-05	0.0E+00	5.4E-04	3.6E-02	1.0E-05	3.66E-02	Veggie
Pb-210	1.5E-03	4.4E-04	3.8E-02	6.8E-02	7.1E-04	1.09E-01	Veggie
Bi-207	2.2E-05	1.3E+01	6.2E-04	6.9E-04	1.2E-05	1.26E+01	Extern
Po-209	1.0E+00	1.5E+00	1.7E+01	1.4E+00	3.2E-01	2.12E+01	Soil Ing
Ra-226	2.1E+01	6.4E+03	4.5E+02	7.2E+02	8.5E+00	7.62E+03	Extern
Ra-228	7.0E-14	2.5E-12	2.8E-14	6.0E-15	5.4E-16	2.62E-12	Extern
Ac-227	3.8E-01	9.8E-02	6.6E-02	6.0E-03	1.3E-03	5.47E-01	Inhale
Th-228	1.3E-45	3.4E-44	2.6E-46	6.0E-48	5.2E-48	3.52E-44	Extern
Th-229	1.6E+03	1.1E+03	2.5E+02	5.4E+00	4.6E+00	2.96E+03	Inhale
Th-230	2.6E+02	8.9E+02	9.1E+01	9.0E+01	1.7E+00	1.33E+03	Extern
Th-232	1.5E+03	1.0E+04	3.1E+02	3.5E+01	5.8E+00	1.22E+04	Extern
Pa-231	6.4E+03	1.5E+03	1.7E+03	1.3E+02	3.1E+01	9.69E+03	Inhale
U-232	4.4E+01	3.6E+02	7.5E+00	3.2E+00	1.4E-01	4.19E+02	Extern
U-233	1.5E+02	3.4E+01	2.5E+01	1.2E+01	4.6E-01	2.19E+02	Inhale
U-234	1.0E+02	2.5E-01	1.7E+01	1.1E+01	3.2E-01	1.32E+02	Inhale
U-235	1.3E+02	3.4E+02	2.6E+01	1.2E+01	4.9E-01	5.08E+02	Extern
U-236	9.6E+01	1.3E-01	1.6E+01	1.1E+01	3.0E-01	1.23E+02	Inhale
U-238	9.6E+01	9.5E+01	1.6E+01	1.1E+01	3.0E-01	2.17E+02	Inhale
Np-237	3.9E+02	9.3E+02	2.5E+02	6.5E+02	4.7E+00	2.23E+03	Extern
Pu-238	3.4E+01	7.7E-03	2.3E+01	2.7E-01	4.3E-01	5.79E+01	Inhale
Pu-239	4.0E+02	1.5E-01	2.8E+02	3.2E+00	5.2E+00	6.89E+02	Inhale
Pu-240	3.9E+02	9.2E-02	2.7E+02	3.1E+00	5.1E+00	6.73E+02	Inhale
Pu-241	8.8E+00	4.0E-01	6.2E+00	6.1E-01	1.2E-01	1.62E+01	Inhale
Pu-242	3.8E+02	6.8E-02	2.7E+02	3.1E+00	5.0E+00	6.57E+02	Inhale
Pu-244	4.0E+02	1.5E+03	2.7E+02	3.1E+00	5.0E+00	2.19E+03	Extern
Am-241	2.6E+02	1.2E+01	1.8E+02	1.8E+01	3.4E+00	4.69E+02	Inhale
Am-242m	2.2E+02	1.2E+01	1.5E+02	7.8E+00	2.8E+00	3.95E+02	Inhale
Am-243	4.1E+02	5.7E+02	2.9E+02	2.8E+01	5.4E+00	1.30E+03	Extern
Cm-243	6.7E-01	2.6E-01	4.6E-01	5.5E-03	8.6E-03	1.40E+00	Inhale
Cm-244	1.1E+00	2.6E-04	7.5E-01	8.6E-03	1.4E-02	1.86E+00	Inhale
Cm-245	5.8E+02	1.7E+02	3.9E+02	1.4E+01	7.4E+00	1.17E+03	Inhale
Cm-246	4.1E+02	5.2E-02	2.8E+02	3.3E+00	5.2E+00	7.01E+02	Inhale
Cm-247	4.0E+02	1.7E+03	2.7E+02	3.2E+00	5.1E+00	2.39E+03	Extern
Cm-248	1.5E+03	5.0E-02	1.0E+03	1.2E+01	1.9E+01	2.58E+03	Inhale

Note: The above values must be multiplied by the volume of waste exhumed.

Intruder Scenarios at 500 Years -- NUREG/CR-5512 -- NO LEACHING
Effective Dose Equivalent, mrem/yr per Ci exhumed

Nuclide	Inhale	Extern	Soil Ing	Root Up	Rain Sp	Case Totals	Maximum Pathway
H-3	4.1E-17	2.5E-20	2.2E-15	0.0E+00	4.2E-17	2.27E-15	Soil Ing
Be-10	2.8E-01	5.7E-01	2.7E-01	8.9E-02	5.1E-03	1.21E+00	Extern
C-14	1.6E-03	9.2E-03	1.3E-01	1.4E+01	2.4E-03	1.40E+01	Veggie
Cl-36	1.6E-02	1.1E+00	1.9E-01	2.1E+03	3.6E-03	2.10E+03	Veggie
K-40	9.6E-03	6.3E+02	1.2E+00	1.1E+02	2.3E-02	7.47E+02	Extern
Co-60	3.1E-30	2.6E-25	4.4E-29	2.3E-28	8.5E-31	2.56E-25	Extern
Ni-59	1.0E-03	1.7E-01	1.3E-02	1.5E-01	2.4E-04	3.37E-01	Extern
Ni-63	7.5E-05	7.8E-06	1.1E-03	1.3E-02	2.1E-05	1.41E-02	Veggie
Se-79	7.1E-03	7.0E-03	5.4E-01	2.1E+00	1.0E-02	2.62E+00	Veggie
Sr-90	1.0E-06	1.4E-04	4.9E-05	5.1E-03	9.2E-07	5.28E-03	Veggie
Zr-93	2.8E-01	6.9E-02	1.4E-01	4.2E-02	2.6E-03	5.29E-01	Inhale
Nb-93m	1.1E-12	3.3E-12	1.6E-12	1.6E-12	3.1E-14	7.61E-12	Extern
Nb-94	2.6E-01	6.0E+03	3.3E-01	3.1E-01	6.1E-03	5.98E+03	Extern
Mo-93	4.1E-02	3.6E-01	1.1E-01	9.0E-01	2.0E-03	1.41E+00	Veggie
Tc-99	6.0E-03	6.6E-02	8.4E-02	5.7E+01	1.6E-03	5.69E+01	Veggie
Pd-107	1.0E-02	5.4E-06	9.1E-03	6.7E-02	1.7E-04	8.69E-02	Veggie
Cd-113m	1.1E-11	5.6E-12	9.8E-11	2.7E-09	1.9E-12	2.85E-09	Veggie
Sn-121m	1.3E-05	1.2E-02	2.4E-04	2.8E-04	4.4E-06	1.28E-02	Extern
Sn-126	6.0E-02	8.5E+03	1.2E+00	1.4E+00	2.2E-02	8.53E+03	Extern
I-129	1.4E-01	7.3E+00	1.8E+01	1.3E+02	3.4E-01	1.56E+02	Veggie
Cs-135	3.6E-03	1.9E-02	4.6E-01	7.6E+00	8.6E-03	8.12E+00	Veggie
Cs-137	2.6E-07	2.4E-02	3.3E-05	5.5E-04	6.2E-07	2.47E-02	Extern
Ba-133	2.5E-17	6.4E-12	9.3E-16	3.6E-15	1.8E-17	6.43E-12	Extern
Sm-147	5.7E+01	0.0E+00	1.2E+01	8.0E+00	2.2E-01	7.65E+01	Inhale
Sm-151	4.9E-04	5.4E-05	4.7E-04	3.2E-04	8.8E-06	1.34E-03	Inhale
Eu-150	1.4E-05	4.3E-01	2.6E-05	1.8E-05	4.9E-07	4.29E-01	Extern
Eu-152	1.5E-12	3.9E-08	3.3E-12	2.2E-12	6.2E-14	3.91E-08	Extern
Eu-154	1.6E-18	3.7E-14	4.5E-18	3.1E-18	8.5E-20	3.69E-14	Extern
Gd-152	1.9E+02	0.0E+00	9.7E+00	6.7E+00	1.8E-01	2.08E+02	Inhale
Re-187	3.9E-05	0.0E+00	5.4E-04	3.6E-02	1.0E-05	3.66E-02	Veggie
Pb-210	2.9E-06	8.6E-07	7.5E-05	6.0E-05	1.4E-06	1.39E-04	Soil Ing
Bi-207	3.4E-07	2.0E-01	9.8E-06	1.1E-05	1.8E-07	1.98E-01	Extern
Po-209	2.7E-01	3.9E-01	4.3E+00	3.9E+00	8.1E-02	8.99E+00	Soil Ing
Ra-226	1.9E+01	5.9E+03	4.1E+02	3.7E+02	7.8E+00	6.69E+03	Extern
Ra-228	2.4E-24	8.5E-23	9.5E-25	7.7E-25	1.8E-26	8.91E-23	Extern
Ac-227	6.5E-04	1.7E-04	1.1E-04	1.0E-05	2.2E-06	9.40E-04	Inhale
Th-228	4.5E-77	1.1E-75	8.7E-78	8.5E-79	1.8E-79	1.20E-75	Extern
Th-229	1.5E+03	1.1E+03	2.4E+02	2.2E+01	4.5E+00	2.92E+03	Inhale
Th-230	2.6E+02	1.4E+03	1.3E+02	8.7E+01	2.4E+00	1.90E+03	Extern
Th-232	1.5E+03	1.0E+04	3.1E+02	1.3E+02	5.8E+00	1.23E+04	Extern
Pa-231	6.3E+03	1.5E+03	1.6E+03	1.3E+02	3.1E+01	9.65E+03	Inhale
U-232	6.4E+00	5.3E+01	1.1E+00	1.2E+00	2.0E-02	6.18E+01	Extern
U-233	1.8E+02	5.5E+01	2.9E+01	3.1E+01	5.5E-01	2.93E+02	Inhale
U-234	1.0E+02	2.5E-01	1.7E+01	2.9E+01	3.2E-01	1.50E+02	Inhale
U-235	1.6E+02	3.4E+02	3.3E+01	2.9E+01	6.2E-01	5.66E+02	Extern
U-236	9.6E+01	1.3E-01	1.6E+01	2.8E+01	3.0E-01	1.40E+02	Inhale
U-238	9.6E+01	9.5E+01	1.6E+01	2.7E+01	3.0E-01	2.34E+02	Inhale
Np-237	3.9E+02	9.3E+02	2.5E+02	3.8E+02	4.7E+00	1.96E+03	Extern
Pu-238	7.1E+00	1.7E-03	4.7E+00	1.3E-01	8.9E-02	1.20E+01	Inhale
Pu-239	4.0E+02	1.4E-01	2.8E+02	7.0E+00	5.2E+00	6.89E+02	Inhale
Pu-240	3.9E+02	9.0E-02	2.6E+02	6.8E+00	5.0E+00	6.63E+02	Inhale
Pu-241	6.4E+00	2.9E-01	4.5E+00	2.6E-01	8.5E-02	1.16E+01	Inhale
Pu-242	3.8E+02	6.8E-02	2.7E+02	6.8E+00	5.0E+00	6.60E+02	Inhale
Pu-244	4.0E+02	1.5E+03	2.7E+02	7.0E+00	5.1E+00	2.21E+03	Extern
Am-241	1.9E+02	8.5E+00	1.3E+02	7.6E+00	2.5E+00	3.35E+02	Inhale
Am-242m	1.0E+02	4.9E+00	6.8E+01	2.7E+00	1.3E+00	1.80E+02	Inhale
Am-243	4.0E+02	5.6E+02	2.8E+02	1.6E+01	5.3E+00	1.26E+03	Extern
Cm-243	4.8E-01	7.3E-03	3.3E-01	8.5E-03	6.2E-03	8.30E-01	Inhale
Cm-244	1.1E+00	2.5E-04	7.3E-01	1.9E-02	1.4E-02	1.83E+00	Inhale
Cm-245	6.4E+02	1.8E+02	4.4E+02	1.7E+01	8.2E+00	1.28E+03	Inhale
Cm-246	4.0E+02	5.1E-02	2.7E+02	7.3E+00	5.1E+00	6.85E+02	Inhale
Cm-247	4.0E+02	1.7E+03	2.7E+02	7.4E+00	5.2E+00	2.41E+03	Extern
Cm-248	1.5E+03	5.0E-02	1.0E+03	2.8E+01	1.9E+01	2.60E+03	Inhale

Note: The above values must be multiplied by the volume of waste exhumed.

Intruder Scenarios at 500 Years -- ORNL-5785 -- NO LEACHING
Effective Dose Equivalent, mrem/yr per Ci exhumed

Nuclide	Inhale	Extern	Soil Ing	Root Up	Rain Sp	Case Totals	Maximum Pathway
H-3	4.1E-17	2.5E-20	2.2E-15	0.0E+00	4.2E-17	2.27E-15	Soil Ing
Be-10	2.8E-01	5.7E-01	2.7E-01	8.9E-02	5.1E-03	1.21E+00	Extern
C-14	1.6E-03	9.2E-03	1.3E-01	1.4E+01	2.4E-03	1.40E+01	Veggie
Cl-36	1.6E-02	1.1E+00	1.9E-01	2.1E+03	3.6E-03	2.10E+03	Veggie
K-40	9.6E-03	6.3E+02	1.2E+00	1.1E+02	2.3E-02	7.47E+02	Extern
Co-60	3.1E-30	2.6E-25	4.4E-29	5.6E-29	8.5E-31	2.56E-25	Extern
Ni-59	1.0E-03	1.7E-01	1.3E-02	1.2E-01	2.4E-04	3.05E-01	Extern
Ni-63	7.5E-05	7.8E-06	1.1E-03	1.0E-02	2.1E-05	1.13E-02	Veggie
Se-79	7.1E-03	7.0E-03	5.4E-01	2.1E+00	1.0E-02	2.62E+00	Veggie
Sr-90	1.0E-06	1.4E-04	4.9E-05	3.2E-03	9.2E-07	3.34E-03	Veggie
Zr-93	2.8E-01	6.9E-02	1.4E-01	4.2E-02	2.6E-03	5.29E-01	Inhale
Nb-93m	1.1E-12	3.3E-12	1.6E-12	1.6E-12	3.1E-14	7.61E-12	Extern
Nb-94	2.6E-01	6.0E+03	3.3E-01	3.1E-01	6.1E-03	5.98E+03	Extern
Mo-93	4.1E-02	3.6E-01	1.1E-01	9.0E-01	2.0E-03	1.41E+00	Veggie
Tc-99	6.0E-03	6.6E-02	8.4E-02	2.7E+01	1.6E-03	2.72E+01	Veggie
Pd-107	1.0E-02	5.4E-06	9.1E-03	6.7E-02	1.7E-04	8.69E-02	Veggie
Cd-113m	1.1E-11	5.6E-12	9.8E-11	2.7E-09	1.9E-12	2.85E-09	Veggie
Sn-121m	1.3E-05	1.2E-02	2.4E-04	2.8E-04	4.4E-06	1.28E-02	Extern
Sn-126	6.0E-02	8.5E+03	1.2E+00	1.4E+00	2.2E-02	8.53E+03	Extern
I-129	1.4E-01	7.3E+00	1.8E+01	1.6E+02	3.4E-01	1.86E+02	Veggie
Cs-135	3.6E-03	1.9E-02	4.6E-01	2.4E+00	8.6E-03	2.88E+00	Veggie
Cs-137	2.6E-07	2.4E-02	3.3E-05	1.7E-04	6.2E-07	2.43E-02	Extern
Ba-133	2.5E-17	6.4E-12	9.3E-16	3.6E-15	1.8E-17	6.43E-12	Extern
Sm-147	5.7E+01	0.0E+00	1.2E+01	8.0E+00	2.2E-01	7.65E+01	Inhale
Sm-151	4.9E-04	5.4E-05	4.7E-04	3.2E-04	8.8E-06	1.34E-03	Inhale
Eu-150	1.4E-05	4.3E-01	2.6E-05	1.8E-05	4.9E-07	4.29E-01	Extern
Eu-152	1.5E-12	3.9E-08	3.3E-12	2.2E-12	6.2E-14	3.91E-08	Extern
Eu-154	1.6E-18	3.7E-14	4.5E-18	3.1E-18	8.5E-20	3.69E-14	Extern
Gd-152	1.9E+02	0.0E+00	9.7E+00	6.7E+00	1.8E-01	2.08E+02	Inhale
Re-187	3.9E-05	0.0E+00	5.4E-04	3.6E-02	1.0E-05	3.66E-02	Veggie
Pb-210	2.9E-06	8.6E-07	7.5E-05	1.3E-04	1.4E-06	2.14E-04	Veggie
Bi-207	3.4E-07	2.0E-01	9.8E-06	1.1E-05	1.8E-07	1.98E-01	Extern
Po-209	2.7E-01	3.9E-01	4.3E+00	3.7E-01	8.1E-02	5.44E+00	Soil Ing
Ra-226	1.9E+01	5.9E+03	4.1E+02	6.6E+02	7.8E+00	6.99E+03	Extern
Ra-228	2.4E-24	8.5E-23	9.5E-25	2.0E-25	1.8E-26	8.86E-23	Extern
Ac-227	6.5E-04	1.7E-04	1.1E-04	1.0E-05	2.2E-06	9.40E-04	Inhale
Th-228	4.5E-77	1.1E-75	8.7E-78	2.1E-79	1.8E-79	1.20E-75	Extern
Th-229	1.5E+03	1.1E+03	2.4E+02	5.3E+00	4.5E+00	2.91E+03	Inhale
Th-230	2.6E+02	1.4E+03	1.3E+02	1.5E+02	2.4E+00	1.96E+03	Extern
Th-232	1.5E+03	1.0E+04	3.1E+02	3.5E+01	5.8E+00	1.22E+04	Extern
Pa-231	6.3E+03	1.5E+03	1.6E+03	1.3E+02	3.1E+01	9.65E+03	Inhale
U-232	6.4E+00	5.3E+01	1.1E+00	4.6E-01	2.0E-02	6.11E+01	Extern
U-233	1.8E+02	5.5E+01	2.9E+01	1.2E+01	5.5E-01	2.74E+02	Inhale
U-234	1.0E+02	2.5E-01	1.7E+01	1.1E+01	3.2E-01	1.32E+02	Inhale
U-235	1.6E+02	3.4E+02	3.3E+01	1.2E+01	6.2E-01	5.49E+02	Extern
U-236	9.6E+01	1.3E-01	1.6E+01	1.1E+01	3.0E-01	1.23E+02	Inhale
U-238	9.6E+01	9.5E+01	1.6E+01	1.1E+01	3.0E-01	2.17E+02	Inhale
Np-237	3.9E+02	9.3E+02	2.5E+02	6.5E+02	4.7E+00	2.23E+03	Extern
Pu-238	7.1E+00	1.7E-03	4.7E+00	5.9E-02	8.9E-02	1.20E+01	Inhale
Pu-239	4.0E+02	1.4E-01	2.8E+02	3.2E+00	5.2E+00	6.85E+02	Inhale
Pu-240	3.9E+02	9.0E-02	2.6E+02	3.0E+00	5.0E+00	6.59E+02	Inhale
Pu-241	6.4E+00	2.9E-01	4.5E+00	4.4E-01	8.5E-02	1.17E+01	Inhale
Pu-242	3.8E+02	6.8E-02	2.7E+02	3.1E+00	5.0E+00	6.57E+02	Inhale
Pu-244	4.0E+02	1.5E+03	2.7E+02	3.2E+00	5.1E+00	2.21E+03	Extern
Am-241	1.9E+02	8.5E+00	1.3E+02	1.3E+01	2.5E+00	3.41E+02	Inhale
Am-242m	1.0E+02	4.9E+00	6.8E+01	3.3E+00	1.3E+00	1.81E+02	Inhale
Am-243	4.0E+02	5.6E+02	2.8E+02	2.7E+01	5.3E+00	1.28E+03	Extern
Cm-243	4.8E-01	7.3E-03	3.3E-01	4.0E-03	6.2E-03	8.26E-01	Inhale
Cm-244	1.1E+00	2.5E-04	7.3E-01	8.4E-03	1.4E-02	1.82E+00	Inhale
Cm-245	6.4E+02	1.8E+02	4.4E+02	1.8E+01	8.2E+00	1.28E+03	Inhale
Cm-246	4.0E+02	5.1E-02	2.7E+02	3.2E+00	5.1E+00	6.80E+02	Inhale
Cm-247	4.0E+02	1.7E+03	2.7E+02	3.2E+00	5.2E+00	2.40E+03	Extern
Cm-248	1.5E+03	5.0E-02	1.0E+03	1.2E+01	1.9E+01	2.58E+03	Inhale

Note: The above values must be multiplied by the volume of waste exhumed.

Ratios of NUREG to ORNL at 100 Years -- With Leaching

Nuclide	Inhale	Extern	Soil Ing	Root Up	Rain Sp	Totals
Cl-36	1.51	1.51	1.51	1.30	1.30	1.30
Co-60				4.13		
Ni-59				1.27		
Ni-63				1.27		1.24
Sr-90				1.60		1.57
Tc-99	0.55	0.55	0.55	1.41	0.67	1.41
I-129	0.78	0.78	0.78	0.71	0.87	0.72
Cs-135				3.19		2.82
Cs-137				3.19		
Pb-210				0.44		0.65
Po-209				10.59		1.65
Ra-226				0.56		
Ra-228				3.78		
Th-228				4.15		
Th-229				4.15		
Th-230				0.71		
Th-232				3.82		
U-232				2.57		
U-233				2.55		
U-234				2.54		1.11
U-235				2.51		
U-236				2.54		1.12
U-238				2.54		
Np-237				0.58		0.84
Pu-238				2.22		
Pu-239				2.22		
Pu-240				2.22		
Pu-241				0.59		
Pu-242				2.22		
Pu-244				2.22		
Am-241				0.59		
Am-242m				0.68		
Am-243				0.59		
Cm-243				2.29		
Cm-244				2.28		
Cm-245				1.45		
Cm-246				2.30		
Cm-247				2.30		
Cm-248				2.30		

Ratios of NUREG to ORNL at 300 Years -- With Leaching

Nuclide	Inhale	Extern	Soil Ing	Root Up	Rain Sp	Totals
Cl-36	1.51	1.51	1.51	1.30	1.30	1.30
Co-60				4.13		
Ni-59				1.27		
Ni-63				1.27		1.24
Sr-90				1.60		1.57
Tc-99	0.55	0.55	0.55	1.41	0.67	1.41
I-129	0.78	0.78	0.78	0.71	0.87	0.72
Cs-135				3.19		2.82
Cs-137				3.19		
Pb-210				0.44		0.65
Po-209				10.59		1.65
Ra-226				0.55		
Ra-228				3.78		
Th-228				4.15		
Th-229				4.15		
Th-230				0.60		
Th-232				3.82		
U-232				2.57		
U-233				2.56		
U-234				2.54		1.11
U-235				2.44		
U-236				2.54		1.12
U-238				2.54		
Np-237				0.58		0.84
Pu-238				2.23		
Pu-239				2.22		
Pu-240				2.22		
Pu-241				0.59		
Pu-242				2.22		
Pu-244				2.22		
Am-241				0.59		
Am-242m				0.77		
Am-243				0.59		
Cm-243				2.17		
Cm-244				2.22		
Cm-246				2.30		
Cm-247				2.30		
Cm-248				2.30		

Ratios of NUREG to ORNL at 500 Years -- With Leaching

Nuclide	Inhale	Extern	Soil Ing	Root Up	Rain Sp	Totals
Cl-36	1.51	1.51	1.51	1.30	1.30	1.30
Co-60				4.13		
Ni-59				1.27		
Ni-63				1.27		1.24
Sr-90				1.60		1.57
Tc-99	0.55	0.55	0.55	1.41	0.67	1.41
I-129	0.78	0.78	0.78	0.71	0.87	0.72
Cs-135				3.19		2.82
Cs-137				3.19		
Pb-210				0.44		0.65
Po-209				10.59		1.65
Ra-226				0.55		
Ra-228				3.78		
Th-228				4.15		
Th-229				4.15		
Th-230				0.58		
Th-232				3.82		
U-232				2.57		
U-233				2.58		
U-234				2.54		1.11
U-235				2.38		
U-236				2.54		1.12
U-238				2.54		
Np-237				0.58		0.84
Pu-238				2.24		
Pu-239				2.22		
Pu-240				2.22		
Pu-241				0.59		
Pu-242				2.22		
Pu-244				2.22		
Am-241				0.59		
Am-242m				0.82		
Am-243				0.59		
Cm-243				2.12		
Cm-244				2.22		
Cm-245				0.90		
Cm-246				2.30		
Cm-247				2.30		
Cm-248				2.30		

Ratios of NUREG to ORNL -- NO Leaching

Nuclide	Vegetable Dose Ratios 100 yr	300 yr	500 yr	Total Dose Ratios
Co-60	4.13	4.13	4.13	
Ni-59	1.27	1.27	1.27	
Ni-63	1.27	1.27	1.27	1.24
Sr-90	1.62	1.62	1.62	1.58
Tc-99	2.10	2.10	2.10	2.09
I-129	0.81	0.81	0.81	0.84
Cs-135	3.19	3.19	3.19	2.82
Cs-137	3.19	3.19	3.19	
Pb-210	0.44	0.44	0.44	0.65
Po-209	10.60	10.60	10.60	1.65
Ra-226	0.56	0.55	0.55	
Ra-228	3.78	3.78	3.78	
Th-228	4.15	4.15	4.15	
Th-229	4.15	4.15	4.15	
Th-230	0.71	0.60	0.58	
Th-232	3.82	3.82	3.82	
U-232	2.60	2.60	2.60	
U-233	2.58	2.59	2.61	1.11
U-234	2.57	2.57	2.57	1.13
U-235	2.54	2.47	2.40	
U-236	2.57	2.57	2.57	1.14
U-238	2.57	2.57	2.57	
Np-237	0.59	0.59	0.59	0.88
Pu-238	2.22	2.23	2.25	
Pu-239	2.22	2.22	2.22	
Pu-240	2.22	2.22	2.22	
Pu-241	0.59	0.59	0.59	
Pu-242	2.22	2.22	2.22	
Pu-244	2.22	2.22	2.22	
Am-241	0.59	0.59	0.59	
Am-242m	0.68	0.77	0.82	
Am-243	0.59	0.59	0.59	
Cm-243	2.29	2.17	2.12	
Cm-244	2.28	2.22	2.22	
Cm-245	1.45		0.90	
Cm-246	2.29	2.29	2.29	
Cm-247	2.29	2.29	2.29	
Cm-248	2.29	2.29	2.29	

Differences less than 10 percent are not shown.

Ratios of Non-Leaching to Leaching -- NUREG/CR-5512

100 Years Nuclide	Inhale	Extern	Soil Ing	Root Up	Rain Sp	100 Years Totals
H-3	2.69	2.69	2.69		2.07	2.68
Cl-36	1.18	1.18	1.18			
Tc-99	2.17	2.17	2.17	1.65	1.65	1.65
I-129	1.29	1.29	1.29	1.15	1.15	1.17

300 Years Nuclide	Inhale	Extern	Soil Ing	Root Up	Rain Sp	300 Years Totals
H-3	2.69	2.69	2.69		2.07	2.68
Cl-36	1.18	1.18	1.18			
Tc-99	2.17	2.17	2.17	1.65	1.65	1.65
I-129	1.29	1.29	1.29	1.15	1.15	1.17

500 Years Nuclide	Inhale	Extern	Soil Ing	Root Up	Rain Sp	500 Years Totals
H-3	2.69	2.69	2.69		2.07	2.68
Cl-36	1.18	1.18	1.18			
Tc-99	2.17	2.17	2.17	1.65	1.65	1.65
I-129	1.29	1.29	1.29	1.15	1.15	1.17

Ratios of Non-Leaching to Leaching -- ORNL-5785

Nuclide	100 Years Inhale	Extern	Soil Ing	Root Up	100 Years Rain Sp	Totals
H-3	2.69	2.69	2.69		2.07	2.68
Cl-36	1.78	1.78	1.78	1.42	1.42	1.42
Tc-99	1.20	1.20	1.20	1.11	1.11	1.11

300 Years Nuclide	Inhale	Extern	Soil Ing	Root Up	Rain Sp	300 Years Totals
H-3	2.69	2.69	2.69		2.07	2.68
Cl-36	1.78	1.78	1.78	1.42	1.42	1.42
Tc-99	1.20	1.20	1.20	1.11	1.11	1.11

500 Years Nuclide	Inhale	Extern	Soil Ing	Root Up	Rain Sp	500 Years Totals
H-3	2.69	2.69	2.69		2.07	2.68
Cl-36	1.78	1.78	1.78	1.42	1.42	1.42
Tc-99	1.20	1.20	1.20	1.11	1.11	1.11

Appendix B.

Irrigation Scenario Doses by Pathway

Irrigator Dose Factors -- NUREG/CR-5512 With Leaching

Nuclide	Inhale	Extern	Soil Ing	Water	Root Up	Rain Sp	Direct	Beef	Milk	Total Dose	Maximum Pathway
	Effective Dose Equivalent, mrem/yr per pCi/L										
H-3	1.3E-11	7.7E-15	6.9E-10	4.6E-05	1.6E-06	0.0E+00	0.0E+00	1.2E-06	3.2E-06	5.20E-05	Water
Be-10	5.7E-07	1.2E-06	5.6E-07	3.1E-03	1.8E-07	1.1E-08	2.9E-04	1.0E-04	1.3E-07	3.46E-03	Water
C-14	3.3E-09	1.9E-08	2.7E-07	1.5E-03	2.9E-05	5.0E-09	1.5E-04	1.1E-03	5.6E-04	3.35E-03	Water
Cl-36	2.8E-08	1.9E-06	3.4E-07	2.2E-03	3.7E-03	6.4E-09	2.1E-04	2.1E-02	7.4E-03	3.49E-02	Beef
K-40	1.9E-08	1.3E-03	2.5E-06	1.4E-02	2.2E-04	4.7E-08	1.3E-03	9.4E-03	4.7E-03	3.08E-02	Water
Co-60	2.3E-07	1.9E-02	3.2E-06	1.9E-02	1.6E-05	6.1E-08	1.8E-03	1.2E-02	1.8E-03	5.37E-02	Extern
Ni-59	2.1E-09	3.5E-07	2.7E-08	1.5E-04	3.1E-07	5.0E-10	1.4E-05	2.9E-05	6.8E-06	1.96E-04	Water
Ni-63	4.9E-09	5.1E-10	7.2E-08	3.9E-04	8.4E-07	1.3E-09	3.7E-05	7.8E-05	1.8E-05	5.29E-04	Water
Se-79	1.5E-08	1.4E-08	1.1E-06	6.1E-03	4.3E-06	2.1E-08	5.8E-04	3.0E-03	1.1E-03	1.07E-02	Water
Sr-90	3.8E-07	5.1E-05	1.8E-05	1.0E-01	1.9E-03	3.4E-07	9.7E-03	1.1E-03	7.6E-03	1.22E-01	Water
Zr-93	5.3E-07	3.7E-09	2.2E-07	1.2E-03	2.2E-08	4.0E-09	1.1E-04	2.4E-04	5.4E-06	1.53E-03	Water
Nb-93m	4.5E-08	1.4E-07	6.9E-08	3.9E-04	6.5E-08	1.3E-09	3.7E-05	3.2E-03	3.6E-04	3.93E-03	Beef
Nb-94	5.4E-07	1.2E-02	6.8E-07	3.7E-03	6.4E-07	1.3E-08	3.5E-04	3.0E-02	3.4E-03	5.03E-02	Beef
Mo-93	4.6E-08	6.6E-07	1.7E-07	9.5E-04	1.9E-06	3.2E-09	9.0E-05	2.2E-04	7.0E-05	1.33E-03	Water
Tc-99	5.7E-09	6.2E-08	8.0E-08	9.5E-04	5.4E-05	1.5E-09	9.0E-05	5.1E-04	1.0E-03	2.63E-03	Milk
Pd-107	2.1E-08	1.1E-11	1.9E-08	1.0E-04	1.4E-07	3.5E-10	9.7E-06	1.3E-05	4.7E-05	1.73E-04	Water
Cd-113m	2.2E-06	1.1E-06	1.9E-05	1.1E-01	5.4E-04	3.6E-07	1.0E-02	2.0E-03	5.2E-03	1.28E-01	Water
Sn-121m	1.5E-08	1.4E-05	2.6E-07	1.5E-03	3.1E-07	4.9E-09	1.4E-04	3.8E-03	6.7E-05	5.46E-03	Beef
Sn-126	1.2E-07	1.8E-02	2.4E-06	1.3E-02	2.9E-06	4.6E-08	1.3E-03	3.5E-02	6.2E-04	6.78E-02	Beef
I-129	2.3E-07	1.2E-05	2.9E-05	2.0E-01	2.1E-04	5.5E-07	1.9E-02	4.7E-02	9.4E-02	3.65E-01	Water
Cs-135	7.4E-09	3.9E-08	9.5E-07	5.2E-03	1.6E-05	1.8E-08	4.9E-04	3.4E-03	1.7E-03	1.08E-02	Water
Cs-137	5.2E-08	4.8E-03	6.6E-06	3.7E-02	1.1E-04	1.2E-07	3.5E-03	2.4E-02	1.2E-02	8.06E-02	Water
Ba-133	1.1E-08	2.8E-03	4.1E-07	2.3E-03	1.6E-06	7.7E-09	2.2E-04	1.1E-05	3.8E-05	5.45E-03	Extern
Sm-147	1.2E-04	0.0E+00	2.4E-05	1.3E-01	1.6E-05	4.5E-07	1.2E-02	2.1E-02	1.2E-04	1.66E-01	Water
Sm-151	4.7E-08	5.2E-09	4.5E-08	2.5E-04	3.1E-08	8.5E-10	2.4E-05	4.0E-05	2.3E-07	3.13E-04	Water
Eu-150	4.4E-07	1.3E-02	8.2E-07	4.5E-03	5.6E-07	1.5E-08	4.3E-04	7.4E-04	4.2E-06	1.91E-02	Extern
Eu-152	3.5E-07	9.4E-03	7.8E-07	4.4E-03	5.3E-07	1.5E-08	4.2E-04	7.1E-04	4.0E-06	1.49E-02	Extern
Eu-154	4.1E-07	9.6E-03	1.2E-06	6.6E-03	8.0E-07	2.2E-08	6.3E-04	1.1E-03	6.1E-06	1.80E-02	Extern
Gd-152	3.9E-04	0.0E+00	2.0E-05	1.1E-01	1.4E-05	3.8E-07	1.0E-02	1.2E-02	1.0E-04	1.33E-01	Water
Re-187	7.9E-11	0.0E+00	1.1E-09	6.1E-06	7.2E-08	2.0E-11	5.8E-07	1.7E-06	4.5E-07	8.82E-06	Water
Pb-210	3.4E-05	1.0E-05	8.8E-04	4.9E+00	7.0E-04	1.7E-05	4.7E-01	4.8E-02	5.7E-02	5.49E+00	Water
Bi-207	2.3E-08	1.3E-02	6.5E-07	3.6E-03	7.2E-07	1.2E-08	3.4E-04	4.7E-05	8.2E-05	1.71E-02	Extern
Po-209	1.6E-05	2.4E-05	2.7E-04	1.5E+00	2.4E-04	5.0E-06	1.4E-01	1.4E-02	2.4E-02	1.64E+00	Water
Ra-226	1.3E-05	1.5E-02	1.6E-04	8.0E-01	2.2E-04	3.0E-06	7.6E-02	6.9E-03	1.7E-02	9.19E-01	Water
Ra-228	8.6E-05	9.7E-03	1.7E-04	8.8E-01	2.2E-04	3.1E-06	8.3E-02	7.2E-03	1.8E-02	9.95E-01	Water
Ac-227	1.1E-02	2.8E-03	1.9E-03	1.1E+01	1.7E-04	3.6E-05	1.0E+00	8.7E-03	9.8E-03	1.17E+01	Water
Th-228	4.3E-04	1.1E-02	8.4E-05	5.5E-01	7.6E-06	1.6E-06	5.2E-02	1.1E-04	1.3E-04	6.14E-01	Water
Th-229	3.3E-03	2.4E-03	5.2E-04	2.9E+00	4.7E-05	9.8E-06	2.7E-01	5.6E-04	6.6E-04	3.13E+00	Water
Th-230	5.3E-04	4.4E-06	7.1E-05	3.9E-01	6.4E-06	1.3E-06	3.7E-02	7.6E-05	9.1E-05	4.24E-01	Water
Th-232	2.6E-03	5.6E-04	3.8E-04	2.0E+00	4.7E-05	7.2E-06	1.9E-01	6.0E-04	9.6E-04	2.24E+00	Water
Pa-231	2.3E-03	2.9E-04	1.5E-03	8.0E+00	9.7E-05	2.8E-05	7.6E-01	2.7E-03	1.9E-03	8.80E+00	Water
U-232	1.2E-03	2.1E-03	1.9E-04	9.5E-01	2.9E-04	3.5E-06	9.0E-02	6.2E-03	2.6E-02	1.08E+00	Water
U-233	2.1E-04	1.4E-06	3.5E-05	2.0E-01	6.1E-05	6.6E-07	1.9E-02	1.3E-03	5.4E-03	2.23E-01	Water
U-234	2.1E-04	5.0E-07	3.4E-05	1.9E-01	5.8E-05	6.4E-07	1.8E-02	1.2E-03	5.2E-03	2.15E-01	Water
U-235	1.9E-04	6.6E-04	3.3E-05	1.8E-01	5.6E-05	6.1E-07	1.7E-02	1.2E-03	5.0E-03	2.07E-01	Water
U-236	1.9E-04	2.6E-07	3.3E-05	1.8E-01	5.6E-05	6.1E-07	1.7E-02	1.2E-03	5.0E-03	2.06E-01	Water
U-238	1.9E-04	1.9E-04	3.2E-05	1.8E-01	5.4E-05	6.0E-07	1.7E-02	1.2E-03	4.9E-03	2.01E-01	Water
Np-237	7.6E-04	1.8E-03	4.9E-04	2.8E+00	7.4E-04	9.2E-06	2.7E-01	5.1E-03	6.6E-04	3.13E+00	Water
Pu-238	7.5E-04	1.7E-07	5.1E-04	2.8E+00	1.3E-05	9.5E-06	2.6E-01	4.5E-05	1.3E-05	3.04E+00	Water
Pu-239	8.4E-04	3.0E-07	5.7E-04	3.1E+00	1.5E-05	1.1E-05	3.0E-01	5.1E-05	1.4E-05	3.44E+00	Water
Pu-240	8.4E-04	2.0E-07	5.7E-04	3.1E+00	1.5E-05	1.1E-05	3.0E-01	5.1E-05	1.4E-05	3.44E+00	Water
Pu-241	1.7E-05	5.8E-08	1.2E-05	6.3E-02	3.1E-07	2.2E-07	6.0E-03	1.2E-06	3.1E-07	6.88E-02	Water
Pu-242	7.9E-04	1.4E-07	5.5E-04	3.0E+00	1.4E-05	1.0E-05	2.8E-01	4.9E-05	1.4E-05	3.28E+00	Water
Pu-244	7.9E-04	3.1E-03	5.3E-04	2.9E+00	1.4E-05	1.0E-05	2.8E-01	4.8E-05	1.3E-05	3.20E+00	Water
Am-241	8.5E-04	3.8E-05	6.0E-04	3.3E+00	3.5E-05	1.1E-05	3.1E-01	3.7E-04	6.0E-05	3.60E+00	Water
Am-242m	8.8E-04	9.7E-05	5.7E-04	3.1E+00	3.3E-05	1.1E-05	3.0E-01	3.6E-04	5.8E-05	3.43E+00	Water
Am-243	8.5E-04	1.2E-03	6.0E-04	3.3E+00	3.5E-05	1.1E-05	3.1E-01	3.7E-04	6.0E-05	3.60E+00	Water
Cm-243	5.7E-04	7.7E-04	3.8E-04	2.1E+00	1.0E-05	7.2E-06	2.0E-01	2.4E-04	1.9E-03	2.32E+00	Water
Cm-244	4.3E-04	1.3E-07	3.0E-04	1.7E+00	8.1E-06	5.7E-06	1.6E-01	1.9E-04	1.5E-03	1.84E+00	Water
Cm-245	8.9E-04	3.5E-04	6.0E-04	3.3E+00	1.6E-05	1.1E-05	3.1E-01	3.7E-04	3.0E-03	3.60E+00	Water
Cm-246	8.9E-04	1.1E-07	6.0E-04	3.3E+00	1.6E-05	1.1E-05	3.1E-01	3.7E-04	3.0E-03	3.60E+00	Water
Cm-247	8.0E-04	3.5E-03	5.5E-04	3.0E+00	1.5E-05	1.0E-05	2.8E-01	3.4E-04	2.8E-03	3.29E+00	Water
Cm-248	3.1E-03	1.0E-07	2.1E-03	1.2E+01	5.8E-05	4.0E-05	1.1E+00	1.3E-03	1.1E-02	1.28E+01	Water

Irrigator Dose Factors -- ORNL-5785 With Leaching

	Effective Dose Equivalent, mrem/yr per pCi/L										
Nuclide	Inhale	Extern	Soil Ing	Water	Root Up	Rain Sp	Direct	Beef	Milk	Total Dose	Maximum Pathway
H-3	1.3E-11	7.7E-15	6.9E-10	4.6E-05	1.6E-06	0.0E+00	0.0E+00	1.2E-06	3.2E-06	5.20E-05	Water
Be-10	5.7E-07	1.2E-06	5.6E-07	3.1E-03	1.8E-07	1.1E-08	2.9E-04	1.0E-04	1.3E-07	3.46E-03	Water
C-14	3.3E-09	1.9E-08	2.7E-07	1.5E-03	2.9E-05	5.0E-09	1.5E-04	1.1E-03	5.6E-04	3.35E-03	Water
Cl-36	1.8E-08	1.3E-06	2.3E-07	2.2E-03	2.4E-03	4.2E-09	2.1E-04	1.8E-02	6.2E-03	2.94E-02	Beef
K-40	1.9E-08	1.2E-03	2.4E-06	1.4E-02	2.2E-04	4.5E-08	1.3E-03	9.4E-03	4.7E-03	3.07E-02	Water
Co-60	2.3E-07	1.9E-02	3.2E-06	1.9E-02	4.0E-06	6.1E-08	1.8E-03	1.2E-02	1.7E-03	5.37E-02	Extern
Ni-59	2.1E-09	3.5E-07	2.7E-08	1.5E-04	2.5E-07	5.0E-10	1.4E-05	2.9E-05	6.7E-06	1.96E-04	Water
Ni-63	4.9E-09	5.1E-10	7.2E-08	3.9E-04	6.6E-07	1.3E-09	3.7E-05	7.7E-05	1.8E-05	5.28E-04	Water
Se-79	1.5E-08	1.4E-08	1.1E-06	6.1E-03	4.3E-06	2.1E-08	5.8E-04	3.0E-03	1.1E-03	1.07E-02	Water
Sr-90	3.8E-07	5.2E-05	1.8E-05	1.0E-01	1.2E-03	3.4E-07	9.7E-03	1.1E-03	7.9E-03	1.22E-01	Water
Zr-93	5.3E-07	3.7E-09	2.2E-07	1.2E-03	2.2E-08	4.0E-09	1.1E-04	2.4E-04	5.4E-06	1.53E-03	Water
Nb-93m	4.5E-08	1.4E-07	6.9E-08	3.9E-04	6.5E-08	1.3E-09	3.7E-05	3.2E-03	3.6E-04	3.93E-03	Beef
Nb-94	5.4E-07	1.2E-02	6.8E-07	3.7E-03	6.4E-07	1.3E-08	3.5E-04	3.0E-02	3.4E-03	5.04E-02	Beef
Mo-93	4.6E-08	6.7E-07	1.7E-07	9.5E-04	1.9E-06	3.2E-09	9.0E-05	2.2E-04	7.0E-05	1.33E-03	Water
Tc-99	1.0E-08	1.1E-07	1.4E-07	9.5E-04	4.6E-05	2.7E-09	9.0E-05	3.4E-04	6.2E-04	2.05E-03	Water
Pd-107	2.1E-08	1.1E-11	1.9E-08	1.0E-04	1.4E-07	3.5E-10	9.7E-06	1.3E-05	4.7E-05	1.73E-04	Water
Cd-113m	2.1E-06	1.1E-06	1.9E-05	1.1E-01	5.1E-04	3.5E-07	1.0E-02	2.0E-03	5.2E-03	1.28E-01	Water
Sn-121m	1.5E-08	1.4E-05	2.6E-07	1.5E-03	3.2E-07	4.9E-09	1.4E-04	3.8E-03	6.7E-05	5.46E-03	Beef
Sn-126	1.2E-07	1.8E-02	2.4E-06	1.3E-02	2.9E-06	4.6E-08	1.3E-03	3.5E-02	6.2E-04	6.78E-02	Beef
I-129	2.9E-07	1.5E-05	3.7E-05	2.0E-01	3.3E-04	7.0E-07	1.9E-02	4.7E-02	9.5E-02	3.66E-01	Water
Cs-135	7.4E-09	3.9E-08	9.5E-07	5.2E-03	4.9E-06	1.8E-08	4.9E-04	3.4E-03	1.7E-03	1.07E-02	Water
Cs-137	5.2E-08	4.8E-03	6.6E-06	3.7E-02	3.4E-05	1.2E-07	3.5E-03	2.4E-02	1.2E-02	8.05E-02	Water
Ba-133	1.1E-08	2.8E-03	4.1E-07	2.3E-03	1.6E-06	7.7E-09	2.2E-04	1.1E-05	3.8E-05	5.45E-03	Extern
Sm-147	1.2E-04	0.0E+00	2.4E-05	1.3E-01	1.6E-05	4.5E-07	1.2E-02	2.1E-02	1.2E-04	1.66E-01	Water
Sm-151	4.7E-08	5.2E-09	4.5E-08	2.5E-04	3.1E-08	8.5E-10	2.4E-05	4.0E-05	2.3E-07	3.13E-04	Water
Eu-150	4.4E-07	1.3E-02	8.2E-07	4.5E-03	5.6E-07	1.5E-08	4.3E-04	7.4E-04	4.2E-06	1.91E-02	Extern
Eu-152	3.5E-07	9.4E-03	7.8E-07	4.4E-03	5.3E-07	1.5E-08	4.2E-04	7.1E-04	4.0E-06	1.49E-02	Extern
Eu-154	4.1E-07	9.6E-03	1.2E-06	6.6E-03	8.0E-07	2.2E-08	6.3E-04	1.1E-03	6.1E-06	1.80E-02	Extern
Gd-152	3.9E-04	0.0E+00	2.0E-05	1.1E-01	1.4E-05	3.8E-07	1.0E-02	1.2E-02	1.0E-04	1.33E-01	Water
Re-187	7.7E-11	0.0E+00	1.1E-09	6.1E-06	7.1E-08	2.0E-11	5.8E-07	1.7E-06	4.5E-07	8.82E-06	Water
Pb-210	3.4E-05	1.0E-05	8.9E-04	4.9E+00	1.6E-03	1.7E-05	4.7E-01	4.8E-02	5.7E-02	5.49E+00	Water
Bi-207	2.3E-08	1.3E-02	6.5E-07	3.6E-03	7.2E-07	1.2E-08	3.4E-04	4.7E-05	8.2E-05	1.71E-02	Extern
Po-209	1.7E-05	2.4E-05	2.7E-04	1.5E+00	2.3E-05	5.0E-06	1.4E-01	1.4E-02	2.4E-02	1.64E+00	Water
Ra-226	1.3E-05	1.5E-02	1.6E-04	8.0E-01	8.1E-05	3.0E-06	7.6E-02	6.9E-03	1.7E-02	9.18E-01	Water
Ra-228	8.6E-05	9.7E-03	1.7E-04	8.8E-01	5.8E-05	3.1E-06	8.3E-02	7.1E-03	1.8E-02	9.95E-01	Water
Ac-227	1.1E-02	2.8E-03	1.9E-03	1.1E+01	1.7E-04	3.6E-05	1.0E+00	8.7E-03	9.8E-03	1.17E+01	Water
Th-228	4.3E-04	1.1E-02	8.4E-05	5.5E-01	1.8E-06	1.6E-06	5.2E-02	1.1E-04	1.3E-04	6.14E-01	Water
Th-229	3.3E-03	2.4E-03	5.2E-04	2.9E+00	1.1E-05	9.8E-06	2.7E-01	5.6E-04	6.6E-04	3.13E+00	Water
Th-230	5.3E-04	4.4E-06	7.1E-05	3.9E-01	1.6E-06	1.3E-06	3.7E-02	7.6E-05	9.1E-05	4.24E-01	Water
Th-232	2.6E-03	5.6E-04	3.8E-04	2.0E+00	1.2E-05	7.2E-06	1.9E-01	6.0E-04	9.6E-04	2.24E+00	Water
Pa-231	2.3E-03	2.9E-04	1.5E-03	8.0E+00	9.7E-05	2.8E-05	7.6E-01	2.7E-03	1.9E-03	8.80E+00	Water
U-232	1.2E-03	2.1E-03	1.9E-04	9.5E-01	1.2E-04	3.5E-06	9.0E-02	6.2E-03	2.6E-02	1.08E+00	Water
U-233	2.1E-04	1.4E-06	3.6E-05	2.0E-01	2.4E-05	6.8E-07	1.9E-02	1.3E-03	5.4E-03	2.23E-01	Water
U-234	2.1E-04	5.1E-07	3.5E-05	1.9E-01	2.3E-05	6.5E-07	1.8E-02	1.2E-03	5.2E-03	2.15E-01	Water
U-235	2.0E-04	6.8E-04	3.3E-05	1.8E-01	2.2E-05	6.3E-07	1.7E-02	1.2E-03	5.0E-03	2.07E-01	Water
U-236	2.0E-04	2.6E-07	3.3E-05	1.8E-01	2.2E-05	6.3E-07	1.7E-02	1.2E-03	5.0E-03	2.06E-01	Water
U-238	2.0E-04	1.9E-04	3.2E-05	1.8E-01	2.2E-05	6.1E-07	1.7E-02	1.2E-03	4.9E-03	2.01E-01	Water
Np-237	8.0E-04	1.9E-03	5.2E-04	2.8E+00	1.3E-03	9.7E-06	2.7E-01	5.1E-03	6.6E-04	3.13E+00	Water
Pu-238	7.5E-04	1.7E-07	5.1E-04	2.8E+00	5.8E-06	9.5E-06	2.6E-01	4.5E-05	1.3E-05	3.04E+00	Water
Pu-239	8.4E-04	3.0E-07	5.7E-04	3.1E+00	6.6E-06	1.1E-05	3.0E-01	5.1E-05	1.4E-05	3.44E+00	Water
Pu-240	8.4E-04	2.0E-07	5.7E-04	3.1E+00	6.6E-06	1.1E-05	3.0E-01	5.1E-05	1.4E-05	3.44E+00	Water
Pu-241	1.7E-05	5.8E-08	1.2E-05	6.3E-02	1.8E-07	2.2E-07	6.0E-03	1.2E-06	3.1E-07	6.88E-02	Water
Pu-242	7.9E-04	1.4E-07	5.5E-04	3.0E+00	6.3E-06	1.0E-05	2.8E-01	4.9E-05	1.4E-05	3.28E+00	Water
Pu-244	7.9E-04	3.1E-03	5.3E-04	2.9E+00	6.1E-06	1.0E-05	2.8E-01	4.8E-05	1.3E-05	3.20E+00	Water
Am-241	8.5E-04	3.8E-05	6.0E-04	3.3E+00	5.9E-05	1.1E-05	3.1E-01	3.7E-04	6.0E-05	3.60E+00	Water
Am-242m	8.8E-04	9.7E-05	5.7E-04	3.1E+00	5.6E-05	1.1E-05	3.0E-01	3.6E-04	5.8E-05	3.43E+00	Water
Am-243	8.5E-04	1.2E-03	6.0E-04	3.3E+00	5.9E-05	1.1E-05	3.1E-01	3.7E-04	6.0E-05	3.60E+00	Water
Cm-243	5.7E-04	7.7E-04	3.8E-04	2.1E+00	4.5E-06	7.2E-06	2.0E-01	2.4E-04	1.9E-03	2.32E+00	Water
Cm-244	4.3E-04	1.3E-07	3.0E-04	1.7E+00	3.5E-06	5.6E-06	1.6E-01	1.9E-04	1.5E-03	1.84E+00	Water
Cm-245	8.9E-04	3.5E-04	6.0E-04	3.3E+00	7.1E-06	1.1E-05	3.1E-01	3.7E-04	3.0E-03	3.60E+00	Water
Cm-246	8.8E-04	1.1E-07	6.0E-04	3.3E+00	7.1E-06	1.1E-05	3.1E-01	3.7E-04	3.0E-03	3.60E+00	Water
Cm-247	8.0E-04	3.5E-03	5.5E-04	3.0E+00	6.4E-06	1.0E-05	2.8E-01	3.4E-04	2.8E-03	3.29E+00	Water
Cm-248	3.1E-03	1.0E-07	2.1E-03	1.2E+01	2.5E-05	4.0E-05	1.1E+00	1.3E-03	1.1E-02	1.28E+01	Water

Irrigator Dose Factors -- NUREG/CR-5512 Without Leaching

Nuclide	Effective Dose Equivalent, mrem/yr per pCi/L Inhale	Extern	Soil Ing	Water	Root Up	Rain Sp	Direct	Beef	Milk	Total Dose	Maximum Pathway
H-3	1.3E-11	7.7E-15	6.9E-10	4.6E-05	1.6E-06	0.0E+00	0.0E+00	1.2E-06	3.2E-06	5.20E-05	Water
Be-10	5.7E-07	1.2E-06	5.6E-07	3.1E-03	1.8E-07	1.1E-08	2.9E-04	1.0E-04	1.3E-07	3.46E-03	Water
C-14	3.4E-09	2.0E-08	2.8E-07	1.5E-03	3.0E-05	5.3E-09	1.5E-04	1.1E-03	5.6E-04	3.35E-03	Water
Cl-36	3.3E-08	2.3E-06	4.0E-07	2.2E-03	4.3E-03	7.5E-09	2.1E-04	2.3E-02	7.9E-03	3.74E-02	Beef
K-40	2.0E-08	1.3E-03	2.5E-06	1.4E-02	2.3E-04	4.8E-08	1.3E-03	9.4E-03	4.7E-03	3.08E-02	Water
Co-60	2.3E-07	1.9E-02	3.3E-06	1.9E-02	1.6E-05	6.1E-08	1.8E-03	1.2E-02	1.8E-03	5.38E-02	Extern
Ni-59	2.1E-09	3.5E-07	2.7E-08	1.5E-04	3.1E-07	5.0E-10	1.4E-05	2.9E-05	6.8E-06	1.96E-04	Water
Ni-63	4.9E-09	5.1E-10	7.2E-08	3.9E-04	8.4E-07	1.3E-09	3.7E-05	7.8E-05	1.8E-05	5.29E-04	Water
Se-79	1.5E-08	1.4E-08	1.1E-06	6.1E-03	4.3E-06	2.1E-08	5.8E-04	3.0E-03	1.1E-03	1.07E-02	Water
Sr-90	3.8E-07	5.2E-05	1.8E-05	1.0E-01	1.9E-03	3.5E-07	9.7E-03	1.1E-03	7.6E-03	1.23E-01	Water
Zr-93	5.3E-07	3.7E-09	2.2E-07	1.2E-03	2.2E-08	4.0E-09	1.1E-04	2.4E-04	5.4E-06	1.53E-03	Water
Nb-93m	4.5E-08	1.4E-07	6.9E-08	3.9E-04	6.5E-08	1.3E-09	3.7E-05	3.2E-03	3.6E-04	3.93E-03	Beef
Nb-94	5.4E-07	1.3E-02	6.8E-07	3.7E-03	6.4E-07	1.3E-08	3.5E-04	3.0E-02	3.4E-03	5.04E-02	Beef
Mo-93	4.7E-08	6.9E-07	1.8E-07	9.5E-04	2.0E-06	3.3E-09	9.0E-05	2.2E-04	7.0E-05	1.33E-03	Water
Tc-99	1.2E-08	1.4E-07	1.7E-07	9.5E-04	1.2E-04	3.3E-09	9.0E-05	6.5E-04	1.3E-03	3.14E-03	Milk
Pd-107	2.1E-08	1.1E-11	1.9E-08	1.0E-04	1.4E-07	3.5E-10	9.7E-06	1.3E-05	4.7E-05	1.73E-04	Water
Cd-113m	2.2E-06	1.1E-06	2.0E-05	1.1E-01	5.4E-04	3.7E-07	1.0E-02	2.0E-03	5.2E-03	1.28E-01	Water
Sn-121m	1.5E-08	1.4E-05	2.6E-07	1.5E-03	3.2E-07	5.0E-09	1.4E-04	3.8E-03	6.7E-05	5.46E-03	Beef
Sn-126	1.2E-07	1.8E-02	2.4E-06	1.3E-02	2.9E-06	4.6E-08	1.3E-03	3.5E-02	6.2E-04	6.78E-02	Beef
I-129	3.0E-07	1.5E-05	3.7E-05	2.0E-01	2.7E-04	7.0E-07	1.9E-02	4.7E-02	9.4E-02	3.65E-01	Water
Cs-135	7.4E-09	3.9E-08	9.5E-07	5.2E-03	1.6E-05	1.8E-08	4.9E-04	3.4E-03	1.7E-03	1.08E-02	Water
Cs-137	5.2E-08	4.8E-03	6.6E-06	3.7E-02	1.1E-04	1.2E-07	3.5E-03	2.4E-02	1.2E-02	8.06E-02	Water
Ba-133	1.1E-08	2.9E-03	4.1E-07	2.3E-03	1.6E-06	7.8E-09	2.2E-04	1.1E-05	3.8E-05	5.47E-03	Extern
Sm-147	1.2E-04	0.0E+00	2.4E-05	1.3E-01	1.6E-05	4.5E-07	1.2E-02	2.1E-02	1.2E-04	1.66E-01	Water
Sm-151	4.7E-08	5.2E-09	4.5E-08	2.5E-04	3.1E-08	8.5E-10	2.4E-05	4.0E-05	2.3E-07	3.13E-04	Water
Eu-150	4.4E-07	1.3E-02	8.2E-07	4.5E-03	5.6E-07	1.5E-08	4.3E-04	7.4E-04	4.2E-06	1.91E-02	Extern
Eu-152	3.5E-07	9.4E-03	7.8E-07	4.4E-03	5.3E-07	1.5E-08	4.2E-04	7.1E-04	4.0E-06	1.49E-02	Extern
Eu-154	4.1E-07	9.6E-03	1.2E-06	6.6E-03	8.0E-07	2.2E-08	6.3E-04	1.1E-03	6.1E-06	1.80E-02	Extern
Gd-152	3.9E-04	0.0E+00	2.0E-05	1.1E-01	1.4E-05	3.8E-07	1.0E-02	1.2E-02	1.0E-04	1.33E-01	Water
Re-187	8.0E-11	0.0E+00	1.1E-09	6.1E-06	7.4E-08	2.1E-11	5.8E-07	1.7E-06	4.5E-07	8.82E-06	Water
Pb-210	3.4E-05	1.0E-05	8.9E-04	4.9E+00	7.1E-04	1.7E-05	4.7E-01	4.8E-02	5.7E-02	5.49E+00	Water
Bi-207	2.3E-08	1.3E-02	6.5E-07	3.6E-03	7.2E-07	1.2E-08	3.4E-04	4.7E-05	8.2E-05	1.71E-02	Extern
Po-209	1.7E-05	2.4E-05	2.7E-04	1.5E+00	2.4E-04	5.0E-06	1.4E-01	1.4E-02	2.4E-02	1.64E+00	Water
Ra-226	1.4E-05	1.5E-02	1.6E-04	8.0E-01	2.2E-04	3.0E-06	7.6E-02	6.9E-03	1.7E-02	9.19E-01	Water
Ra-228	8.6E-05	9.7E-03	1.7E-04	8.8E-01	2.2E-04	3.1E-06	8.3E-02	7.2E-03	1.8E-02	9.95E-01	Water
Ac-227	1.1E-02	2.8E-03	1.9E-03	1.1E+01	1.7E-04	3.6E-05	1.0E+00	8.7E-03	9.8E-03	1.17E+01	Water
Th-228	4.3E-04	1.1E-02	8.4E-05	5.5E-01	7.6E-06	1.6E-06	5.2E-02	1.1E-04	1.3E-04	6.14E-01	Water
Th-229	3.3E-03	2.4E-03	5.2E-04	2.9E+00	4.7E-05	9.8E-06	2.7E-01	5.6E-04	6.6E-04	3.13E+00	Water
Th-230	5.3E-04	4.4E-06	7.1E-05	3.9E-01	6.4E-06	1.3E-06	3.7E-02	7.6E-05	9.1E-05	4.24E-01	Water
Th-232	2.6E-03	5.6E-04	3.8E-04	2.0E+00	4.7E-05	7.2E-06	1.9E-01	6.0E-04	9.6E-04	2.24E+00	Water
Pa-231	2.3E-03	2.9E-04	1.5E-03	8.0E+00	9.7E-05	2.8E-05	7.6E-01	2.7E-03	1.9E-03	8.80E+00	Water
U-232	1.2E-03	2.1E-03	1.9E-04	9.5E-01	3.0E-04	3.5E-06	9.0E-02	6.2E-03	2.6E-02	1.08E+00	Water
U-233	2.1E-04	1.4E-06	3.6E-05	2.0E-01	6.2E-05	6.8E-07	1.9E-02	1.3E-03	5.4E-03	2.23E-01	Water
U-234	2.1E-04	5.1E-07	3.5E-05	1.9E-01	6.0E-05	6.5E-07	1.8E-02	1.2E-03	5.2E-03	2.15E-01	Water
U-235	2.0E-04	6.8E-04	3.3E-05	1.8E-01	5.7E-05	6.3E-07	1.7E-02	1.2E-03	5.0E-03	2.07E-01	Water
U-236	2.0E-04	2.6E-07	3.3E-05	1.8E-01	5.7E-05	6.3E-07	1.7E-02	1.2E-03	5.0E-03	2.06E-01	Water
U-238	2.0E-04	1.9E-04	3.2E-05	1.8E-01	5.6E-05	6.1E-07	1.7E-02	1.2E-03	4.9E-03	2.01E-01	Water
Np-237	8.0E-04	1.9E-03	5.2E-04	2.8E+00	7.9E-04	9.8E-06	2.7E-01	5.1E-03	6.6E-04	3.13E+00	Water
Pu-238	7.5E-04	1.7E-07	5.1E-04	2.8E+00	1.3E-05	9.5E-06	2.6E-01	4.5E-05	1.3E-05	3.04E+00	Water
Pu-239	8.4E-04	3.0E-07	5.7E-04	3.1E+00	1.5E-05	1.1E-05	3.0E-01	5.1E-05	1.4E-05	3.44E+00	Water
Pu-240	8.4E-04	2.0E-07	5.7E-04	3.1E+00	1.5E-05	1.1E-05	3.0E-01	5.1E-05	1.4E-05	3.44E+00	Water
Pu-241	1.7E-05	5.8E-08	1.2E-05	6.3E-02	3.1E-07	2.2E-07	6.0E-03	1.2E-06	3.1E-07	6.88E-02	Water
Pu-242	7.9E-04	1.4E-07	5.5E-04	3.0E+00	1.4E-05	1.0E-05	2.8E-01	4.9E-05	1.4E-05	3.28E+00	Water
Pu-244	7.9E-04	3.1E-03	5.3E-04	2.9E+00	1.4E-05	1.0E-05	2.8E-01	4.8E-05	1.3E-05	3.20E+00	Water
Am-241	8.5E-04	3.8E-05	6.0E-04	3.3E+00	3.5E-05	1.1E-05	3.1E-01	3.7E-04	6.0E-05	3.60E+00	Water
Am-242m	8.8E-04	9.7E-05	5.7E-04	3.1E+00	3.3E-05	1.1E-05	3.0E-01	3.6E-04	5.8E-05	3.43E+00	Water
Am-243	8.5E-04	1.2E-03	6.0E-04	3.3E+00	3.5E-05	1.1E-05	3.1E-01	3.7E-04	6.0E-05	3.60E+00	Water
Cm-243	5.7E-04	7.7E-04	3.8E-04	2.1E+00	1.0E-05	7.2E-06	2.0E-01	2.4E-04	1.9E-03	2.32E+00	Water
Cm-244	4.3E-04	1.3E-07	3.0E-04	1.7E+00	8.1E-06	5.7E-06	1.6E-01	1.9E-04	1.5E-03	1.84E+00	Water
Cm-245	8.9E-04	3.5E-04	6.0E-04	3.3E+00	1.6E-05	1.1E-05	3.1E-01	3.7E-04	3.0E-03	3.60E+00	Water
Cm-246	8.9E-04	1.1E-07	6.0E-04	3.3E+00	1.6E-05	1.1E-05	3.1E-01	3.7E-04	3.0E-03	3.60E+00	Water
Cm-247	8.0E-04	3.5E-03	5.5E-04	3.0E+00	1.5E-05	1.0E-05	2.8E-01	3.4E-04	2.8E-03	3.29E+00	Water
Cm-248	3.1E-03	1.0E-07	2.1E-03	1.2E+01	5.8E-05	4.0E-05	1.1E+00	1.3E-03	1.1E-02	1.28E+01	Water

Irrigator Dose Factors -- ORNL-5785 Without Leaching

Nuclide	Inhale	Extern	Soil Ing	Water	Root Up	Rain Sp	Direct	Beef	Milk	Total Dose	Maximum Pathway
	Effective Dose Equivalent, mrem/yr per pCi/L										
H-3	1.3E-11	7.7E-15	6.9E-10	4.6E-05	1.6E-06	0.0E+00	0.0E+00	1.2E-06	3.2E-06	5.20E-05	Water
Be-10	5.7E-07	1.2E-06	5.6E-07	3.1E-03	1.8E-07	1.1E-08	2.9E-04	1.0E-04	1.3E-07	3.46E-03	Water
C-14	3.4E-09	2.0E-08	2.8E-07	1.5E-03	3.0E-05	5.3E-09	1.5E-04	1.1E-03	5.6E-04	3.35E-03	Water
Cl-36	3.3E-08	2.3E-06	4.0E-07	2.2E-03	4.3E-03	7.5E-09	2.1E-04	2.3E-02	7.9E-03	3.74E-02	Beef
K-40	2.0E-08	1.3E-03	2.5E-06	1.4E-02	2.3E-04	4.8E-08	1.3E-03	9.4E-03	4.7E-03	3.08E-02	Water
Co-60	2.3E-07	1.9E-02	3.3E-06	1.9E-02	4.0E-06	6.1E-08	1.8E-03	1.2E-02	1.7E-03	5.38E-02	Extern
Ni-59	2.1E-09	3.5E-07	2.7E-08	1.5E-04	2.5E-07	5.0E-10	1.4E-05	2.9E-05	6.7E-06	1.96E-04	Water
Ni-63	4.9E-09	5.1E-10	7.2E-08	3.9E-04	6.6E-07	1.3E-09	3.7E-05	7.7E-05	1.8E-05	5.28E-04	Water
Se-79	1.5E-08	1.4E-08	1.1E-06	6.1E-03	4.3E-06	2.1E-08	5.8E-04	3.0E-03	1.1E-03	1.07E-02	Water
Sr-90	3.8E-07	5.2E-05	1.8E-05	1.0E-01	1.2E-03	3.5E-07	9.7E-03	1.1E-03	7.9E-03	1.22E-01	Water
Zr-93	5.3E-07	3.7E-09	2.2E-07	1.2E-03	2.2E-08	4.0E-09	1.1E-04	2.4E-04	5.4E-06	1.53E-03	Water
Nb-93m	4.5E-08	1.4E-07	6.9E-08	3.9E-04	6.5E-08	1.3E-09	3.7E-05	3.2E-03	3.6E-04	3.93E-03	Beef
Nb-94	5.4E-07	1.3E-02	6.8E-07	3.7E-03	6.4E-07	1.3E-08	3.5E-04	3.0E-02	3.4E-03	5.04E-02	Beef
Mo-93	4.7E-08	6.9E-07	1.8E-07	9.5E-04	2.0E-06	3.3E-09	9.0E-05	2.2E-04	7.0E-05	1.33E-03	Water
Tc-99	1.2E-08	1.4E-07	1.7E-07	9.5E-04	5.6E-05	3.3E-09	9.0E-05	3.5E-04	6.4E-04	2.08E-03	Water
Pd-107	2.1E-08	1.1E-11	1.9E-08	1.0E-04	1.4E-07	3.5E-10	9.7E-06	1.3E-05	4.7E-05	1.73E-04	Water
Cd-113m	2.2E-06	1.1E-06	2.0E-05	1.1E-01	5.4E-04	3.7E-07	1.0E-02	2.0E-03	5.2E-03	1.28E-01	Water
Sn-121m	1.5E-08	1.4E-05	2.6E-07	1.5E-03	3.2E-07	5.0E-09	1.4E-04	3.8E-03	6.7E-05	5.46E-03	Beef
Sn-126	1.2E-07	1.8E-02	2.4E-06	1.3E-02	2.9E-06	4.6E-08	1.3E-03	3.5E-02	6.2E-04	6.78E-02	Beef
I-129	3.0E-07	1.5E-05	3.7E-05	2.0E-01	3.3E-04	7.0E-07	1.9E-02	4.7E-02	9.5E-02	3.66E-01	Water
Cs-135	7.4E-09	3.9E-08	9.5E-07	5.2E-03	4.9E-06	1.8E-08	4.9E-04	3.4E-03	1.7E-03	1.07E-02	Water
Cs-137	5.2E-08	4.8E-03	6.6E-06	3.7E-02	3.4E-05	1.2E-07	3.5E-03	2.4E-02	1.2E-02	8.05E-02	Water
Ba-133	1.1E-08	2.9E-03	4.1E-07	2.3E-03	1.6E-06	7.8E-09	2.2E-04	1.1E-05	3.8E-05	5.47E-03	Extern
Sm-147	1.2E-04	0.0E+00	2.4E-05	1.3E-01	1.6E-05	4.5E-07	1.2E-02	2.1E-02	1.2E-04	1.66E-01	Water
Sm-151	4.7E-08	5.2E-09	4.5E-08	2.5E-04	3.1E-08	8.5E-10	2.4E-05	4.0E-05	2.3E-07	3.13E-04	Water
Eu-150	4.4E-07	1.3E-02	8.2E-07	4.5E-03	5.6E-07	1.5E-08	4.3E-04	7.4E-04	4.2E-06	1.91E-02	Extern
Eu-152	3.5E-07	9.4E-03	7.8E-07	4.4E-03	5.3E-07	1.5E-08	4.2E-04	7.1E-04	4.0E-06	1.49E-02	Extern
Eu-154	4.1E-07	9.6E-03	1.2E-06	6.6E-03	8.0E-07	2.2E-08	6.3E-04	1.1E-03	6.1E-06	1.80E-02	Extern
Gd-152	3.9E-04	0.0E+00	2.0E-05	1.1E-01	1.4E-05	3.8E-07	1.0E-02	1.2E-02	1.0E-04	1.33E-01	Water
Re-187	8.0E-11	0.0E+00	1.1E-09	6.1E-06	7.4E-08	2.1E-11	5.8E-07	1.7E-06	4.5E-07	8.82E-06	Water
Pb-210	3.4E-05	1.0E-05	8.9E-04	4.9E+00	1.6E-03	1.7E-05	4.7E-01	4.8E-02	5.7E-02	5.49E+00	Water
Bi-207	2.3E-08	1.3E-02	6.5E-07	3.6E-03	7.2E-07	1.2E-08	3.4E-04	4.7E-05	8.2E-05	1.71E-02	Extern
Po-209	1.7E-05	2.4E-05	2.7E-04	1.5E+00	2.3E-05	5.0E-06	1.4E-01	1.4E-02	2.4E-02	1.64E+00	Water
Ra-226	1.4E-05	1.5E-02	1.6E-04	8.0E-01	8.1E-05	3.0E-06	7.6E-02	6.9E-03	1.7E-02	9.18E-01	Water
Ra-228	8.6E-05	9.7E-03	1.7E-04	8.8E-01	5.8E-05	3.1E-06	8.3E-02	7.1E-03	1.8E-02	9.95E-01	Water
Ac-227	1.1E-02	2.8E-03	1.9E-03	1.1E+01	1.7E-04	3.6E-05	1.0E+00	8.7E-03	9.8E-03	1.17E+01	Water
Th-228	4.3E-04	1.1E-02	8.4E-05	5.5E-01	1.8E-06	1.6E-06	5.2E-02	1.1E-04	1.3E-04	6.14E-01	Water
Th-229	3.3E-03	2.4E-03	5.2E-04	2.9E+00	1.1E-05	9.8E-06	2.7E-01	5.6E-04	6.6E-04	3.13E+00	Water
Th-230	5.3E-04	4.4E-06	7.1E-05	3.9E-01	1.6E-06	1.3E-06	3.7E-02	7.6E-05	9.1E-05	4.24E-01	Water
Th-232	2.6E-03	5.6E-04	3.8E-04	2.0E+00	1.2E-05	7.2E-06	1.9E-01	6.0E-04	9.6E-04	2.24E+00	Water
Pa-231	2.3E-03	2.9E-04	1.5E-03	8.0E+00	9.7E-05	2.8E-05	7.6E-01	2.7E-03	1.9E-03	8.80E+00	Water
U-232	1.2E-03	2.1E-03	1.9E-04	9.5E-01	1.2E-04	3.5E-06	9.0E-02	6.2E-03	2.6E-02	1.08E+00	Water
U-233	2.1E-04	1.4E-06	3.6E-05	2.0E-01	2.4E-05	6.8E-07	1.9E-02	1.3E-03	5.4E-03	2.23E-01	Water
U-234	2.1E-04	5.1E-07	3.5E-05	1.9E-01	2.3E-05	6.5E-07	1.8E-02	1.2E-03	5.2E-03	2.15E-01	Water
U-235	2.0E-04	6.8E-04	3.3E-05	1.8E-01	2.2E-05	6.3E-07	1.7E-02	1.2E-03	5.0E-03	2.07E-01	Water
U-236	2.0E-04	2.6E-07	3.3E-05	1.8E-01	2.2E-05	6.3E-07	1.7E-02	1.2E-03	5.0E-03	2.06E-01	Water
U-238	2.0E-04	1.9E-04	3.2E-05	1.8E-01	2.2E-05	6.1E-07	1.7E-02	1.2E-03	4.9E-03	2.01E-01	Water
Np-237	8.0E-04	1.9E-03	5.2E-04	2.8E+00	1.3E-03	9.8E-06	2.7E-01	5.1E-03	6.6E-04	3.13E+00	Water
Pu-238	7.5E-04	1.7E-07	5.1E-04	2.8E+00	5.8E-06	9.5E-06	2.6E-01	4.5E-05	1.3E-05	3.04E+00	Water
Pu-239	8.4E-04	3.0E-07	5.7E-04	3.1E+00	6.6E-06	1.1E-05	3.0E-01	5.1E-05	1.4E-05	3.44E+00	Water
Pu-240	8.4E-04	2.0E-07	5.7E-04	3.1E+00	6.6E-06	1.1E-05	3.0E-01	5.1E-05	1.4E-05	3.44E+00	Water
Pu-241	1.7E-05	5.8E-08	1.2E-05	6.3E-02	1.8E-07	2.2E-07	6.0E-03	1.2E-06	3.1E-07	6.88E-02	Water
Pu-242	7.9E-04	1.4E-07	5.5E-04	3.0E+00	6.3E-06	1.0E-05	2.8E-01	4.9E-05	1.4E-05	3.28E+00	Water
Pu-244	7.9E-04	3.1E-03	5.3E-04	2.9E+00	6.1E-06	1.0E-05	2.8E-01	4.8E-05	1.3E-05	3.20E+00	Water
Am-241	8.5E-04	3.8E-05	6.0E-04	3.3E+00	5.9E-05	1.1E-05	3.1E-01	3.7E-04	6.0E-05	3.60E+00	Water
Am-242m	8.8E-04	9.7E-05	5.7E-04	3.1E+00	5.6E-05	1.1E-05	3.0E-01	3.6E-04	5.8E-05	3.43E+00	Water
Am-243	8.5E-04	1.2E-03	6.0E-04	3.3E+00	5.9E-05	1.1E-05	3.1E-01	3.7E-04	6.0E-05	3.60E+00	Water
Cm-243	5.7E-04	7.7E-04	3.8E-04	2.1E+00	4.5E-06	7.2E-06	2.0E-01	2.4E-04	1.9E-03	2.32E+00	Water
Cm-244	4.3E-04	1.3E-07	3.0E-04	1.7E+00	3.5E-06	5.7E-06	1.6E-01	1.9E-04	1.5E-03	1.84E+00	Water
Cm-245	8.9E-04	3.5E-04	6.0E-04	3.3E+00	7.1E-06	1.1E-05	3.1E-01	3.7E-04	3.0E-03	3.60E+00	Water
Cm-246	8.9E-04	1.1E-07	6.0E-04	3.3E+00	7.1E-06	1.1E-05	3.1E-01	3.7E-04	3.0E-03	3.60E+00	Water
Cm-247	8.0E-04	3.5E-03	5.5E-04	3.0E+00	6.4E-06	1.0E-05	2.8E-01	3.4E-04	2.8E-03	3.29E+00	Water
Cm-248	3.1E-03	1.0E-07	2.1E-03	1.2E+01	2.5E-05	4.0E-05	1.1E+00	1.3E-03	1.1E-02	1.28E+01	Water

Ratios of NUREG/CR-5512 Doses to ORNL-5785 Doses

Leaching Allowed:

Nuclide	Inhale	Extern	Soil	Root	Rain	Beef	Milk
Cl-36	1.51	1.51	1.51	1.51	1.51	1.17	1.19
Co-60				4.14			
Ni-59				1.27			
Ni-63				1.27			
Sr-90				1.60			
Tc-99	0.55	0.55	0.55	1.16	0.55	1.51	1.65
I-129	0.78	0.78	0.78	0.63	0.78		
Cs-135				3.19			
Cs-137				3.19			
Pb-210				0.44			
Po-209				10.58			
Ra-226				2.75			
Ra-228				3.76			
Th-228				4.15			
Th-229				4.15			
Th-230				4.13			
Th-232				4.03			
U-232				2.52			
U-233				2.52			
U-234				2.52			
U-235				2.52			
U-236				2.52			
U-238				2.52			
Np-237				0.56			
Pu-238				2.22			
Pu-239				2.22			
Pu-240				2.22			
Pu-241				1.79			
Pu-242				2.22			
Pu-244				2.22			
Am-241				0.59			
Am-242m				0.59			
Am-243				0.59			
Cm-243				2.30			
Cm-244				2.30			
Cm-245				2.30			
Cm-246				2.30			
Cm-247				2.30			
Cm-248				2.30			

Note: Water and Vegetable-Direct Deposition doses are identical.

Ratios of NUREG/CR-5512 Doses to ORNL-5785 Doses

Without Leaching:

Nuclide	Inhale	Extern	Soil	Root	Rain	Beef	Milk
Co-60				4.13			
Ni-59				1.27			
Ni-63				1.27			
Sr-90				1.62			
Tc-99				2.10		1.85	2.09
I-129				0.81			
Cs-135				3.19			
Cs-137				3.19			
Pb-210				0.44			
Po-209				10.60			
Ra-226				2.75			
Ra-228				3.76			
Th-228				4.15			
Th-229				4.15			
Th-230				4.13			
Th-232				4.03			
U-232				2.58			
U-233				2.57			
U-234				2.57			
U-235				2.57			
U-236				2.57			
U-238				2.57			
Np-237				0.59			
Pu-238				2.22			
Pu-239				2.22			
Pu-240				2.22			
Pu-241				1.79			
Pu-242				2.22			
Pu-244				2.22			
Am-241				0.59			
Am-242m				0.59			
Am-243				0.59			
Cm-243				2.29			
Cm-244				2.29			
Cm-245				2.29			
Cm-246				2.29			
Cm-247				2.29			
Cm-248				2.29			

Differences less than 10 percent are not shown.

Ratios of Non-Leaching to Leaching Doses

NUREG/CR-5512 Concentration Ratios:

Nuclide	Inhale	Extern	Soil	Root	Rain	Beef	Milk
Cl-36	1.18	1.18	1.18	1.18	1.18		
Tc-99	2.17	2.17	2.17	2.17	2.17	1.26	1.30
I-129	1.29	1.29	1.29	1.29	1.29		

ORNL-5785 Concentration Ratios:

Nuclide	Inhale	Extern	Soil	Root	Rain	Beef	Milk
Cl-36	1.78	1.78	1.78	1.78	1.78	1.25	1.27
Tc-99	1.20	1.20	1.20	1.20	1.20		

Differences less than 10 percent are not shown.

Appendix C.

Columbia River Population Doses by Pathway

Differences greater than 10 percent are only seen for Tc-99. The ratios of Tc-99 doses are shown on the table below.

Ratios of NUREG/CR-5512 Doses to ORNL-5785 Doses

Nuclide	Vege	Beef	Milk
Tc-99	1.21	1.84	2.07

Columbia River Dose Factors -- NUREG/CR-5512 Without Leaching

Nuclide	Effective Dose Equivalent, person-rem/yr per pCi/L Inhale	Extern	Veggie	Beef	Milk	Soil Ing	Water	Fish	Total Dose	Maximum Pathway
H-3	1.2E-07	5.2E-11	4.6E-02	1.2E-02	3.2E-02	3.5E-06	2.3E-01	9.4E-07	3.20E-01	Water
Be-10	4.2E-03	6.0E-03	7.9E+00	7.8E-01	1.0E-03	2.2E-03	1.5E+01	1.3E-04	2.40E+01	Water
C-14	2.5E-05	1.0E-04	4.7E+00	8.5E+00	4.4E+00	1.1E-03	7.7E+00	1.4E-01	2.54E+01	Beef
Cl-36	2.4E-04	1.2E-02	1.1E+02	1.8E+02	6.1E+01	1.5E-03	1.1E+01	2.3E-03	3.61E+02	Beef
K-40	1.4E-04	6.8E+00	4.1E+01	7.3E+01	3.7E+01	9.8E-03	6.9E+01	2.9E-01	2.28E+02	Beef
Co-60	1.7E-03	9.8E+01	4.9E+01	9.7E+01	1.4E+01	1.3E-02	9.5E+01	1.3E-01	3.53E+02	Extern
Ni-59	1.5E-05	1.8E-03	3.8E-01	2.3E-01	5.4E-02	1.0E-04	7.3E-01	3.0E-04	1.39E+00	Water
Ni-63	3.5E-05	2.6E-06	1.0E+00	6.1E-01	1.5E-01	2.8E-04	2.0E+00	8.1E-04	3.75E+00	Water
Se-79	1.1E-04	7.5E-05	1.6E+01	2.3E+01	8.9E+00	4.3E-03	3.0E+01	2.1E-02	7.80E+01	Water
Sr-90	2.8E-03	2.7E-01	2.9E+02	8.2E+00	6.0E+01	7.1E-02	5.1E+02	1.1E-01	8.75E+02	Water
Zr-93	3.8E-03	1.9E-05	3.0E+00	1.9E+00	4.2E-02	8.3E-04	5.8E+00	4.8E-03	1.08E+01	Water
Nb-93m	3.2E-04	7.2E-04	9.9E-01	2.5E+01	2.8E+00	2.7E-04	1.9E+00	1.6E-03	3.04E+01	Beef
Nb-94	3.9E-03	6.5E+01	9.6E+00	2.4E+02	2.7E+01	2.6E-03	1.9E+01	1.5E-02	3.57E+02	Beef
Mo-93	3.4E-04	3.6E-03	2.5E+00	1.7E+00	5.5E-01	6.8E-04	4.7E+00	1.9E-04	9.52E+00	Water
Tc-99	8.9E-05	7.0E-04	4.4E+00	5.0E+00	1.0E+01	6.7E-04	4.7E+00	2.9E-04	2.46E+01	Milk
Pd-107	1.5E-04	5.8E-08	2.7E-01	1.0E-01	3.8E-01	7.2E-05	5.1E-01	2.1E-05	1.26E+00	Water
Cd-113m	1.6E-02	5.8E-03	2.9E+02	1.6E+01	4.1E+01	7.5E-02	5.5E+02	4.5E-01	8.98E+02	Water
Sn-121m	1.1E-04	7.1E-02	3.7E+00	3.0E+01	5.3E-01	1.0E-03	7.3E+00	9.0E-02	4.13E+01	Beef
Sn-126	8.9E-04	9.1E+01	3.4E+01	2.7E+02	4.9E+00	9.4E-03	6.7E+01	8.2E-01	4.71E+02	Beef
I-129	2.1E-03	7.8E-02	5.3E+02	3.6E+02	7.5E+02	1.4E-01	1.0E+03	2.1E+00	2.67E+03	Water
Cs-135	5.3E-05	2.0E-04	1.4E+01	2.7E+01	1.3E+01	3.7E-03	2.6E+01	2.1E-01	7.95E+01	Beef
Cs-137	3.8E-04	2.5E+01	9.6E+01	1.9E+02	9.4E+01	2.5E-02	1.8E+02	1.5E+00	5.85E+02	Beef
Ba-133	7.9E-05	1.5E+01	6.0E+00	9.0E-02	3.0E-01	1.6E-03	1.2E+01	9.6E-03	3.29E+01	Extern
Sm-147	8.4E-01	0.0E+00	3.4E+02	1.7E+02	9.6E-01	9.3E-02	6.6E+02	6.8E-02	1.16E+03	Water
Sm-151	3.4E-04	2.7E-05	6.4E-01	3.2E-01	1.8E-03	1.7E-04	1.2E+00	1.3E-04	2.20E+00	Water
Eu-150	3.2E-03	6.9E+01	1.2E+01	5.8E+00	3.3E-02	3.2E-03	2.3E+01	2.3E-03	1.09E+02	Extern
Eu-152	2.5E-03	4.9E+01	1.1E+01	5.6E+00	3.2E-02	3.0E-03	2.2E+01	2.3E-03	8.74E+01	Extern
Eu-154	3.0E-03	5.0E+01	1.7E+01	8.5E+00	4.8E-02	4.5E-03	3.3E+01	3.4E-03	1.09E+02	Extern
Gd-152	2.8E+00	0.0E+00	2.8E+02	9.8E+01	8.0E-01	7.7E-02	5.5E+02	5.6E-02	9.30E+02	Water
Re-187	5.8E-07	0.0E+00	1.7E-02	1.3E-02	3.6E-03	4.3E-06	3.0E-02	1.5E-05	6.41E-02	Water
Pb-210	2.5E-01	5.3E-02	1.3E+04	3.8E+02	4.5E+02	3.4E+00	2.5E+04	7.3E+00	3.80E+04	Water
Bi-207	1.6E-04	6.8E+01	9.2E+00	3.6E-01	6.5E-01	2.5E-03	1.8E+01	1.1E-03	9.60E+01	Extern
Po-209	1.2E-01	1.2E-01	3.7E+03	1.1E+02	1.9E+02	1.0E+00	7.3E+03	1.5E+01	1.14E+04	Water
Ra-226	9.8E-02	7.8E+01	2.1E+03	5.4E+01	1.4E+02	6.2E-01	4.0E+03	1.2E+00	6.35E+03	Water
Ra-228	6.2E-01	5.0E+01	2.2E+03	5.6E+01	1.4E+02	6.4E-01	4.4E+03	1.3E+00	6.88E+03	Water
Ac-227	7.8E+01	1.5E+01	2.7E+04	6.8E+01	7.8E+01	7.4E+00	5.3E+04	5.5E+00	8.08E+04	Water
Th-228	3.1E+00	5.7E+01	1.4E+03	8.4E-01	1.0E+00	3.3E-01	2.8E+03	1.3E+00	4.23E+03	Water
Th-229	2.4E+01	1.3E+01	7.3E+03	4.4E+00	5.2E+00	2.0E+00	1.4E+04	5.9E+00	2.16E+04	Water
Th-230	3.8E+00	2.3E-02	9.9E+02	6.0E-01	7.2E-01	2.7E-01	1.9E+03	8.0E-01	2.93E+03	Water
Th-232	1.9E+01	2.9E+00	5.2E+03	4.7E+00	7.5E+00	1.5E+00	1.0E+04	4.2E+00	1.55E+04	Water
Pa-231	1.7E+01	1.5E+00	2.1E+04	2.1E+01	1.5E+01	5.8E+00	4.0E+04	1.8E+00	6.08E+04	Water
U-232	8.5E+00	1.1E+01	2.4E+03	4.8E+01	2.1E+02	7.3E-01	4.7E+03	9.7E-01	7.46E+03	Water
U-233	1.5E+00	7.3E-03	5.1E+02	1.0E+01	4.3E+01	1.4E-01	9.9E+02	2.0E-01	1.55E+03	Water
U-234	1.5E+00	2.6E-03	4.9E+02	9.7E+00	4.2E+01	1.3E-01	9.5E+02	1.9E-01	1.49E+03	Water
U-235	1.4E+00	3.5E+00	4.7E+02	9.3E+00	4.0E+01	1.3E-01	9.1E+02	1.9E-01	1.44E+03	Water
U-236	1.4E+00	1.4E-03	4.7E+02	9.3E+00	4.0E+01	1.3E-01	9.1E+02	1.9E-01	1.43E+03	Water
U-238	1.4E+00	1.0E+00	4.6E+02	9.0E+00	3.9E+01	1.3E-01	8.9E+02	1.8E-01	1.39E+03	Water
Np-237	5.8E+00	9.9E+00	7.3E+03	4.0E+01	5.2E+00	2.0E+00	1.4E+04	1.5E+01	2.16E+04	Water
Pu-238	5.4E+00	8.7E-04	7.1E+03	3.5E-01	1.0E-01	2.0E+00	1.4E+04	1.4E+01	2.10E+04	Water
Pu-239	6.0E+00	1.6E-03	8.0E+03	4.0E-01	1.1E-01	2.2E+00	1.6E+04	1.6E+01	2.38E+04	Water
Pu-240	6.0E+00	1.0E-03	8.0E+03	4.0E-01	1.1E-01	2.2E+00	1.6E+04	1.6E+01	2.38E+04	Water
Pu-241	1.2E-01	3.0E-04	1.6E+02	9.1E-03	2.5E-03	4.5E-02	3.1E+02	3.2E-01	4.75E+02	Water
Pu-242	5.7E+00	7.3E-04	7.7E+03	3.8E-01	1.1E-01	2.1E+00	1.5E+04	1.5E+01	2.27E+04	Water
Pu-244	5.7E+00	1.6E+01	7.5E+03	3.7E-01	1.1E-01	2.1E+00	1.5E+04	1.5E+01	2.21E+04	Water
Am-241	6.2E+00	2.0E-01	8.4E+03	2.9E+00	4.8E-01	2.3E+00	1.6E+04	1.7E+01	2.49E+04	Water
Am-242m	6.3E+00	5.0E-01	8.0E+03	2.8E+00	4.6E-01	2.2E+00	1.6E+04	1.6E+01	2.37E+04	Water
Am-243	6.2E+00	6.3E+00	8.4E+03	2.9E+00	4.8E-01	2.3E+00	1.6E+04	1.7E+01	2.49E+04	Water
Cm-243	4.1E+00	4.0E+00	5.4E+03	1.9E+00	1.5E+01	1.5E+00	1.1E+04	1.1E+01	1.61E+04	Water
Cm-244	3.1E+00	6.9E-04	4.3E+03	1.5E+00	1.2E+01	1.2E+00	8.4E+03	8.6E+00	1.27E+04	Water
Cm-245	6.4E+00	1.8E+00	8.4E+03	2.9E+00	2.4E+01	2.3E+00	1.6E+04	1.7E+01	2.49E+04	Water
Cm-246	6.4E+00	5.8E-04	8.4E+03	2.9E+00	2.4E+01	2.3E+00	1.6E+04	1.7E+01	2.49E+04	Water
Cm-247	5.8E+00	1.8E+01	7.7E+03	2.7E+00	2.2E+01	2.1E+00	1.5E+04	1.5E+01	2.27E+04	Water
Cm-248	2.3E+01	5.3E-04	3.0E+04	1.0E+01	8.5E+01	8.2E+00	5.8E+04	6.0E+01	8.85E+04	Water

Columbia River Dose Factors -- ORNL-5785 Without Leaching

Nuclide	Effective Dose Equivalent, person-rem/yr per pCi/L Inhale	Extern	Veggie	Beef	Milk	Soil Ing	Water	Fish	Total Dose	Maximum Pathway
H-3	1.2E-07	5.2E-11	4.6E-02	1.2E-02	3.2E-02	3.5E-06	2.3E-01	9.4E-07	3.20E-01	Water
Be-10	4.2E-03	6.0E-03	7.9E+00	7.8E-01	1.0E-03	2.2E-03	1.5E+01	1.3E-04	2.40E+01	Water
C-14	2.5E-05	1.0E-04	4.7E+00	8.5E+00	4.4E+00	1.1E-03	7.7E+00	1.4E-01	2.54E+01	Beef
Cl-36	2.4E-04	1.2E-02	1.1E+02	1.8E+02	6.1E+01	1.5E-03	1.1E+01	2.3E-03	3.61E+02	Beef
K-40	1.4E-04	6.8E+00	4.1E+01	7.3E+01	3.7E+01	9.8E-03	6.9E+01	2.9E-01	2.28E+02	Beef
Co-60	1.7E-03	9.8E+01	4.9E+01	9.7E+01	1.4E+01	1.3E-02	9.5E+01	1.3E-01	3.52E+02	Extern
Ni-59	1.5E-05	1.8E-03	3.8E-01	2.2E-01	5.3E-02	1.0E-04	7.3E-01	3.0E-04	1.39E+00	Water
Ni-63	3.5E-05	2.6E-06	1.0E+00	6.0E-01	1.4E-01	2.8E-04	2.0E+00	8.1E-04	3.75E+00	Water
Se-79	1.1E-04	7.5E-05	1.6E+01	2.3E+01	8.9E+00	4.3E-03	3.0E+01	2.1E-02	7.80E+01	Water
Sr-90	2.8E-03	2.7E-01	2.9E+02	8.5E+00	6.2E+01	7.1E-02	5.1E+02	1.1E-01	8.69E+02	Water
Zr-93	3.8E-03	1.9E-05	3.0E+00	1.9E+00	4.2E-02	8.3E-04	5.8E+00	4.8E-03	1.08E+01	Water
Nb-93m	3.2E-04	7.2E-04	9.9E-01	2.5E+01	2.8E+00	2.7E-04	1.9E+00	1.6E-03	3.04E+01	Beef
Nb-94	3.9E-03	6.5E+01	9.6E+00	2.4E+02	2.7E+01	2.6E-03	1.9E+01	1.5E-02	3.57E+02	Beef
Mo-93	3.4E-04	3.6E-03	2.5E+00	1.7E+00	5.5E-01	6.8E-04	4.7E+00	1.9E-04	9.52E+00	Water
Tc-99	8.9E-05	7.0E-04	3.7E+00	2.7E+00	5.0E+00	6.7E-04	4.7E+00	2.9E-04	1.61E+01	Milk
Pd-107	1.5E-04	5.8E-08	2.7E-01	1.0E-01	3.8E-01	7.2E-05	5.1E-01	2.1E-05	1.26E+00	Water
Cd-113m	1.6E-02	5.8E-03	2.9E+02	1.6E+01	4.1E+01	7.5E-02	5.5E+02	4.5E-01	8.98E+02	Water
Sn-121m	1.1E-04	7.1E-02	3.7E+00	3.0E+01	5.3E-01	1.0E-03	7.3E+00	9.0E-02	4.13E+01	Beef
Sn-126	8.9E-04	9.1E+01	3.4E+01	2.7E+02	4.9E+00	9.4E-03	6.7E+01	8.2E-01	4.71E+02	Beef
I-129	2.1E-03	7.8E-02	5.3E+02	3.7E+02	7.5E+02	1.4E-01	1.0E+03	2.1E+00	2.67E+03	Water
Cs-135	5.3E-05	2.0E-04	1.3E+01	2.6E+01	1.3E+01	3.7E-03	2.6E+01	2.1E-01	7.93E+01	Beef
Cs-137	3.8E-04	2.5E+01	9.4E+01	1.9E+02	9.4E+01	2.5E-02	1.8E+02	1.5E+00	5.84E+02	Beef
Ba-133	7.9E-05	1.5E+01	6.0E+00	9.0E-02	3.0E-01	1.6E-03	1.2E+01	9.6E-03	3.29E+01	Extern
Sm-147	8.4E-01	0.0E+00	3.4E+02	1.7E+02	9.6E+01	9.3E-02	6.6E+02	6.8E-02	1.16E+03	Water
Sm-151	3.4E-04	2.7E-05	6.4E-01	3.2E-01	1.8E-03	1.7E-04	1.2E+00	1.3E-04	2.20E+00	Water
Eu-150	3.2E-03	6.9E+01	1.2E+01	5.8E+00	3.3E-02	3.2E-03	2.3E+01	2.3E-03	1.09E+02	Extern
Eu-152	2.5E-03	4.9E+01	1.1E+01	5.6E+00	3.2E-02	3.0E-03	2.2E+01	2.3E-03	8.74E+01	Extern
Eu-154	3.0E-03	5.0E+01	1.7E+01	8.5E+00	4.8E-02	4.5E-03	3.3E+01	3.4E-03	1.09E+02	Extern
Gd-152	2.8E+00	0.0E+00	2.8E+02	9.8E+01	8.0E-01	7.7E-02	5.5E+02	5.6E-02	9.30E+02	Water
Re-187	5.8E-07	0.0E+00	1.7E-02	1.3E-02	3.6E-03	4.3E-06	3.0E-02	1.5E-05	6.41E-02	Water
Pb-210	2.5E-01	5.3E-02	1.3E+04	3.8E+02	4.5E+02	3.4E+00	2.5E+04	7.3E+00	3.81E+04	Water
Bi-207	1.6E-04	6.8E+01	9.2E+00	3.6E-01	6.5E-01	2.5E-03	1.8E+01	1.1E-03	9.60E+01	Extern
Po-209	1.2E-01	1.2E-01	3.7E+03	1.1E+02	1.9E+02	1.0E+00	7.3E+03	1.5E+01	1.14E+04	Water
Ra-226	9.8E-02	7.8E+01	2.1E+03	5.4E+01	1.3E+02	6.2E-01	4.0E+03	1.2E+00	6.34E+03	Water
Ra-228	6.2E-01	5.0E+01	2.2E+03	5.6E+01	1.4E+02	6.4E-01	4.4E+03	1.3E+00	6.88E+03	Water
Ac-227	7.8E+01	1.5E+01	2.7E+04	6.8E+01	7.8E+01	7.4E+00	5.3E+04	5.5E+00	8.08E+04	Water
Th-228	3.1E+00	5.7E+01	1.4E+03	8.4E-01	1.0E+00	3.3E-01	2.8E+03	1.3E+00	4.23E+03	Water
Th-229	2.4E+01	1.3E+01	7.3E+03	4.4E+00	5.2E+00	2.0E+00	1.4E+04	5.9E+00	2.16E+04	Water
Th-230	3.8E+00	2.3E-02	9.9E+02	6.0E-01	7.2E-01	2.7E-01	1.9E+03	8.0E-01	2.93E+03	Water
Th-232	1.9E+01	2.9E+00	5.2E+03	4.7E+00	7.5E+00	1.5E+00	1.0E+04	4.2E+00	1.55E+04	Water
Pa-231	1.7E+01	1.5E+00	2.1E+04	2.1E+01	1.5E+01	5.8E+00	4.0E+04	1.8E+00	6.08E+04	Water
U-232	8.5E+00	1.1E+01	2.4E+03	4.8E+01	2.1E+02	7.3E-01	4.7E+03	9.7E-01	7.46E+03	Water
U-233	1.5E+00	7.3E-03	5.1E+02	1.0E+01	4.3E+01	1.4E-01	9.9E+02	2.0E-01	1.55E+03	Water
U-234	1.5E+00	2.6E-03	4.9E+02	9.7E+00	4.2E+01	1.3E-01	9.5E+02	1.9E-01	1.49E+03	Water
U-235	1.4E+00	3.5E+00	4.7E+02	9.3E+00	4.0E+01	1.3E-01	9.1E+02	1.9E-01	1.44E+03	Water
U-236	1.4E+00	1.4E-03	4.7E+02	9.3E+00	4.0E+01	1.3E-01	9.1E+02	1.9E-01	1.43E+03	Water
U-238	1.4E+00	1.0E+00	4.6E+02	9.0E+00	3.9E+01	1.3E-01	8.9E+02	1.8E-01	1.39E+03	Water
Np-237	5.8E+00	9.9E+00	7.3E+03	4.0E+01	5.2E+00	2.0E+00	1.4E+04	1.5E+01	2.16E+04	Water
Pu-238	5.4E+00	8.7E-04	7.1E+03	3.5E-01	1.0E-01	2.0E+00	1.4E+04	1.4E+01	2.10E+04	Water
Pu-239	6.0E+00	1.6E-03	8.0E+03	4.0E-01	1.1E-01	2.2E+00	1.6E+04	1.6E+01	2.38E+04	Water
Pu-240	6.0E+00	1.0E-03	8.0E+03	4.0E-01	1.1E-01	2.2E+00	1.6E+04	1.6E+01	2.38E+04	Water
Pu-241	1.2E-01	3.0E-04	1.6E+02	9.1E-03	2.5E-03	4.5E-02	3.1E+02	3.2E-01	4.75E+02	Water
Pu-242	5.7E+00	7.3E-04	7.7E+03	3.8E-01	1.1E-01	2.1E+00	1.5E+04	1.5E+01	2.27E+04	Water
Pu-244	5.7E+00	1.6E+01	7.5E+03	3.7E-01	1.1E-01	2.1E+00	1.5E+04	1.5E+01	2.21E+04	Water
Am-241	6.2E+00	2.0E-01	8.4E+03	2.9E+00	4.8E-01	2.3E+00	1.6E+04	1.7E+01	2.49E+04	Water
Am-242m	6.3E+00	5.0E-01	8.0E+03	2.8E+00	4.6E-01	2.2E+00	1.6E+04	1.6E+01	2.37E+04	Water
Am-243	6.2E+00	6.3E+00	8.4E+03	2.9E+00	4.8E-01	2.3E+00	1.6E+04	1.7E+01	2.49E+04	Water
Cm-243	4.1E+00	4.0E+00	5.4E+03	1.9E+00	1.5E+01	1.5E+00	1.1E+04	1.1E+01	1.61E+04	Water
Cm-244	3.1E+00	6.9E-04	4.3E+03	1.5E+00	1.2E+01	1.2E+00	8.4E+03	8.6E+00	1.27E+04	Water
Cm-245	6.4E+00	1.8E+00	8.4E+03	2.9E+00	2.4E+01	2.3E+00	1.6E+04	1.7E+01	2.49E+04	Water
Cm-246	6.4E+00	5.8E-04	8.4E+03	2.9E+00	2.4E+01	2.3E+00	1.6E+04	1.7E+01	2.49E+04	Water
Cm-247	5.8E+00	1.8E+01	7.7E+03	2.7E+00	2.2E+01	2.1E+00	1.5E+04	1.5E+01	2.27E+04	Water
Cm-248	2.3E+01	5.3E-04	3.0E+04	1.0E+01	8.5E+01	8.2E+00	5.8E+04	6.0E+01	8.85E+04	Water

Appendix D.

Comparisons With GENII

Special Input Assumptions for the Comparisons

The comparisons were done using the NUREG/CR-5512 concentration ratios. In addition, since GENII does not allow input of internal dose factors, the spreadsheet used the values that are currently in GENII (Rittmann, 1993a). These were shown on Table 9.

The comparisons were done for each nuclide in the spreadsheet. Three intrusion scenarios were used: 100 year decay with leaching, 100 year decay without leaching, and 500 year decay without leaching. Two irrigation scenarios were also used, with and without leaching. Only one population dose was computed, without leaching.

To compare the parts of the vegetation model (root uptake, rain splash, and direct deposition by irrigation water), special input files (DEFAULT.IN and FTRANS.DAT) were prepared for GENII. These are shown at the end of this appendix, along with the other GENII input files. Note that asterisks mark those lines which were changed from the GENII defaults. A special version of FTRANS.DAT was used to set the leaching coefficients to zero for the non-leaching runs. The two main input files used for the intruder and irrigator comparison tables are also attached. These show the inhalation and external exposure times, as well as the food and water consumption rates.

Comparison Results

The tables below summarize the observed differences. All spreadsheet results were divided by the corresponding GENII results. Nuclides with differences less than 10 percent are not shown. If one column for a nuclide has a difference greater than 10 percent, then the other differences are also shown. In some cases, entire columns were deleted. This was true for the irrigated farm inhalation, external, soil ingestion and drinking water. Table columns are described below.

Beef - dose from ingested beef
Direct - dose from vegetation, direct deposition by irrigation water only
Extern - external dose from what is in the surface soil
Fish - dose from ingested fish
Inhale - inhalation dose
Milk - dose from ingested milk
Rain - dose from vegetation, rain splash only
Root - dose from vegetation, root uptake only
Soil - dose from soil ingestion
Total - all pathways used in a given exposure scenario
Vege - dose from ingested garden produce (sum of root, rain and direct)

For the intruder's garden, the spreadsheet computes the effect of contaminant leaching differently than GENII. The spreadsheet computes the annual dose allowing for continuous exposure during the year that leaching occurs. GENII computes the soil concentration at the end of the year and assumes this existed throughout the entire year. GENII thus underestimates the inhalation, external, and soil ingestion doses for nuclides which are mobile in the soil (H-3, Cl-36, Tc-99, I-129, and Np-237). For these nuclides the dose ratios are greater than one. Note that the dose ratios increase for the vegetable pathways (Root and Rain). This difference is due to the assumed growing period. In the spreadsheet the vegetables grow for 100 days, and then are harvested. In GENII, however, the vegetables grow for the entire year, and then are harvested. For mobile nuclides, this leads GENII to further lower the amount used in the dose calculation, and increases the dose ratios.

For the intruder's garden, the spreadsheet gives lower doses than GENII for Co-60, Ra-228, and Th-228. These dose ratios are different because GENII does not compute radioactive decay along with leaching during the year of exposure. Since these nuclides have comparatively short halflives and are not mobile, the difference is noticeable.

For the intruder's garden, the spreadsheet gives noticeably lower doses via root uptake than GENII for Ra-228, Ac-227, Th-228, and Th-229. Note that the Ra-228 difference is due to the difference in its progeny nuclide Th-228. The differences for Ac-227, Th-228 and Th-229 are due to the spreadsheet assumption that the progeny nuclides (Ra-223, Ra-224, and Ra-225) are in radioactive equilibrium with the parents. However, GENII computes the actual amounts in the plants based on the different concentration ratios. Since the radium concentration ratios are roughly an order of magnitude larger than thorium or actinium, the amount of the progeny is much greater than is assumed by the spreadsheet. Thus the GENII doses are larger and the dose ratios are less than one for some pathways.

For C-14, the vegetation doses are based on different models. The GENII result is zero, while the spreadsheet result from vegetation exceeds all other pathways for the intruder. The total doses differ by two orders of magnitude, as shown on the next page.

At 500 years of prior decay, there begins to be noticeable departures from the spreadsheet decay calculation for nuclides with short halflives. Evidently, GENII does something which introduces differences in the decay calculation after 50 or so halflives. The difference for Cm-248 external dose comes about because the spreadsheet ignores the ingrowth of U-240. The other differences are as described before.

For the irrigated farm the leaching computations are similar in both GENII and the spreadsheet. The differences shown on the tables on the second page are largely due to the different treatment of short-lived progeny nuclides. The following nuclides illustrate this: Pb-210 (Po-210), Ac-227 (Ra-223), Th-228 (Ra-224), Th-229 (Ra-225), Pu-244 (U-240), and Am-242m (Cm-242). The principal progeny nuclide is shown in parentheses. In each case, the progeny nuclide is found in the cow (or fish) in higher than equilibrium amounts. Therefore, GENII gives larger doses than the spreadsheet, since the spreadsheet assumes the progeny nuclides are always present in equilibrium amounts.

The differences for Zr-93, Tc-99, and Th-232 for Beef and Milk follow from differences in the calculation of soil leaching and progeny ingrowth during the growing period.

DOSE RATIOS (SPREADSHEET DIVIDED BY GENII) AFTER INTRUSION:
Differences less than 10 percent are not shown.

Post-Intrusion Scenario -- 100 Years -- Leaching

Nuclide	Inhale	Extern	Soil	Root	Rain	Total
H-3	4.24	4.43	4.23			4.41
C-14						108.26
Cl-36	1.15	1.14	1.16	1.25	1.31	1.25
Co-60	0.92	0.92	0.92	0.90	0.96	0.92
Tc-99	2.79	2.85	2.67	3.70	3.75	3.71
I-129	1.32	1.31	1.30	1.48	1.46	1.44
Ra-228	0.90	0.89	0.90	0.89	0.90	0.89
Ac-227	0.96	0.98	0.98	0.88		
Th-228	0.84	0.80	0.84	0.67	0.91	0.84
Th-229				0.60		
Np-237				1.11	1.10	

Post-Intrusion Scenario -- 100 Years -- NO Leaching

Nuclide	Inhale	Extern	Soil	Root	Rain	Total
C-14						103.22
Co-60	0.87	0.92	0.92	0.91	0.92	0.93
Ra-228	0.90	0.89	0.90	0.89	0.90	0.89
Ac-227				0.88		
Th-228	0.84	0.80	0.84	0.67	0.91	0.84
Th-229				0.60		

Post-Intrusion Scenario -- 500 Years -- NO Leaching

Nuclide	Inhale	Extern	Soil	Root	Rain	Total
C-14						98.35
Co-60	0.73	0.73	0.74	0.75	0.79	0.73
Cd-113m	0.89	0.93	0.89	0.96	0.96	0.94
Ra-228	0.68	0.68	0.72	0.72	0.75	0.72
Ac-227				0.84		
Th-229				0.61		
Cm-248		0.88				

DOSE RATIOS (SPREADSHEET DIVIDED BY GENII) FOR IRRIGATION SCENARIOS
Differences less than 10 percent are not shown.

Irrigated Farm Scenario -- With or Without Leaching

Nuclide	Root	Rain	Direct	Beef	Milk
C-14			0.31	1.12	0.81
Zr-93					1.25
Tc-99[1]				1.16	1.26
Ac-227	0.89				0.74
Th-228	0.77	1.11		0.85	0.044
Th-229	0.62			0.42	0.17
Th-232					1.15
Pu-244					0.28
Am-242m					0.44

[1]The Tc-99 difference only occurs if leaching is allowed.

Columbia River Population Scenario -- NO Leaching

Nuclide	Vege	Beef	Milk	Fish
C-14	0.16	1.13	0.75	
Zr-93			1.66	
Pb-210			0.84	0.36
Ac-227			0.71	
Th-228		1.16	0.065	1.27
Th-229		0.54	0.16	
Th-232			1.30	
Pu-244			0.85	
Am-242m			0.40	

Note that the total doses in all cases differed by less than 10 percent. This favorable result is follows from the fact that the dose from drinking water is larger than any other source. Thus any differences in the calculation of dose from other pathways become insignificant.

GENII Input File: DEFAULT.IN

Grout PA Parameter Values (10-Mar-94 PDR)

```
INVENTORY PARAMETERS-----------------------------------------------------------
0.037, 3.7E4, 3.7E7, 3.7E10, 1.0           NVU     Source input conversion
1.0, 0.15, 224.0                           SVU     Soil source conversion
ENVIRONMENTAL PARAMETERS-------------------------------------------------------
0.008                                      ABSHUM  Absolute humidity (kg/m3)
2                                          PRCNTI  Air dispersion conserv. flag
0.001                                      DPVRES  Deposition vel./resuspension
1.0E-9                                     LEAFRS  Leaf resuspension factor
2.0,2.0,3.0,3*0.8,3*1.0,1.5              * BIOMAS  BIOMA2 Biomass (kg/m2)
0.25                                       DEPFR2  Interception frac./irrigate
15.0                                       SURCM   Depth of surface soil (cm)
224.0                                      SLDN    Surface soil density (kg/m2)
1.5E3                                      SSLDN   Soil density (kg/m3)
True                                       HARVST  Harvest removal considered?
100.0                                    * SOLING  Soil ingested (mg/da)
14.0                                       WTIM    Weathering time (da)
1.0, 0.1, 0.1, 0.1                         TRANS   Translocation, plants
0.1, 0.1, 0.1, 0.1, 1.0, 1.0               TRANSA  Translocation, animal food
68.0, 0.12, 55.0, 0.12, 68.0, 55.0         CONSUM  Animal Consumption (kg/da)
50.0, 0.3, 60., 0.3                        DWATER  Animal drinking water (L/da)
0.0, 0.8, 1.0, 0.8                         FRACUT  Acute fresh forage by season
0.2, 0.3, 0.5, 1.0                         SHORWI  Shore width factors
0.02                                       INGWAT  Swim water ingested (L/hr)
25295.0                                    TCWS    H2O/sed. transfer (L/m2/yr)
0.4,  5.0, 4.0                             YELDBT  BIOT: Veg. prod. (kg/m2/yr)
9.41E-4, 2*7.48E-4                         TOTEXC  BIOT: Excavation (m2/m3-yr)
1.0, 0.81, 0.19, 0.02, 0.008, 0.002,       EXCAV   BIOT: Frac. soil brought to
1.0, 0.9, 0.096, 0.006, 0.0005, 0.0005,            surface from within the
1.0, 0.9, 0.096, 0.006, 0.0005, 0.0005             waste by animal excavation
270.0                                      RINH    Chronic breathing (cm3/sec)
330.0                                      RINHA   Acute breathing (cm3/sec)
10                                         NDIST   Number of distances
805.0, 2414.0, 4023.0, 5632.0, 7241.0,
12068.0, 24135.0, 40255.0, 56315.0,
72405.0                                    X       JF/chi/Q/pop grid dist. (m)
0.1, 0.25, 6*0.18, 2*0.2                   DRYFAC, DRYFA2 dry/wet ratio
METABOLIC PARAMETERS-----------------------------------------------------------
0.5, 50.0, 500.0                                          XDIV
0.5,  0.5,  0.95, 0.05,  0.8, 0.0, 0.0,   0.2, 0.0,      ADJ
0.1,  0.9,  0.5,  0.5,  0.15, 0.4, 0.4,  0.05, 0.0,
0.01, 0.99, 0.01, 0.99, 0.05, 0.4, 0.4, 0.135, 0.015

DOSE PARAMETERS----------------------------------------------------------------
0.25, 0.15, 0.12, 0.12, 0.03, 0.03, 5*0.06               WT   Weighting factors
2.0                                                      SI2I Semi-infinite/inf
===============================================================================
```

GENII Input File: DEFAULT.IN -- Special Version for Root Uptake

Grout PA with Root Uptake Only (10-Feb-94 PDR)

```
INVENTORY PARAMETERS------------------------------------------------------------
0.037, 3.7E4, 3.7E7, 3.7E10, 1.0          NVU     Source input conversion
1.0, 0.15, 224.0                          SVU     Soil source conversion
ENVIRONMENTAL PARAMETERS--------------------------------------------------------
0.008                                     ABSHUM  Absolute humidity (kg/m3)
2                                         PRCNTI  Air dispersion conserv. flag
0.001                                     DPVRES  Deposition vel./resuspension
0.0                                     * LEAFRS  Leaf resuspension factor
2.0,2.0,3.0,3*0.8,3*1.0,1.5             * BIOMAS  BIOMA2 Biomass (kg/m2)
0.0                                     * DEPFR2  Interception frac./irrigate
15.0                                      SURCM   Depth of surface soil (cm)
224.0                                     SLDN    Surface soil density (kg/m2)
1.5E3                                     SSLDN   Soil density (kg/m3)
True                                      HARVST  Harvest removal considered?
100.0                                   * SOLING  Soil ingested (mg/da)
14.0                                      WTIM    Weathering time (da)
1.0, 0.1, 0.1, 0.1                        TRANS   Translocation, plants
0.1, 0.1, 0.1, 0.1, 1.0, 1.0              TRANSA  Translocation, animal food
68.0, 0.12, 55.0, 0.12, 68.0, 55.0        CONSUM  Animal Consumption (kg/da)
50.0, 0.3, 60., 0.3                       DWATER  Animal drinking water (L/da)
0.0, 0.8, 1.0, 0.8                        FRACUT  Acute fresh forage by season
0.2, 0.3, 0.5, 1.0                        SHORWI  Shore width factors
0.02                                      INGWAT  Swim water ingested (L/hr)
25295.0                                   TCWS    H2O/sed. transfer (L/m2/yr)
0.4,  5.0, 4.0                            YELDBT  BIOT: Veg. prod. (kg/m2/yr)
9.41E-4, 2*7.48E-4                        TOTEXC  BIOT: Excavation (m2/m3-yr)
1.0, 0.81, 0.19, 0.02, 0.008, 0.002,      EXCAV   BIOT: Frac. soil brought to
1.0, 0.9, 0.096, 0.006, 0.0005, 0.0005,           surface from within the
1.0, 0.9, 0.096, 0.006, 0.0005, 0.0005            waste by animal excavation
270.0                                     RINH    Chronic breathing (cm3/sec)
330.0                                     RINHA   Acute breathing (cm3/sec)
10                                        NDIST   Number of distances
805.0, 2414.0, 4023.0, 5632.0, 7241.0,
12068.0, 24135.0, 40255.0, 56315.0,
72405.0                                   X       JF/chi/Q/pop grid dist. (m)
0.1, 0.25, 6*0.18, 2*0.2                  DRYFAC, DRYFA2 dry/wet ratio
METABOLIC PARAMETERS------------------------------------------------------------
0.5, 50.0, 500.0                                       XDIV
0.5,  0.5,  0.95, 0.05,  0.8, 0.0, 0.0,   0.2, 0.0,    ADJ
0.1,  0.9,  0.5,  0.5,  0.15, 0.4, 0.4,  0.05, 0.0,
0.01, 0.99, 0.01, 0.99, 0.05, 0.4, 0.4, 0.135, 0.015

DOSE PARAMETERS-----------------------------------------------------------------
0.25, 0.15, 0.12, 0.12, 0.03, 0.03, 5*0.06             WT   Weighting factors
2.0                                                    SI2I Semi-infinite/inf
================================================================================
```

GENII Input File: DEFAULT.IN -- Special Version for Rain Splash
Note: This must be used with the Special FTRANS.DAT that zeros all Concentration Ratios.

```
Grout PA with Rain Splash Only (10-Mar-94 PDR)

INVENTORY PARAMETERS--------------------------------------------------------
0.037, 3.7E4, 3.7E7, 3.7E10, 1.0            NVU     Source input conversion
1.0, 0.15, 224.0                            SVU     Soil source conversion
ENVIRONMENTAL PARAMETERS----------------------------------------------------
0.008                                       ABSHUM  Absolute humidity (kg/m3)
2                                           PRCNTI  Air dispersion conserv. flag
0.001                                       DPVRES  Deposition vel./resuspension
1.0E-9                                      LEAFRS  Leaf resuspension factor
2.0,2.0,3.0,3*0.8,3*1.0,1.5               * BIOMAS  BIOMA2 Biomass (kg/m2)
0.0                                       * DEPFR2  Interception frac./irrigate
15.0                                        SURCM   Depth of surface soil (cm)
224.0                                       SLDN    Surface soil density (kg/m2)
1.5E3                                       SSLDN   Soil density (kg/m3)
True                                        HARVST  Harvest removal considered?
100.0                                     * SOLING  Soil ingested (mg/da)
14.0                                        WTIM    Weathering time (da)
1.0, 0.1, 0.1, 0.1                          TRANS   Translocation, plants
0.1, 0.1, 0.1, 0.1, 1.0, 1.0                TRANSA  Translocation, animal food
68.0, 0.12, 55.0, 0.12, 68.0, 55.0          CONSUM  Animal Consumption (kg/da)
50.0, 0.3, 60., 0.3                         DWATER  Animal drinking water (L/da)
0.0, 0.8, 1.0, 0.8                          FRACUT  Acute fresh forage by season
0.2, 0.3, 0.5, 1.0                          SHORWI  Shore width factors
0.02                                        INGWAT  Swim water ingested (L/hr)
25295.0                                     TCWS    H2O/sed. transfer (L/m2/yr)
0.4,  5.0, 4.0                              YELDBT  BIOT: Veg. prod. (kg/m2/yr)
9.41E-4, 2*7.48E-4                          TOTEXC  BIOT: Excavation (m2/m3-yr)
1.0, 0.81, 0.19, 0.02, 0.008, 0.002,        EXCAV   BIOT: Frac. soil brought to
1.0, 0.9, 0.096, 0.006, 0.0005, 0.0005,             surface from within the
1.0, 0.9, 0.096, 0.006, 0.0005, 0.0005              waste by animal excavation
270.0                                       RINH    Chronic breathing (cm3/sec)
330.0                                       RINHA   Acute breathing (cm3/sec)
10                                          NDIST   Number of distances
805.0, 2414.0, 4023.0, 5632.0, 7241.0,
12068.0, 24135.0, 40255.0, 56315.0,
72405.0                                     X       JF/chi/Q/pop grid dist. (m)
0.1, 0.25, 6*0.18, 2*0.2                    DRYFAC, DRYFA2 dry/wet ratio
METABOLIC PARAMETERS--------------------------------------------------------
0.5, 50.0, 500.0                                              XDIV
0.5,  0.5,  0.95, 0.05,  0.8, 0.0, 0.0,   0.2, 0.0,          ADJ
0.1,  0.9,  0.5,  0.5,  0.15, 0.4, 0.4,  0.05, 0.0,
0.01, 0.99, 0.01, 0.99, 0.05, 0.4, 0.4, 0.135, 0.015

DOSE PARAMETERS-------------------------------------------------------------
0.25, 0.15, 0.12, 0.12, 0.03, 0.03, 5*0.06                    WT   Weighting factors
2.0                                                           SI2I Semi-infinite/inf
============================================================================
```

GENII Input File: DEFAULT.IN -- Special Version for Direct Deposition
Note: This must be used with the Special FTRANS.DAT that zeros all Concentration Ratios.

```
Grout PA with Direct Deposition Only (10-Mar-94 PDR)

INVENTORY PARAMETERS---------------------------------------------------------------
0.037, 3.7E4, 3.7E7, 3.7E10, 1.0          NVU     Source input conversion
1.0, 0.15, 224.0                          SVU     Soil source conversion
ENVIRONMENTAL PARAMETERS------------------------------------------------------------
0.008                                     ABSHUM  Absolute humidity (kg/m3)
2                                         PRCNTI  Air dispersion conserv. flag
0.001                                     DPVRES  Deposition vel./resuspension
0.0                                     * LEAFRS  Leaf resuspension factor
2.0,2.0,3.0,3*0.8,3*1.0,1.5             * BIOMAS  BIOMA2 Biomass (kg/m2)
0.25                                      DEPFR2  Interception frac./irrigate
15.0                                      SURCM   Depth of surface soil (cm)
224.0                                     SLDN    Surface soil density (kg/m2)
1.5E3                                     SSLDN   Soil density (kg/m3)
True                                      HARVST  Harvest removal considered?
100.0                                   * SOLING  Soil ingested (mg/da)
14.0                                      WTIM    Weathering time (da)
1.0, 0.1, 0.1, 0.1                        TRANS   Translocation, plants
0.1, 0.1, 0.1, 0.1, 1.0, 1.0              TRANSA  Translocation, animal food
68.0, 0.12, 55.0, 0.12, 68.0, 55.0        CONSUM  Animal Consumption (kg/da)
50.0, 0.3, 60., 0.3                       DWATER  Animal drinking water (L/da)
0.0, 0.8, 1.0, 0.8                        FRACUT  Acute fresh forage by season
0.2, 0.3, 0.5, 1.0                        SHORWI  Shore width factors
0.02                                      INGWAT  Swim water ingested (L/hr)
25295.0                                   TCWS    H2O/sed. transfer (L/m2/yr)
0.4,  5.0, 4.0                            YELDBT  BIOT: Veg. prod. (kg/m2/yr)
9.41E-4, 2*7.48E-4                        TOTEXC  BIOT: Excavation (m2/m3-yr)
1.0, 0.81, 0.19, 0.02, 0.008, 0.002,      EXCAV   BIOT: Frac. soil brought to
1.0, 0.9, 0.096, 0.006, 0.0005, 0.0005,           surface from within the
1.0, 0.9, 0.096, 0.006, 0.0005, 0.0005            waste by animal excavation
270.0                                     RINH    Chronic breathing (cm3/sec)
330.0                                     RINHA   Acute breathing (cm3/sec)
10                                        NDIST   Number of distances
805.0, 2414.0, 4023.0, 5632.0, 7241.0,
12068.0, 24135.0, 40255.0, 56315.0,
72405.0                                   X       JF/chi/Q/pop grid dist. (m)
10*0.0                                  * DRYFAC, DRYFA2 dry/wet ratio
METABOLIC PARAMETERS---------------------------------------------------------------
0.5, 50.0, 500.0                                         XDIV
0.5,  0.5,  0.95, 0.05,  0.8, 0.0, 0.0,   0.2, 0.0,      ADJ
0.1,  0.9,  0.5,  0.5,  0.15, 0.4, 0.4,  0.05, 0.0,
0.01, 0.99, 0.01, 0.99, 0.05, 0.4, 0.4, 0.135, 0.015

DOSE PARAMETERS-------------------------------------------------------------------
0.25, 0.15, 0.12, 0.12, 0.03, 0.03, 5*0.06               WT   Weighting factors
2.0                                                      SI2I Semi-infinite/inf
==================================================================================
```

GENII Input File: FTRANS.DAT with NUREG/CR-5512 Values but Zero Leaching Factors

Food Transfer Factors, NUREG/CR-5512, No Leaching (2/17/93 PDR) by Z

Ele-ment	Dep Spd m/sec	Soil-to-Plant Conc Ratios Leafy	Root	Fruit	Grain	Beef day/kg	Poultry day/kg	Milk day/L	Egg day/kg	Leach Factr
H	0	0	0	0	0	0	0	0	0	0.0
BE	0.0008	0.01	0.0015	0.0015	0.0015	0.001	0.4	9E-07	0.02	0.0
C	0	0.7	0.7	0.7	0.7	0	0	0	0	0.0
N	0.0008	30	30	30	30	0.075	0.1	0.025	0.8	0.0
F	0.0008	0.06	0.006	0.006	0.006	0.15	0.01	0.001	2	0.0
NA	0.0008	0.075	0.055	0.055	0.055	0.055	0.01	0.035	0.2	0.0
MG	0.0008	1	0.55	0.55	0.55	0.005	0.03	0.004	1.6	0.0
SI	0.0008	0.35	0.07	0.07	0.07	4E-05	0.2	2E-05	0.8	0.0
P	0.0008	3.5	3.5	3.5	3.5	0.055	0.19	0.015	10	0.0
S	0.0008	1.5	1.5	1.5	1.5	0.1	0.9	0.015	7	0.0
CL	0.0008	70	70	70	70	0.08	0.03	0.015	2	0.0
AR	0	0	0	0	0	0	0	0	0	0.0
K	0.0008	1	0.55	0.55	0.55	0.02	0.4	0.007	0.7	0.0
CA	0.0008	3.5	0.35	0.35	0.35	0.0007	0.044	0.01	0.44	0.0
SC	0.0008	0.006	0.001	0.001	0.001	0.015	0.004	5E-06	0.003	0.0
CR	0.0008	0.0075	0.0045	0.0045	0.0045	0.0055	0.2	0.0015	0.8	0.0
MN	0.0008	0.56	0.15	0.05	0.29	0.0004	0.05	0.00035	0.065	0.0
FE	0.0008	0.004	0.001	0.001	0.001	0.02	1.5	0.00025	1.3	0.0
CO	0.0008	0.081	0.04	0.007	0.0037	0.02	0.5	0.002	0.1	0.0
NI	0.0008	0.28	0.06	0.06	0.03	0.006	0.001	0.001	0.1	0.0
CU	0.0008	0.4	0.25	0.25	0.25	0.01	0.51	0.0015	0.49	0.0
ZN	0.0008	1.4	0.59	0.9	1.3	0.1	6.5	0.01	2.6	0.0
GA	0.0008	0.004	0.0004	0.0004	0.0004	0.0005	0.3	5E-05	0.8	0.0
AS	0.0008	0.04	0.006	0.006	0.006	0.002	0.83	6E-05	0.8	0.0
SE	0.0008	0.025	0.025	0.025	0.025	0.015	8.5	0.004	9.3	0.0
BR	0.01	1.5	1.5	1.5	1.5	0.025	0.004	0.02	1.6	0.0
KR	0	0	0	0	0	0	0	0	0	0.0
RB	0.0008	0.15	0.07	0.07	0.07	0.015	2	0.01	3	0.0
SR	0.0008	1.6	0.81	0.17	0.13	0.0003	0.035	0.0015	0.3	0.0
Y	0.0008	0.015	0.006	0.006	0.006	0.0003	0.01	2E-05	0.002	0.0
ZR	0.0008	0.002	0.0005	0.0005	0.0005	0.0055	6.4E-05	3E-05	0.00019	0.0
NB	0.0008	0.02	0.005	0.005	0.005	0.25	0.00031	0.02	0.0013	0.0
MO	0.0008	0.25	0.06	0.06	0.06	0.006	0.19	0.0015	0.78	0.0
TC	0.0008	44	1.1	1.5	0.73	0.0085	0.03	0.01	3	0.0
RU	0.0008	0.52	0.02	0.02	0.005	0.002	0.007	6E-07	0.006	0.0
RH	0.0008	0.15	0.04	0.04	0.04	0.002	0.5	0.01	0.1	0.0
PD	0.0008	0.15	0.04	0.04	0.04	0.004	0.0003	0.01	0.004	0.0
AG	0.0008	0.00027	0.0013	0.0008	0.1	0.003	0.5	0.02	0.5	0.0
CD	0.0008	0.55	0.15	0.15	0.15	0.00055	0.84	0.001	0.1	0.0
IN	0.0008	0.004	0.0004	0.0004	0.0004	0.008	0.3	0.0001	0.8	0.0
SN	0.0008	0.03	0.006	0.006	0.006	0.08	0.2	0.001	0.8	0.0
SB	0.0008	0.00013	0.00056	8E-05	0.03	0.001	0.006	0.0001	0.07	0.0
TE	0.0008	0.025	0.004	0.004	0.004	0.015	0.085	0.0002	5.2	0.0
I	0.01	0.0034	0.05	0.05	0.05	0.007	0.018	0.01	2.8	0.0
XE	0	0	0	0	0	0	0	0	0	0.0
CS	0.0008	0.13	0.049	0.22	0.026	0.02	4.4	0.007	0.49	0.0
BA	0.0008	0.15	0.015	0.015	0.015	0.00015	0.00081	0.00035	1.5	0.0

FTRANS.DAT, continued

LA	0.0008	0.00057	0.00064	0.004	0.004	0.0003	0.1	2E-05	0.009	0.0
CE	0.0008	0.01	0.004	0.004	0.004	0.00075	0.01	2E-05	0.005	0.0
PR	0.0008	0.01	0.004	0.004	0.004	0.0003	0.03	2E-05	0.005	0.0
ND	0.0008	0.01	0.004	0.004	0.004	0.0003	0.004	2E-05	0.0002	0.0
PM	0.0008	0.01	0.004	0.004	0.004	0.005	0.002	2E-05	0.02	0.0
SM	0.0008	0.01	0.004	0.004	0.004	0.005	0.004	2E-05	0.007	0.0
EU	0.0008	0.01	0.004	0.004	0.004	0.005	0.004	2E-05	0.007	0.0
GD	0.0008	0.01	0.004	0.004	0.004	0.0035	0.004	2E-05	0.007	0.0
TB	0.0008	0.01	0.004	0.004	0.004	0.0045	0.004	2E-05	0.007	0.0
DY	0.0008	0.01	0.004	0.004	0.004	0.0055	0.004	2E-05	0.007	0.0
HO	0.0008	0.01	0.004	0.004	0.004	0.0045	0.004	2E-05	0.007	0.0
ER	0.0008	0.01	0.004	0.004	0.004	0.004	0.004	2E-05	0.007	0.0
HF	0.0008	0.0035	0.00085	0.00085	0.00085	0.001	6E-05	5E-06	0.0002	0.0
TA	0.0008	0.01	0.0025	0.0025	0.0025	0.0006	0.0003	3E-06	0.001	0.0
W	0.0008	0.045	0.01	0.01	0.01	0.045	0.2	0.0003	0.8	0.0
RE	0.0008	1.5	0.35	0.35	0.35	0.008	0.04	0.0015	0.4	0.0
OS	0.0008	0.015	0.0035	0.0035	0.0035	0.4	0.1	0.005	0.09	0.0
IR	0.0008	0.055	0.015	0.015	0.015	0.0015	0.5	2E-06	0.1	0.0
AU	0.0008	0.4	0.1	0.1	0.1	0.008	0.5	5.5E-06	0.5	0.0
HG	0.0008	0.9	0.2	0.2	0.2	0.25	0.011	0.00045	0.2	0.0
TL	0.0008	0.004	0.0004	0.0004	0.0004	0.04	0.3	0.002	0.8	0.0
PB	0.0008	0.0058	0.0032	0.009	0.0047	0.0003	0.2	0.00025	0.8	0.0
BI	0.0008	0.035	0.005	0.005	0.005	0.0004	0.1	0.0005	0.8	0.0
PO	0.0008	0.0025	0.009	0.0004	0.0004	0.0003	0.9	0.00035	7	0.0
RN	0	0	0	0	0	0	0	0	0	0.0
RA	0.0008	0.075	0.0032	0.0061	0.0012	0.00025	0.03	0.00045	2E-05	0.0
AC	0.0008	0.0035	0.00035	0.00035	0.00035	2.5E-05	0.004	2E-05	0.002	0.0
TH	0.0008	0.0066	0.00012	8.5E-05	3.4E-05	6E-06	0.004	5E-06	0.002	0.0
PA	0.0008	0.0025	0.00025	0.00025	0.00025	1E-05	0.004	5E-06	0.002	0.0
U	0.0008	0.017	0.014	0.004	0.0013	0.0002	1.2	0.0006	0.99	0.0
NP	0.0008	0.013	0.0094	0.01	0.0027	5.5E-05	0.004	5E-06	0.002	0.0
PU	0.0008	0.00039	0.0002	4.5E-05	2.6E-05	5E-07	0.00015	1E-07	0.008	0.0
AM	0.0008	0.00058	0.00041	0.00025	5.9E-05	3.5E-06	0.0002	4E-07	0.009	0.0
CM	0.0008	0.0003	0.00024	1.5E-05	2.1E-05	3.5E-06	0.004	2E-05	0.002	0.0
CF	0.0008	0.01	0.01	0.01	0.01	0.005	0.004	7.5E-07	0.002	0.0

GENII Input File: FTRANS.DAT with Zeros for Rain Splash & Direct Deposition Only

Zero Food Transfer Factors, No Leaching (2/10/94 PDR) by atomic number

Ele-ment	Dep Spd m/sec	Soil-to-Plant Conc Ratios Leafy	Root	Fruit	Grain	Beef day/kg	Poultry day/kg	Milk day/L	Egg day/kg	Leaching Factor
H	0	0	0	0	0	0	0	0	0	0
LI	0.0008	0	0	0	0	0	0	0	0	0
BE	0.0008	0	0	0	0	0	0	0	0	0
B	0.0008	0	0	0	0	0	0	0	0	0
C	0	0	0	0	0	0	0	0	0	0
N	0.0008	0	0	0	0	0	0	0	0	0
F	0.0008	0	0	0	0	0	0	0	0	0
NE	0	0	0	0	0	0	0	0	0	0
NA	0.0008	0	0	0	0	0	0	0	0	0
MG	0.0008	0	0	0	0	0	0	0	0	0
AL	0.0008	0	0	0	0	0	0	0	0	0
SI	0.0008	0	0	0	0	0	0	0	0	0
P	0.0008	0	0	0	0	0	0	0	0	0
S	0.0008	0	0	0	0	0	0	0	0	0
CL	0.0008	0	0	0	0	0	0	0	0	0
AR	0	0	0	0	0	0	0	0	0	0
K	0.0008	0	0	0	0	0	0	0	0	0
CA	0.0008	0	0	0	0	0	0	0	0	0
SC	0.0008	0	0	0	0	0	0	0	0	0
TI	0.0008	0	0	0	0	0	0	0	0	0
V	0.0008	0	0	0	0	0	0	0	0	0
CR	0.0008	0	0	0	0	0	0	0	0	0
MN	0.0008	0	0	0	0	0	0	0	0	0
FE	0.0008	0	0	0	0	0	0	0	0	0
CO	0.0008	0	0	0	0	0	0	0	0	0
NI	0.0008	0	0	0	0	0	0	0	0	0
CU	0.0008	0	0	0	0	0	0	0	0	0
ZN	0.0008	0	0	0	0	0	0	0	0	0
GA	0.0008	0	0	0	0	0	0	0	0	0
GE	0.0008	0	0	0	0	0	0	0	0	0
AS	0.0008	0	0	0	0	0	0	0	0	0
SE	0.0008	0	0	0	0	0	0	0	0	0
BR	0.01	0	0	0	0	0	0	0	0	0
KR	0	0	0	0	0	0	0	0	0	0
RB	0.0008	0	0	0	0	0	0	0	0	0
SR	0.0008	0	0	0	0	0	0	0	0	0
Y	0.0008	0	0	0	0	0	0	0	0	0
ZR	0.0008	0	0	0	0	0	0	0	0	0
NB	0.0008	0	0	0	0	0	0	0	0	0
MO	0.0008	0	0	0	0	0	0	0	0	0
TC	0.0008	0	0	0	0	0	0	0	0	0
RU	0.0008	0	0	0	0	0	0	0	0	0
RH	0.0008	0	0	0	0	0	0	0	0	0
PD	0.0008	0	0	0	0	0	0	0	0	0
AG	0.0008	0	0	0	0	0	0	0	0	0
CD	0.0008	0	0	0	0	0	0	0	0	0
IN	0.0008	0	0	0	0	0	0	0	0	0

FTRANS.DAT, continued

SN	0.0008	0	0	0	0	0	0	0	0	0
SB	0.0008	0	0	0	0	0	0	0	0	0
TE	0.0008	0	0	0	0	0	0	0	0	0
I	0.01	0	0	0	0	0	0	0	0	0
XE	0	0	0	0	0	0	0	0	0	0
CS	0.0008	0	0	0	0	0	0	0	0	0
BA	0.0008	0	0	0	0	0	0	0	0	0
LA	0.0008	0	0	0	0	0	0	0	0	0
CE	0.0008	0	0	0	0	0	0	0	0	0
PR	0.0008	0	0	0	0	0	0	0	0	0
ND	0.0008	0	0	0	0	0	0	0	0	0
PM	0.0008	0	0	0	0	0	0	0	0	0
SM	0.0008	0	0	0	0	0	0	0	0	0
EU	0.0008	0	0	0	0	0	0	0	0	0
GD	0.0008	0	0	0	0	0	0	0	0	0
TB	0.0008	0	0	0	0	0	0	0	0	0
DY	0.0008	0	0	0	0	0	0	0	0	0
HO	0.0008	0	0	0	0	0	0	0	0	0
ER	0.0008	0	0	0	0	0	0	0	0	0
TM	0.0008	0	0	0	0	0	0	0	0	0
YB	0.0008	0	0	0	0	0	0	0	0	0
LU	0.0008	0	0	0	0	0	0	0	0	0
HF	0.0008	0	0	0	0	0	0	0	0	0
TA	0.0008	0	0	0	0	0	0	0	0	0
W	0.0008	0	0	0	0	0	0	0	0	0
RE	0.0008	0	0	0	0	0	0	0	0	0
OS	0.0008	0	0	0	0	0	0	0	0	0
IR	0.0008	0	0	0	0	0	0	0	0	0
PT	0.0008	0	0	0	0	0	0	0	0	0
AU	0.0008	0	0	0	0	0	0	0	0	0
HG	0.0008	0	0	0	0	0	0	0	0	0
TL	0.0008	0	0	0	0	0	0	0	0	0
PB	0.0008	0	0	0	0	0	0	0	0	0
BI	0.0008	0	0	0	0	0	0	0	0	0
PO	0.0008	0	0	0	0	0	0	0	0	0
AT	0.0008	0	0	0	0	0	0	0	0	0
RN	0	0	0	0	0	0	0	0	0	0
FR	0.0008	0	0	0	0	0	0	0	0	0
RA	0.0008	0	0	0	0	0	0	0	0	0
AC	0.0008	0	0	0	0	0	0	0	0	0
TH	0.0008	0	0	0	0	0	0	0	0	0
PA	0.0008	0	0	0	0	0	0	0	0	0
U	0.0008	0	0	0	0	0	0	0	0	0
NP	0.0008	0	0	0	0	0	0	0	0	0
PU	0.0008	0	0	0	0	0	0	0	0	0
AM	0.0008	0	0	0	0	0	0	0	0	0
CM	0.0008	0	0	0	0	0	0	0	0	0
BK	0.0008	0	0	0	0	0	0	0	0	0
CF	0.0008	0	0	0	0	0	0	0	0	0

GENII Input File for Intrusion Scenarios:

```
######################### Program GENII Input File ############ 8 Jul 88 ####
Title: Deep Post-Intrusion, rem/yr per Ci Exhumed
     \PID.IN                                       Created on 02-09-1994 at 07:30
OPTIONS======================== Default ===================================
T    Near-field scenario?       (Far-field)   NEAR-FIELD: narrowly-focused
F    Population dose?          (Individual)               release, single site
F    Acute release?              (Chronic)    FAR-FIELD:  wide-scale release,
     Average Individual data set used                     multiple sites
                               Complete                               Complete
TRANSPORT OPTIONS=========== Section    EXPOSURE PATHWAY OPTIONS===== Section
F  Air Transport                  1      F  Finite plume, external        5
F  Surface Water Transport        2      F  Infinite plume, external      5
F  Biotic Transport (near-field)  3,4    T  Ground, external              5
F  Waste Form Degradation (near)  3,4    F  Recreation, external          5
                                         T  Inhalation uptake             5,6
REPORT OPTIONS=======================    F  Drinking water ingestion      7,8
T  Report AEDE only                      F  Aquatic foods ingestion       7,8
F  Report by radionuclide                T  Terrestrial foods ingestion   7,9
F  Report by exposure pathway            F  Animal product ingestion      7,10
F  Debug report on screen                T  Inadvertent soil ingestion

INVENTORY ##################################################################

3      Inventory input activity units: (1-pCi  2-µCi  3-mCi  4-Ci  5-Bq)
1      Surface soil source units (1- m²  2- m3  3- kg)
       Equilibrium question goes here

       --------|----Release Terms------|----------Basic Concentrations---------|
       Use when| transport selected    | near-field scenario, optionally       |
       --------|-----------------------|---------------------------------------|
       Release |      Surface Buried   |      Surface Deep    Ground  Surface|
       Radio-  |Air   Water   Waste    |Air   Soil    Soil    Water   Water  |
       nuclide |/yr   /yr     /m3      |/m3   /unit   /m3     /L      /L     |
       --------|------- ------- -------|------- ------- ------- ------- -------|
       NB94                                           1.0E+00
       TC99                                           1.0E+00
       CS137                                          1.0E+00
       PU239                                          1.0E+00

       --------|----Derived Concentrations-----|
       Use when|  measured values are known    |
       --------|-------------------------------|
       Release |Terres. Animal  Drink   Aquatic|
       Radio-  |Plant   Product Water   Food   |
       nuclide |/kg     /kg     /L      /kg    |
       --------|------- ------- ------- -------|

TIME #######################################################################

1      Intake ends after (yr)
50     Dose calc. ends after (yr)
0      Release ends after (yr)
0      No. of years of air deposition prior to the intake period
0      No. of years of irrigation water deposition prior to the intake period

FAR-FIELD SCENARIOS (IF POPULATION DOSE) ###################################

0          Definition option: 1-Use population grid in file POP.IN
0                             2-Use total entered on this line

NEAR-FIELD SCENARIOS #######################################################

           Prior to the beginning of the intake period: (yr)
100          When was the inventory disposed?  (Package degradation starts)
0            When was LOIC?  (Biotic transport starts)
1.0        Fraction of roots in upper soil (top 15 cm)
0.0        Fraction of roots in deep soil
0.4        Manual Redistribution Factor = waste volume/garden area (meter)
1250       Source area for external dose modification factor (m²)
```

```
TRANSPORT ###################################################################
          ====AIR TRANSPORT====================================SECTION 1=====
                  0-Calculate PM              |0       Release type (0-3)
1         Option: 1-Use chi/Q or PM value     |F       Stack release (T/F)
                  2-Select MI dist & dir      |0       Stack height (m)
                  3-Specify MI dist & dir     |0       Stack flow (m3/sec)
0         Chi/Q or PM value                   |0       Stack radius (m)
0         MI sector index (1=S)               |0       Effluent temp. (C)
0         MI distance from release point (m)  |0       Building x-section (m²)
T         Use jf data, (T/F) else chi/Q grid  |0       Building height (m)

          ====SURFACE WATER TRANSPORT==========================SECTION 2=====
0         Mixing ratio model: 0-use value, 1-river, 2-lake
0         Mixing ratio, dimensionless
0         Average river flow rate for: MIXFLG=0 (m3/s), MIXFLG=1,2 (m/s),
0         Transit time to irrigation withdrawl location (hr)
          If mixing ratio model > 0:
0           Rate of effluent discharge to receiving water body (m3/s)
0           Longshore distance from release point to usage location (m)
0           Offshore distance to the water intake (m)
0           Average water depth in surface water body (m)
0           Average river width (m), MIXFLG=1 only
0           Depth of effluent discharge point to surface water (m), lake only

          ====WASTE FORM AVAILABILITY==========================SECTION 3=====
0         Waste form/package half life, (yr)
1.0       Waste thickness, (m)
5.0       Depth of soil overburden, m

          ====BIOTIC TRANSPORT OF BURIED SOURCE================SECTION 4=====
T         Consider during inventory decay/buildup period (T/F)?
T         Consider during intake period (T/F)?  | 1-Arid non agricultural
0         Pre-Intake site condition.............| 2-Humid non agricultural
                                                | 3-Agricultural

EXPOSURE ####################################################################

          ====EXTERNAL EXPOSURE================================SECTION 5=====
          Exposure time:                |  Residential irrigation:
0           Plume (hr)                  | T       Consider: (T/F)
3260.0      Soil contamination (hr)     | 0       Source: 1-ground water
0           Swimming (hr)               |                 2-surface water
0           Boating (hr)                | 0       Application rate (in/yr)
0           Shoreline activities (hr)   | 0       Duration (mo/yr)
0         Shoreline type: (1-river, 2-lake, 3-ocean, 4-tidal basin)
0         Transit time for release to reach aquatic recreation (hr)
0         Average fraction of time submersed in acute cloud (hr/person hr)

          ====INHALATION=======================================SECTION 6=====
4680.0    Hours of exposure to contamination per year
1         0-No resus-  1-Use Mass Loading        2-Use Anspaugh model
0.0001      pension      Mass loading factor (g/m3)   Top soil available (cm)

          ====INGESTION POPULATION=============================SECTION 7=====
0         Atmospheric production definition (select option):
0           0-Use food-weighted chi/Q, (food-sec/m3), enter value on this line
            1-Use population-weighted chi/Q
            2-Use uniform production
            3-Use chi/Q and production grids (PRODUCTION will be overridden)
0         Population ingesting aquatic foods, 0 defaults to total (person)
0         Population ingesting drinking water, 0 defaults to total (person)
F         Consider dose from food exported out of region (default=F)
```

Note below: S* or Source: 0-none, 1-ground water, 2-surface water
3-Derived concentration entered above

==== AQUATIC FOODS / DRINKING WATER INGESTION=========SECTION 8====

F Salt water? (default is fresh)

USE ? T/F	FOOD TYPE	TRAN-SIT hr	PROD-UCTION kg/yr	-CONSUMPTION- HOLDUP da	RATE kg/yr	DRINKING WATER	
F	FISH	0.00	0.0E+00	0.00	0.0	0	Source (see above)
F	MOLLUS	0.00	0.0E+00	0.00	0.0	T	Treatment? T/F
F	CRUSTA	0.00	0.0E+00	0.00	0.0	0	Holdup/transit(da)
F	PLANTS	0.00	0.0E+00	0.00	0.0	0	Consumption (L/yr)

====TERRESTRIAL FOOD INGESTION======================SECTION 9=====

USE ? T/F	FOOD TYPE	GROW TIME da	--IRRIGATION-- S *	RATE in/yr	TIME mo/yr	YIELD kg/m²	PROD-UCTION kg/yr	--CONSUMPTION-- HOLDUP da	RATE kg/yr
T	LEAF V	90.00	0	0.0	0.0	2.0	0.0E+00	14.0	4.1
T	ROOT V	90.00	0	0.0	0.0	2.0	0.0E+00	14.0	13.9
T	FRUIT	90.00	0	0.0	0.0	3.0	0.0E+00	14.0	9.6
T	GRAIN	90.00	0	0.0	0.0	0.8	0.0E+00	180.0	18.5

====ANIMAL PRODUCTION CONSUMPTION==================SECTION 10====

USE ? T/F	FOOD TYPE	---HUMAN---- CONSUMPTION RATE kg/yr	HOLDUP da	TOTAL PROD-UCTION kg/yr	DRINK WATER CONTAM FRACT.	------------STORED FEED------------- DIET FRAC-TION	GROW TIME da	-IRRIGATION-- S *	RATE in/yr	TIME mo/yr	YIELD kg/m3	STOR-AGE da
F	BEEF	0.0	0.0	0.00	0.00	0.00	0.0	0	0.0	0.00	0.00	0.0
F	POULTR	0.0	0.0	0.00	0.00	0.00	0.0	0	0.0	0.00	0.00	0.0
F	MILK	0.0	0.0	0.00	0.00	0.00	0.0	0	0.0	0.00	0.00	0.0
F	EGG	0.0	0.0	0.00	0.00	0.00	0.0	0	0.0	0.00	0.00	0.0
						-------------FRESH FORAGE-----------						
	BEEF					0.00	0.0	0	0.0	0.00	0.00	0.0
	MILK					0.00	0.0	0	0.0	0.00	0.00	0.0

##

GENII Input File for Irrigated Farm Scenarios:

```
######################## Program GENII Input File ########### 8 Jul 88 ####
Title: All Pathways from Ground Water
      \IRRIG.IN                                Created on 02-10-1994 at 17:39
OPTIONS======================== Default ===================================
T    Near-field scenario?       (Far-field)   NEAR-FIELD: narrowly-focused
F    Population dose?          (Individual)               release, single site
F    Acute release?             (Chronic)     FAR-FIELD:  wide-scale release,
     Average Individual data set used                     multiple sites
                               Complete                                Complete
TRANSPORT OPTIONS=========== Section   EXPOSURE PATHWAY OPTIONS===== Section
F  Air Transport                  1     F  Finite plume, external       5
F  Surface Water Transport        2     F  Infinite plume, external     5
F  Biotic Transport (near-field) 3,4    T  Ground, external             5
F  Waste Form Degradation (near) 3,4    F  Recreation, external         5
                                        T  Inhalation uptake            5,6
REPORT OPTIONS=====================     T  Drinking water ingestion     7,8
T  Report AEDE only                     F  Aquatic foods ingestion      7,8
F  Report by radionuclide               T  Terrestrial foods ingestion  7,9
F  Report by exposure pathway           T  Animal product ingestion     7,10
F  Debug report on screen               T  Inadvertent soil ingestion

INVENTORY ################################################################

 1   Inventory input activity units: (1-pCi  2-uCi  3-mCi  4-Ci  5-Bq)
 1   Surface soil source units (1- m²  2- m3  3- kg)
     Equilibrium question goes here

     --------|----Release Terms------|----------Basic Concentrations---------|
     Use when|  transport selected   |  near-field scenario, optionally      |
     --------|-----------------------|---------------------------------------|
     Release |        Surface Buried |        Surface Deep    Ground  Surface|
     Radio-  |Air     Water   Waste  |Air     Soil    Soil    Water   Water  |
     nuclide |/yr     /yr     /m3    |/m3     /unit   /m3     /L      /L     |
     --------|------- ------- -------|------- ------- ------- ------- -------|
     CO60                                                     1.0E+00
     NB94                                                     1.0E+00
     TC99                                                     1.0E+00
     CS137                                                    1.0E+00
     PU239                                                    1.0E+00

     --------|----Derived Concentrations-----|
     Use when|   measured values are known   |
     --------|-------------------------------|
     Release |Terres. Animal  Drink   Aquatic|
     Radio-  |Plant   Product Water   Food   |
     nuclide |/kg     /kg     /L      /kg    |
     --------|------- ------- ------- -------|

TIME #####################################################################

1    Intake ends after (yr)
50   Dose calc. ends after (yr)
0    Release ends after (yr)
0    No. of years of air deposition prior to the intake period
0    No. of years of irrigation water deposition prior to the intake period

FAR-FIELD SCENARIOS (IF POPULATION DOSE) #################################

0          Definition option: 1-Use population grid in file POP.IN
0                             2-Use total entered on this line

NEAR-FIELD SCENARIOS #####################################################

           Prior to the beginning of the intake period: (yr)
0            When was the inventory disposed?  (Package degradation starts)
0            When was LOIC?  (Biotic transport starts)
1.0        Fraction of roots in upper soil (top 15 cm)
0.0        Fraction of roots in deep soil
0.0        Manual Redistribution: deep soil/surface soil dilution factor
1250       Source area for external dose modification factor (m²)
```

```
TRANSPORT ###################################################################
          ====AIR TRANSPORT==================================SECTION 1=====
                  0-Calculate PM              |0         Release type (0-3)
1         Option: 1-Use chi/Q or PM value     |F         Stack release (T/F)
                  2-Select MI dist & dir      |0         Stack height (m)
                  3-Specify MI dist & dir     |0         Stack flow (m3/sec)
0         Chi/Q or PM value                   |0         Stack radius (m)
0         MI sector index (1=S)               |0         Effluent temp. (C)
0         MI distance from release point (m)|0           Building x-section (m²)
T         Use jf data, (T/F) else chi/Q grid|0           Building height (m)

          ====SURFACE WATER TRANSPORT=========================SECTION 2=====
0         Mixing ratio model: 0-use value, 1-river, 2-lake
0         Mixing ratio, dimensionless
0         Average river flow rate for: MIXFLG=0 (m3/s), MIXFLG=1,2 (m/s),
0         Transit time to irrigation withdrawl location (hr)
          If mixing ratio model > 0:
0           Rate of effluent discharge to receiving water body (m3/s)
0           Longshore distance from release point to usage location (m)
0           Offshore distance to the water intake (m)
0           Average water depth in surface water body (m)
0           Average river width (m), MIXFLG=1 only
0           Depth of effluent discharge point to surface water (m), lake only

          ====WASTE FORM AVAILABILITY=========================SECTION 3=====
0         Waste form/package half life, (yr)
0         Waste thickness, (m)
0         Depth of soil overburden, m

          ====BIOTIC TRANSPORT OF BURIED SOURCE================SECTION 4=====
T         Consider during inventory decay/buildup period (T/F)?
T         Consider during intake period (T/F)?   | 1-Arid non agricultural
0         Pre-Intake site condition..............| 2-Humid non agricultural
                                                 | 3-Agricultural

EXPOSURE ####################################################################

          ====EXTERNAL EXPOSURE================================SECTION 5=====
          Exposure time:                    |  Residential irrigation:
0           Plume (hr)                      | T         Consider: (T/F)
3260.0      Soil contamination (hr)         | 1         Source: 1-ground water
0           Swimming (hr)                   |                   2-surface water
0           Boating (hr)                    | 32.4      Application rate (in/yr)
0           Shoreline activities (hr)       | 6.0       Duration (mo/yr)
0         Shoreline type: (1-river, 2-lake, 3-ocean, 4-tidal basin)
0         Transit time for release to reach aquatic recreation (hr)
0         Average fraction of time submersed in acute cloud (hr/person hr)

          ====INHALATION======================================SECTION 6=====
4680.0    Hours of exposure to contamination per year
1         0-No resus-  1-Use Mass Loading          2-Use Anspaugh model
0.0001      pension      Mass loading factor (g/m3)   Top soil available (cm)

          ====INGESTION POPULATION============================SECTION 7=====
0         Atmospheric production definition (select option):
0           0-Use food-weighted chi/Q, (food-sec/m3), enter value on this line
            1-Use population-weighted chi/Q
            2-Use uniform production
            3-Use chi/Q and production grids (PRODUCTION will be overridden)
0         Population ingesting aquatic foods, 0 defaults to total (person)
0         Population ingesting drinking water, 0 defaults to total (person)
F         Consider dose from food exported out of region (default=F)
```

Note below: S* or Source: 0-none, 1-ground water, 2-surface water
3-Derived concentration entered above

==== AQUATIC FOODS / DRINKING WATER INGESTION=========SECTION 8====

F Salt water? (default is fresh)

USE ? T/F	FOOD TYPE	TRAN-SIT hr	PROD-UCTION kg/yr	-CONSUMPTION- HOLDUP da	RATE kg/yr	DRINKING WATER	
F	FISH	0.00	0.0E+00	0.00	0.0	1	Source (see above)
F	MOLLUS	0.00	0.0E+00	0.00	0.0	F	Treatment? T/F
F	CRUSTA	0.00	0.0E+00	0.00	0.0	1.0	Holdup/transit(da)
F	PLANTS	0.00	0.0E+00	0.00	0.0	730.0	Consumption (L/yr)

====TERRESTRIAL FOOD INGESTION=====================SECTION 9=====

USE ? T/F	FOOD TYPE	GROW TIME da	--IRRIGATION-- S *	RATE in/yr	TIME mo/yr	YIELD kg/m²	PROD-UCTION kg/yr	--CONSUMPTION-- HOLDUP da	RATE kg/yr
T	LEAF V	90.00	1	32.4	6.0	2.0	0.0E+00	14.0	4.1
T	ROOT V	90.00	1	32.4	6.0	2.0	0.0E+00	14.0	13.9
T	FRUIT	90.00	1	32.4	6.0	3.0	0.0E+00	14.0	9.6
F	GRAIN	90.00	1	0.0	0.0	0.8	0.0E+00	180.0	18.5

====ANIMAL PRODUCTION CONSUMPTION==================SECTION 10====

USE ? T/F	FOOD TYPE	---HUMAN---- CONSUMPTION RATE kg/yr	HOLDUP da	TOTAL PROD-UCTION kg/yr	DRINK WATER CONTAM FRACT.	-------------STORED FEED------------- DIET FRAC-TION	GROW TIME da	-IRRIGATION-- S *	RATE in/yr	TIME mo/yr	YIELD kg/m3	STOR-AGE da
T	BEEF	21.0	20.0	0.00	1.00	0.25	90.0	1	32.4	6.00	0.80	100.0
F	POULTR	4.6	1.0	0.00	1.00	1.00	90.0	1	32.4	6.00	1.00	100.0
T	MILK	51.7	1.0	0.00	1.00	0.25	90.0	1	32.4	6.00	1.00	100.0
F	EGG	10.6	1.0	0.00	1.00	1.00	90.0	1	32.4	6.00	1.00	100.0
						-------------FRESH FORAGE-----------						
	BEEF					0.75	45.0	1	32.4	6.00	1.00	45.0
	MILK					0.75	45.0	1	32.4	6.00	1.50	45.0

##

GENII Input File for the Columbia River Population:

```
######################### Program GENII Input File ########### 8 Jul 88 ####
Title: Population Dose from Columbia River Use
       \RIVER.IN                                    Created on 03-07-1994 at 10:40
OPTIONS========================= Default ===================================
T     Near-field scenario?       (Far-field)   NEAR-FIELD: narrowly-focused
F     Population dose?          (Individual)               release, single site
F     Acute release?              (Chronic)     FAR-FIELD: wide-scale release,
      Average Individual data set used                     multiple sites
                                 Complete                                 Complete
TRANSPORT OPTIONS=========== Section    EXPOSURE PATHWAY OPTIONS===== Section
F  Air Transport                  1      F  Finite plume, external         5
F  Surface Water Transport        2      F  Infinite plume, external       5
F  Biotic Transport (near-field) 3,4     T  Ground, external               5
F  Waste Form Degradation (near) 3,4     T  Recreation, external           5
                                         T  Inhalation uptake              5,6
REPORT OPTIONS=====================      T  Drinking water ingestion       7,8
T  Report AEDE only                      T  Aquatic foods ingestion        7,8
F  Report by radionuclide                T  Terrestrial foods ingestion    7,9
T  Report by exposure pathway            T  Animal product ingestion       7,10
F  Debug report on screen                T  Inadvertent soil ingestion

INVENTORY ##############################################################

 1    Inventory input activity units: (1-pCi  2-uCi  3-mCi  4-Ci  5-Bq)
 0    Surface soil source units (1- m2  2- m3  3- kg)
      Equilibrium question goes here

      --------|----Release Terms-----|----------Basic Concentrations---------|
      Use when|  transport selected  |  near-field scenario, optionally      |
      --------|----------------------|---------------------------------------|
      Release |       Surface Buried |       Surface Deep    Ground  Surface|
      Radio-  |Air    Water   Waste  |Air    Soil    Soil    Water   Water  |
      nuclide |/yr    /yr     /m3    |/m3    /unit   /m3     /L      /L     |
      --------|------- ------- -------|------- ------- ------- ------- -------|
      TC99                                                          1.0E+00

      --------|----Derived Concentrations-----|
      Use when|  measured values are known    |
      --------|-------------------------------|
      Release |Terres. Animal  Drink   Aquatic|
      Radio-  |Plant   Product Water   Food   |
      nuclide |/kg     /kg     /L      /kg    |
      --------|------- ------- ------- -------|

TIME ###################################################################

1     Intake ends after (yr)
50    Dose calc. ends after (yr)
1     Release ends after (yr)
0     No. of years of air deposition prior to the intake period
0     No. of years of irrigation water deposition prior to the intake period

FAR-FIELD SCENARIOS (IF POPULATION DOSE) ###############################

0          Definition option: 1-Use population grid in file POP.IN
5.0E+06                       2-Use total entered on this line

NEAR-FIELD SCENARIOS ###################################################

           Prior to the beginning of the intake period: (yr)
0            When was the inventory disposed?  (Package degradation starts)
0            When was LOIC?  (Biotic transport starts)
1.0        Fraction of roots in upper soil (top 15 cm)
0.0        Fraction of roots in deep soil
0.0        Manual redistribution: deep soil/surface soil dilution factor
1250       Source area for external dose modification factor (m2)
```

```
TRANSPORT #######################################################################
          ====AIR TRANSPORT====================================SECTION 1=====
                  0-Calculate PM              |0         Release type (0-3)
1         Option: 1-Use chi/Q or PM value     |F         Stack release (T/F)
                  2-Select MI dist & dir      |0         Stack height (m)
                  3-Specify MI dist & dir     |0         Stack flow (m3/sec)
0         Chi/Q or PM value                   |0         Stack radius (m)
0         MI sector index (1=S)               |0         Effluent temp. (C)
0         MI distance from release point (m)  |0         Building x-section (m2)
F         Use jf data, (T/F) else chi/Q grid  |0         Building height (m)

          ====SURFACE WATER TRANSPORT==========================SECTION 2=====
0         Mixing ratio model: 0-use value, 1-river, 2-lake
1.0       Mixing ratio, dimensionless
3400.0    Average river flow rate for: MIXFLG=0 (m3/s), MIXFLG=1,2 (m/s),
24.0      Transit time to irrigation withdrawl location (hr)
          If mixing ratio model > 0:
0           Rate of effluent discharge to receiving water body (m3/s)
0           Longshore distance from release point to usage location (m)
0           Offshore distance to the water intake (m)
0           Average water depth in surface water body (m)
0           Average river width (m), MIXFLG=1 only
0           Depth of effluent discharge point to surface water (m), lake only

          ====WASTE FORM AVAILABILITY==========================SECTION 3=====
0         Waste form/package half life, (yr)
0         Waste thickness, (m)
0         Depth of soil overburden, m

          ====BIOTIC TRANSPORT OF BURIED SOURCE================SECTION 4=====
T         Consider during inventory decay/buildup period (T/F)?
T         Consider during intake period (T/F)?  | 1-Arid non agricultural
0         Pre-Intake site condition.............| 2-Humid non agricultural
                                                | 3-Agricultural

EXPOSURE ########################################################################

          ====EXTERNAL EXPOSURE================================SECTION 5=====
          Exposure time:                 |  Residential irrigation:
0           Plume (hr)                   | T        Consider: (T/F)
4383.0      Soil contamination (hr)      | 2        Source: 1-ground water
10.0        Swimming (hr)                |                  2-surface water
0.0         Boating (hr)                 | 25.0     Application rate (in/yr)
17.0        Shoreline activities (hr)    | 6.0      Duration (mo/yr)
1         Shoreline type: (1-river, 2-lake, 3-ocean, 4-tidal basin)
24.0      Transit time for release to reach aquatic recreation (hr)
0         Average fraction of time submersed in acute cloud (hr/person hr)

          ====INHALATION=======================================SECTION 6=====
8766.0    Hours of exposure to contamination per year
1         0-No resus-  1-Use Mass Loading          2-Use Anspaugh model
0.0001      pension      Mass loading factor (g/m3)  Top soil available (cm)

          ====INGESTION POPULATION=============================SECTION 7=====
0         Atmospheric production definition (select option):
0           0-Use food-weighted chi/Q, (food-sec/m3), enter value on this line
            1-Use population-weighted chi/Q
            2-Use uniform production
            3-Use chi/Q and production grids (PRODUCTION will be overridden)
0         Population ingesting aquatic foods, 0 defaults to total (person)
0         Population ingesting drinking water, 0 defaults to total (person)
F         Consider dose from food exported out of region (default=F)
```

```
          Note below: S* or Source: 0-none, 1-ground water, 2-surface water
                                    3-Derived concentration entered above
          ==== AQUATIC FOODS / DRINKING WATER INGESTION=========SECTION 8====

F         Salt water? (default is fresh)

          USE         TRAN-  PROD-     -CONSUMPTION- |
          ?   FOOD    SIT    UCTION    HOLDUP   RATE |
          T/F TYPE    hr     kg/yr     da      kg/yr |      DRINKING WATER
          --- ------  -----  -------   ------  ----- |-------------------------
          T   FISH    24.00  0.0E+00     1.00  0.003 | 2      Source (see above)
          F   MOLLUS   0.00  0.0E+00     0.00    0.0 | F      Treatment? T/F
          F   CRUSTA   0.00  0.0E+00     0.00    0.0 | 1.0    Holdup/transit(da)
          F   PLANTS   0.00  0.0E+00     0.00    0.0 | 730.0  Consumption (L/yr)

          ====TERRESTRIAL FOOD INGESTION=====================SECTION 9=====

          USE         GROW   --IRRIGATION--            PROD-     --CONSUMPTION--
          ?   FOOD    TIME   S RATE   TIME     YIELD   UCTION    HOLDUP   RATE
          T/F TYPE    da     * in/yr  mo/yr    kg/m²   kg/yr     da       kg/yr
          --- ------  -----  - -----  -----    -----   -------   ------   ------
          T   LEAF V  90.00  2  25.0   6.0      2.0    0.0E+00    14.0     16.5
          T   ROOT V  90.00  2  25.0   6.0      2.0    0.0E+00    14.0     55.7
          T   FRUIT   90.00  2  25.0   6.0      3.0    0.0E+00    14.0     38.4
          T   GRAIN   90.00  2  25.0   6.0      0.8    0.0E+00    74.0     74.0

          ====ANIMAL PRODUCTION CONSUMPTION===================SECTION 10====

               ---HUMAN---- TOTAL  DRINK   ------------STORED FEED-------------
USE            CONSUMPTION  PROD-  WATER   DIET  GROW  -IRRIGATION--       STOR-
?   FOOD       RATE  HOLDUP UCTION CONTAM  FRAC- TIME  S RATE  TIME  YIELD AGE
T/F TYPE       kg/yr  da    kg/yr  FRACT.  TION  da    * in/yr mo/yr kg/m3 da
--- ------     ------ ----- ------ ------- ----  ----  - ----- ----- ----- -----
T   BEEF        42.0  34.0   0.00    1.00  0.25  90.0  2  25.0  6.00  0.80 180.0
F   POULTR      10.5  34.0   0.00    1.00  1.00  90.0  2  25.0  6.00  1.00 180.0
T   MILK       103.5   4.0   0.00    1.00  0.25  90.0  2  25.0  6.00  1.00 100.0
F   EGG         24.1  18.0   0.00    1.00  1.00  90.0  2  25.0  6.00  1.00 180.0
                                           -------------FRESH FORAGE-----------
    BEEF                                   0.75  45.0  2  25.0  6.00  1.00 100.0
    MILK                                   0.75  45.0  2  25.0  6.00  1.50  14.0

###############################################################################
```

Appendix E.

Data Used in the ISC2 Calculations

ISCLT Input for the Area Source Calculations

```
CO STARTING
   TITLEONE  Area Source Emissions from Burial Ground Sites
   TITLETWO  25 Acre Source (316 meter)²
   MODELOPT  DFAULT  CONC  RURAL
   AVERTIME  annual
   POLLUTID  Dust
   RUNORNOT  RUN
CO FINISHED

SO STARTING
   LOCATION  Burial1   AREA  -158.0    -158.0  0.0
**                      g/s/m²    ht,m    length,m
   SRCPARAM  Burial1   1.00E-5     1.0      52.67
   LOCATION  Burial2   AREA  -158.0    -105.33  0.0
**                      g/s/m²    ht,m    length,m
   SRCPARAM  Burial2   1.00E-5     1.0      52.67
   LOCATION  Burial3   AREA  -158.0     -52.66  0.0
**                      g/s/m²    ht,m    length,m
   SRCPARAM  Burial3   1.00E-5     1.0      52.67
   LOCATION  Burial4   AREA  -158.0       0.0   0.0
**                      g/s/m²    ht,m    length,m
   SRCPARAM  Burial4   1.00E-5     1.0      52.67
   LOCATION  Burial5   AREA  -158.0      52.66  0.0
**                      g/s/m²    ht,m    length,m
   SRCPARAM  Burial5   1.00E-5     1.0      52.67
   LOCATION  Burial6   AREA  -158.0     105.33  0.0
**                      g/s/m²    ht,m    length,m
   SRCPARAM  Burial6   1.00E-5     1.0      52.67
   LOCATION  Burial7   AREA  -105.33   -158.0  0.0
**                      g/s/m²    ht,m    length,m
   SRCPARAM  Burial7   1.00E-5     1.0      52.67
   LOCATION  Burial8   AREA  -105.33   -105.33  0.0
**                      g/s/m²    ht,m    length,m
   SRCPARAM  Burial8   1.00E-5     1.0      52.67
   LOCATION  Burial9   AREA  -105.33    -52.66  0.0
**                      g/s/m²    ht,m    length,m
   SRCPARAM  Burial9   1.00E-5     1.0      52.67
   LOCATION  Burial10  AREA  -105.33     0.0   0.0
**                      g/s/m²    ht,m    length,m
   SRCPARAM  Burial10  1.00E-5     1.0      52.67
   LOCATION  Burial11  AREA  -105.33    52.66  0.0
**                      g/s/m²    ht,m    length,m
   SRCPARAM  Burial11  1.00E-5     1.0      52.67
   LOCATION  Burial12  AREA  -105.33   105.33  0.0
**                      g/s/m²    ht,m    length,m
   SRCPARAM  Burial12  1.00E-5     1.0      52.67
   LOCATION  Burial13  AREA   -52.66  -158.0  0.0
**                      g/s/m²    ht,m    length,m
   SRCPARAM  Burial13  1.00E-5     1.0      52.67
   LOCATION  Burial14  AREA   -52.66  -105.33  0.0
**                      g/s/m²    ht,m    length,m
   SRCPARAM  Burial14  1.00E-5     1.0      52.67
   LOCATION  Burial15  AREA   -52.66   -52.66  0.0
**                      g/s/m²    ht,m    length,m
```

```
   SRCPARAM  Burial15  1.00E-5     1.0      52.67
   LOCATION  Burial16  AREA    -52.66      0.0   0.0
**                     g/s/m^2    ht,m    length,m
   SRCPARAM  Burial16  1.00E-5     1.0      52.67
   LOCATION  Burial17  AREA    -52.66     52.66  0.0
**                     g/s/m^2    ht,m    length,m
   SRCPARAM  Burial17  1.00E-5     1.0      52.67
   LOCATION  Burial18  AREA    -52.66    105.33  0.0
**                     g/s/m^2    ht,m    length,m
   SRCPARAM  Burial18  1.00E-5     1.0      52.67
   LOCATION  Burial19  AREA      0.0    -158.0   0.0
**                     g/s/m^2    ht,m    length,m
   SRCPARAM  Burial19  1.00E-5     1.0      52.67
   LOCATION  Burial20  AREA      0.0    -105.33  0.0
**                     g/s/m^2    ht,m    length,m
   SRCPARAM  Burial20  1.00E-5     1.0      52.67
   LOCATION  Burial21  AREA      0.0     -52.66  0.0
**                     g/s/m^2    ht,m    length,m
   SRCPARAM  Burial21  1.00E-5     1.0      52.67
   LOCATION  Burial22  AREA      0.0       0.0   0.0
**                     g/s/m^2    ht,m    length,m
   SRCPARAM  Burial22  1.00E-5     1.0      52.67
   LOCATION  Burial23  AREA      0.0      52.66  0.0
**                     g/s/m^2    ht,m    length,m
   SRCPARAM  Burial23  1.00E-5     1.0      52.67
   LOCATION  Burial24  AREA      0.0     105.33  0.0
**                     g/s/m^2    ht,m    length,m
   SRCPARAM  Burial24  1.00E-5     1.0      52.67
   LOCATION  Burial25  AREA     52.66   -158.0   0.0
**                     g/s/m^2    ht,m    length,m
   SRCPARAM  Burial25  1.00E-5     1.0      52.67
   LOCATION  Burial26  AREA     52.66   -105.33  0.0
**                     g/s/m^2    ht,m    length,m
   SRCPARAM  Burial26  1.00E-5     1.0      52.67
   LOCATION  Burial27  AREA     52.66    -52.66  0.0
**                     g/s/m^2    ht,m    length,m
   SRCPARAM  Burial27  1.00E-5     1.0      52.67
   LOCATION  Burial28  AREA     52.66      0.0   0.0
**                     g/s/m^2    ht,m    length,m
   SRCPARAM  Burial28  1.00E-5     1.0      52.67
   LOCATION  Burial29  AREA     52.66     52.66  0.0
**                     g/s/m^2    ht,m    length,m
   SRCPARAM  Burial29  1.00E-5     1.0      52.67
   LOCATION  Burial30  AREA     52.66    105.33  0.0
**                     g/s/m^2    ht,m    length,m
   SRCPARAM  Burial30  1.00E-5     1.0      52.67
   LOCATION  Burial31  AREA    105.33   -158.0   0.0
**                     g/s/m^2    ht,m    length,m
   SRCPARAM  Burial31  1.00E-5     1.0      52.67
   LOCATION  Burial32  AREA    105.33   -105.33  0.0
**                     g/s/m^2    ht,m    length,m
   SRCPARAM  Burial32  1.00E-5     1.0      52.67
   LOCATION  Burial33  AREA    105.33    -52.66  0.0
**                     g/s/m^2    ht,m    length,m
   SRCPARAM  Burial33  1.00E-5     1.0      52.67
   LOCATION  Burial34  AREA    105.33      0.0   0.0
**                     g/s/m^2    ht,m    length,m
```

```
   SRCPARAM  Burial34  1.00E-5    1.0      52.67
   LOCATION  Burial35  AREA   105.33     52.66  0.0
**                      g/s/m²    ht,m    length,m
   SRCPARAM  Burial35  1.00E-5    1.0      52.67
   LOCATION  Burial36  AREA   105.33    105.33  0.0
**                      g/s/m²    ht,m    length,m
   SRCPARAM  Burial36  1.00E-5    1.0      52.67
   SRCGROUP ALL
SO FINISHED

RE STARTING
   GRIDPOLR Nearby STA
                   ORIG   0    0
**    distance from edge:   50    70   100   150   200   250   300   350   500   700
                   DIST   221   241   271   321   371   421   471   521   671   871
**    distance from edge: 1000  2000  5000  9829 m
                   DIST   1171  2171  5171  10000
                   GDIR    16    0    22.5
   GRIDPOLR Nearby END
RE FINISHED

ME STARTING
   INPUTFIL  JF20010.STA  FREE
   ANEMHGHT  10.0
   SURFDATA  67656  1991  HANFORD200
   UAIRDATA  67656  1991  HANFORD200
   STARDATA  ANNUAL
   AVESPEED  1.00   2.682  4.694  7.153  9.835  14.304
   AVETEMPS  ANNUAL    6*285.3
   AVEMIXHT  ANNUAL  A  6*1000.0
   AVEMIXHT  ANNUAL  B  6*1000.0
   AVEMIXHT  ANNUAL  C  6*1000.0
   AVEMIXHT  ANNUAL  D  6*1000.0
   AVEMIXHT  ANNUAL  E  6*1000.0
   AVEMIXHT  ANNUAL  F  6*1000.0
ME FINISHED

OU STARTING
   RECTABLE  SRCGRP
   MAXTABLE  10  INDSRC  SOCONT
OU FINISHED
```

Wind Data for ISCLT (file named JF20010.STA)

0.003602	0.006904	0.002602	0.000700	0.000200	0.000300
0.002001	0.004403	0.002401	0.000700	0.000200	0.000400
0.002301	0.002902	0.001001	0.000500	0.000100	0.000000
0.002602	0.003202	0.000300	0.000100	0.000000	0.000000
0.004002	0.006004	0.000800	0.000000	0.000000	0.000000
0.002401	0.005103	0.001001	0.000000	0.000000	0.000000
0.001701	0.004503	0.001001	0.000100	0.000000	0.000000
0.001001	0.002902	0.001301	0.000300	0.000000	0.000000
0.001001	0.002401	0.001201	0.000400	0.000100	0.000000
0.000600	0.001201	0.000700	0.000400	0.000100	0.000000
0.000600	0.001701	0.001401	0.001101	0.000500	0.000200
0.000600	0.001901	0.003402	0.002502	0.001601	0.000700
0.001001	0.002502	0.003502	0.002502	0.001001	0.000200
0.001001	0.003002	0.003502	0.002502	0.001101	0.000200
0.001401	0.004203	0.004002	0.003302	0.002401	0.000400
0.002201	0.004803	0.001701	0.000500	0.000000	0.000000
0.001501	0.002101	0.000901	0.000200	0.000100	0.000100
0.001301	0.001501	0.000600	0.000300	0.000100	0.000200
0.001001	0.000600	0.000300	0.000100	0.000000	0.000000
0.001101	0.000800	0.000100	0.000100	0.000000	0.000000
0.001601	0.001601	0.000300	0.000000	0.000000	0.000000
0.000901	0.001301	0.000300	0.000000	0.000000	0.000000
0.000700	0.001301	0.000400	0.000000	0.000000	0.000000
0.000300	0.000901	0.000500	0.000100	0.000000	0.000000
0.000500	0.000800	0.000300	0.000200	0.000000	0.000000
0.000200	0.000400	0.000200	0.000100	0.000000	0.000000
0.000100	0.000300	0.000500	0.000400	0.000200	0.000100
0.000300	0.000500	0.000700	0.000800	0.000400	0.000200
0.000400	0.000700	0.001001	0.000600	0.000200	0.000100
0.000500	0.000901	0.001401	0.000700	0.000300	0.000000
0.000700	0.001601	0.001201	0.000901	0.000600	0.000100
0.001001	0.001601	0.000600	0.000100	0.000000	0.000000
0.001401	0.001901	0.000800	0.000200	0.000100	0.000200
0.001001	0.001201	0.000500	0.000300	0.000100	0.000400
0.000901	0.000600	0.000300	0.000100	0.000000	0.000000
0.001201	0.000901	0.000100	0.000000	0.000000	0.000000
0.001401	0.001301	0.000200	0.000000	0.000000	0.000000
0.001001	0.001301	0.000200	0.000000	0.000000	0.000000
0.000600	0.001901	0.000400	0.000000	0.000000	0.000000
0.000400	0.001001	0.000400	0.000100	0.000000	0.000000
0.000400	0.000600	0.000500	0.000200	0.000100	0.000000
0.000200	0.000200	0.000200	0.000100	0.000000	0.000000
0.000200	0.000300	0.000300	0.000200	0.000200	0.000200
0.000200	0.000500	0.000600	0.000700	0.000500	0.000200
0.000400	0.000800	0.000901	0.000600	0.000200	0.000000
0.000400	0.001001	0.001301	0.000700	0.000300	0.000100
0.001001	0.001901	0.001201	0.000600	0.000500	0.000100
0.001001	0.001501	0.000300	0.000100	0.000000	0.000000
0.008705	0.008405	0.003202	0.001001	0.000200	0.000700
0.005803	0.004803	0.002001	0.001001	0.000400	0.001201
0.005904	0.004002	0.000901	0.000300	0.000100	0.000000
0.005904	0.003302	0.000400	0.000100	0.000000	0.000000
0.007705	0.006604	0.001201	0.000000	0.000000	0.000000
0.005003	0.005703	0.001101	0.000100	0.000000	0.000000

0.004303	0.007505	0.002502	0.000300	0.000000	0.000000
0.003202	0.005303	0.002702	0.000700	0.000000	0.000000
0.002702	0.003502	0.002401	0.001001	0.000200	0.000000
0.001901	0.001801	0.001301	0.001101	0.000700	0.000200
0.002101	0.002401	0.002301	0.002502	0.001601	0.001201
0.001701	0.002802	0.003902	0.003802	0.002401	0.001201
0.004002	0.006904	0.008305	0.005803	0.001301	0.000500
0.004403	0.010907	0.014609	0.011407	0.005003	0.000700
0.005403	0.010506	0.008405	0.005003	0.002902	0.000800
0.005503	0.007705	0.002101	0.000500	0.000100	0.000000
0.003902	0.003202	0.001901	0.000700	0.000100	0.000901
0.002602	0.001701	0.000901	0.001201	0.000600	0.001501
0.002802	0.001101	0.000400	0.000100	0.000100	0.000100
0.002502	0.001301	0.000100	0.000000	0.000000	0.000000
0.004603	0.003102	0.000600	0.000000	0.000000	0.000000
0.003402	0.003402	0.000600	0.000000	0.000000	0.000000
0.003102	0.004703	0.001501	0.000100	0.000000	0.000000
0.003002	0.005203	0.002502	0.000500	0.000000	0.000000
0.003402	0.004603	0.002201	0.000700	0.000100	0.000000
0.002101	0.002101	0.001201	0.000800	0.000500	0.000100
0.002502	0.002902	0.001801	0.001701	0.001101	0.000500
0.002902	0.004803	0.003902	0.003002	0.001501	0.000200
0.004903	0.015809	0.019812	0.006504	0.000600	0.000100
0.004403	0.016810	0.025015	0.017511	0.003802	0.000500
0.004503	0.011107	0.007505	0.004102	0.001101	0.000300
0.003902	0.003902	0.001301	0.000200	0.000000	0.000000
0.003302	0.001701	0.000500	0.000300	0.000100	0.000400
0.001701	0.000700	0.000600	0.000200	0.000100	0.000700
0.002001	0.000700	0.000100	0.000000	0.000000	0.000000
0.002201	0.000800	0.000100	0.000000	0.000000	0.000000
0.004403	0.002502	0.000100	0.000000	0.000000	0.000000
0.003602	0.003102	0.000300	0.000000	0.000000	0.000000
0.004102	0.005904	0.000600	0.000000	0.000000	0.000000
0.004002	0.006704	0.002602	0.000200	0.000000	0.000000
0.005203	0.006504	0.002101	0.000200	0.000100	0.000000
0.003202	0.002902	0.000400	0.000000	0.000000	0.000000
0.003202	0.003702	0.000901	0.000100	0.000000	0.000000
0.003602	0.006604	0.002902	0.000200	0.000000	0.000000
0.007004	0.024215	0.017511	0.000700	0.000000	0.000000
0.005003	0.023814	0.024415	0.000901	0.000000	0.000000
0.004603	0.011207	0.004503	0.000300	0.000000	0.000000
0.003202	0.003302	0.000700	0.000000	0.000000	0.000000

200 AREA (HMS) - 10 M - Pasquill A - G (1983 - 1991 Average)
Created 8/26/92 KR, ***> ISCLT2 Format 3-15-93, PDR

ISCST Input for the Area Source Calculations

```
CO STARTING
   TITLEONE  Area Source Emissions from Burial Ground Sites
   TITLETWO  25 Acre Source (316 meter)²
   MODELOPT  DFAULT  CONC  RURAL
   AVERTIME  1
   POLLUTID  Dust
   RUNORNOT  RUN
CO FINISHED

SO STARTING
   LOCATION  Burial1   AREA  -158.0    -158.0  0.0
**                          g/s/m²   ht,m   length,m
   SRCPARAM  Burial1   1.00E-5     1.0     52.67
   LOCATION  Burial2   AREA  -158.0    -105.33  0.0
**                          g/s/m²   ht,m   length,m
   SRCPARAM  Burial2   1.00E-5     1.0     52.67
   LOCATION  Burial3   AREA  -158.0     -52.66  0.0
**                          g/s/m²   ht,m   length,m
   SRCPARAM  Burial3   1.00E-5     1.0     52.67
   LOCATION  Burial4   AREA  -158.0      0.0   0.0
**                          g/s/m²   ht,m   length,m
   SRCPARAM  Burial4   1.00E-5     1.0     52.67
   LOCATION  Burial5   AREA  -158.0     52.66  0.0
**                          g/s/m²   ht,m   length,m
   SRCPARAM  Burial5   1.00E-5     1.0     52.67
   LOCATION  Burial6   AREA  -158.0    105.33  0.0
**                          g/s/m²   ht,m   length,m
   SRCPARAM  Burial6   1.00E-5     1.0     52.67
   LOCATION  Burial7   AREA  -105.33  -158.0  0.0
**                          g/s/m²   ht,m   length,m
   SRCPARAM  Burial7   1.00E-5     1.0     52.67
   LOCATION  Burial8   AREA  -105.33  -105.33  0.0
**                          g/s/m²   ht,m   length,m
   SRCPARAM  Burial8   1.00E-5     1.0     52.67
   LOCATION  Burial9   AREA  -105.33   -52.66  0.0
**                          g/s/m²   ht,m   length,m
   SRCPARAM  Burial9   1.00E-5     1.0     52.67
   LOCATION  Burial10  AREA  -105.33    0.0   0.0
**                          g/s/m²   ht,m   length,m
   SRCPARAM  Burial10  1.00E-5     1.0     52.67
   LOCATION  Burial11  AREA  -105.33   52.66  0.0
**                          g/s/m²   ht,m   length,m
   SRCPARAM  Burial11  1.00E-5     1.0     52.67
   LOCATION  Burial12  AREA  -105.33  105.33  0.0
**                          g/s/m²   ht,m   length,m
   SRCPARAM  Burial12  1.00E-5     1.0     52.67
   LOCATION  Burial13  AREA   -52.66  -158.0  0.0
**                          g/s/m²   ht,m   length,m
   SRCPARAM  Burial13  1.00E-5     1.0     52.67
   LOCATION  Burial14  AREA   -52.66  -105.33  0.0
**                          g/s/m²   ht,m   length,m
   SRCPARAM  Burial14  1.00E-5     1.0     52.67
   LOCATION  Burial15  AREA   -52.66   -52.66  0.0
**                          g/s/m²   ht,m   length,m
```

```
    SRCPARAM  Burial15  1.00E-5     1.0      52.67
    LOCATION  Burial16  AREA   -52.66     0.0   0.0
**                      g/s/m²    ht,m    length,m
    SRCPARAM  Burial16  1.00E-5     1.0      52.67
    LOCATION  Burial17  AREA   -52.66    52.66  0.0
**                      g/s/m²    ht,m    length,m
    SRCPARAM  Burial17  1.00E-5     1.0      52.67
    LOCATION  Burial18  AREA   -52.66   105.33  0.0
**                      g/s/m²    ht,m    length,m
    SRCPARAM  Burial18  1.00E-5     1.0      52.67
    LOCATION  Burial19  AREA      0.0   -158.0  0.0
**                      g/s/m²    ht,m    length,m
    SRCPARAM  Burial19  1.00E-5     1.0      52.67
    LOCATION  Burial20  AREA      0.0  -105.33  0.0
**                      g/s/m²    ht,m    length,m
    SRCPARAM  Burial20  1.00E-5     1.0      52.67
    LOCATION  Burial21  AREA      0.0   -52.66  0.0
**                      g/s/m²    ht,m    length,m
    SRCPARAM  Burial21  1.00E-5     1.0      52.67
    LOCATION  Burial22  AREA      0.0     0.0   0.0
**                      g/s/m²    ht,m    length,m
    SRCPARAM  Burial22  1.00E-5     1.0      52.67
    LOCATION  Burial23  AREA      0.0    52.66  0.0
**                      g/s/m²    ht,m    length,m
    SRCPARAM  Burial23  1.00E-5     1.0      52.67
    LOCATION  Burial24  AREA      0.0   105.33  0.0
**                      g/s/m²    ht,m    length,m
    SRCPARAM  Burial24  1.00E-5     1.0      52.67
    LOCATION  Burial25  AREA    52.66   -158.0  0.0
**                      g/s/m²    ht,m    length,m
    SRCPARAM  Burial25  1.00E-5     1.0      52.67
    LOCATION  Burial26  AREA    52.66  -105.33  0.0
**                      g/s/m²    ht,m    length,m
    SRCPARAM  Burial26  1.00E-5     1.0      52.67
    LOCATION  Burial27  AREA    52.66   -52.66  0.0
**                      g/s/m²    ht,m    length,m
    SRCPARAM  Burial27  1.00E-5     1.0      52.67
    LOCATION  Burial28  AREA    52.66     0.0   0.0
**                      g/s/m²    ht,m    length,m
    SRCPARAM  Burial28  1.00E-5     1.0      52.67
    LOCATION  Burial29  AREA    52.66    52.66  0.0
**                      g/s/m²    ht,m    length,m
    SRCPARAM  Burial29  1.00E-5     1.0      52.67
    LOCATION  Burial30  AREA    52.66   105.33  0.0
**                      g/s/m²    ht,m    length,m
    SRCPARAM  Burial30  1.00E-5     1.0      52.67
    LOCATION  Burial31  AREA   105.33   -158.0  0.0
**                      g/s/m²    ht,m    length,m
    SRCPARAM  Burial31  1.00E-5     1.0      52.67
    LOCATION  Burial32  AREA   105.33  -105.33  0.0
**                      g/s/m²    ht,m    length,m
    SRCPARAM  Burial32  1.00E-5     1.0      52.67
    LOCATION  Burial33  AREA   105.33   -52.66  0.0
**                      g/s/m²    ht,m    length,m
    SRCPARAM  Burial33  1.00E-5     1.0      52.67
    LOCATION  Burial34  AREA   105.33     0.0   0.0
**                      g/s/m²    ht,m    length,m
```

```
   SRCPARAM  Burial34  1.00E-5    1.0      52.67
   LOCATION  Burial35  AREA   105.33     52.66  0.0
**                      g/s/m²    ht,m    length,m
   SRCPARAM  Burial35  1.00E-5    1.0      52.67
   LOCATION  Burial36  AREA   105.33   105.33  0.0
**                      g/s/m²    ht,m    length,m
   SRCPARAM  Burial36  1.00E-5    1.0      52.67
   SRCGROUP ALL
SO FINISHED

RE STARTING
   GRIDPOLR Nearby STA
                   ORIG   0    0
**   distance from edge:   50   70  100  150  200  250  300  350  500  700
                   DIST   221  241  271  321  371  421  471  521  671  871
**   distance from edge: 1000 2000 5000  9829 m
                   DIST  1171 2171 5171 10000
                   GDIR   16    0   22.5
   GRIDPOLR Nearby END
RE FINISHED

ME STARTING
   INPUTFIL  JF-F.HR
   ANEMHGHT  10.0
   SURFDATA  67656  1987  HANFORD200
   UAIRDATA  67656  1987  HANFORD200
ME FINISHED

OU STARTING
   RECTABLE  ALLAVE  1st
OU FINISHED
```

Wind Data Used by ISCST (file named JF-F.HR)

```
 67656     87  67656     87   Class F
87 1 1 1 180.00     1.00   293.0 6 1000.0 1000.0
87 1 1 2 202.50     1.00   293.0 6 1000.0 1000.0
87 1 1 3 225.00     1.00   293.0 6 1000.0 1000.0
87 1 1 4 247.50     1.00   293.0 6 1000.0 1000.0
87 1 1 5 270.00     1.00   293.0 6 1000.0 1000.0
87 1 1 6 292.50     1.00   293.0 6 1000.0 1000.0
87 1 1 7 315.00     1.00   293.0 6 1000.0 1000.0
87 1 1 8 337.50     1.00   293.0 6 1000.0 1000.0
87 1 1 9   0.00     1.00   293.0 6 1000.0 1000.0
87 1 110  22.50     1.00   293.0 6 1000.0 1000.0
87 1 111  45.00     1.00   293.0 6 1000.0 1000.0
87 1 112  67.50     1.00   293.0 6 1000.0 1000.0
87 1 113  90.00     1.00   293.0 6 1000.0 1000.0
87 1 114 112.50     1.00   293.0 6 1000.0 1000.0
87 1 115 135.00     1.00   293.0 6 1000.0 1000.0
87 1 116 157.50     1.00   293.0 6 1000.0 1000.0
87 1 117 180.00     2.00   293.0 6 1000.0 1000.0
87 1 118 202.50     2.00   293.0 6 1000.0 1000.0
87 1 119 225.00     2.00   293.0 6 1000.0 1000.0
87 1 120 247.50     2.00   293.0 6 1000.0 1000.0
87 1 121 270.00     2.00   293.0 6 1000.0 1000.0
87 1 122 292.50     2.00   293.0 6 1000.0 1000.0
87 1 123 315.00     2.00   293.0 6 1000.0 1000.0
87 1 124 337.50     2.00   293.0 6 1000.0 1000.0
87 1 2 1   0.00     2.00   293.0 6 1000.0 1000.0
87 1 2 2  22.50     2.00   293.0 6 1000.0 1000.0
87 1 2 3  45.00     2.00   293.0 6 1000.0 1000.0
87 1 2 4  67.50     2.00   293.0 6 1000.0 1000.0
87 1 2 5  90.00     2.00   293.0 6 1000.0 1000.0
87 1 2 6 112.50     2.00   293.0 6 1000.0 1000.0
87 1 2 7 135.00     2.00   293.0 6 1000.0 1000.0
87 1 2 8 157.50     2.00   293.0 6 1000.0 1000.0
87 1 2 9 180.00     3.00   293.0 6 1000.0 1000.0
87 1 210 202.50     3.00   293.0 6 1000.0 1000.0
87 1 211 225.00     3.00   293.0 6 1000.0 1000.0
87 1 212 247.50     3.00   293.0 6 1000.0 1000.0
87 1 213 270.00     3.00   293.0 6 1000.0 1000.0
87 1 214 292.50     3.00   293.0 6 1000.0 1000.0
87 1 215 315.00     3.00   293.0 6 1000.0 1000.0
87 1 216 337.50     3.00   293.0 6 1000.0 1000.0
87 1 217   0.00     3.00   293.0 6 1000.0 1000.0
87 1 218  22.50     3.00   293.0 6 1000.0 1000.0
87 1 219  45.00     3.00   293.0 6 1000.0 1000.0
87 1 220  67.50     3.00   293.0 6 1000.0 1000.0
87 1 221  90.00     3.00   293.0 6 1000.0 1000.0
87 1 222 112.50     3.00   293.0 6 1000.0 1000.0
87 1 223 135.00     3.00   293.0 6 1000.0 1000.0
87 1 224 157.50     3.00   293.0 6 1000.0 1000.0
```

Appendix F.

Hanford Environmental Dose Overview Panel Approval

HEDOP REVIEW CHECKLIST
for
Radiological and Nonradiological Release Calculations

Document reviewed (include title or description of calculation, document number, author, and date, as applicable):

Rittmann, P. D. August 1994. Dose Estimates for the Solid Waste Performance Assessment, WHC-SD-WM-TI-616, Westinghouse Hanford Co., Richland, WA.

Submitted by: P. D. Rittmann Date Submitted: 8/1/94

Scope of Review:

YES	NO*	N/A		
[x]	[ ]	[ ]	1.	A detailed technical review and approval of the environmental transport and dose calculation portion of the analysis has been performed and documented.
[x]	[ ]	[ ]	2.	Detailed technical review(s) and approval(s) of scenario and release determinations have been performed and documented.
[ ]	[x]	[ ]	3.	HEDOP-approved code(s) were used.
[ ]	[ ]	[x]	4.	Receptor locations were selected according to HEDOP recommendations.
[x]	[ ]	[ ]	5.	All applicable environmental pathways and code options were included and are appropriate for the calculations.
[x]	[ ]	[ ]	6.	Hanford site data were used.
[x]	[ ]	[ ]	7.	Model adjustments external to the computer program were justified and performed correctly.
[x]	[ ]	[ ]	8.	The analysis is consistent with HEDOP recommendations.
[x]		[ ]	9.	Supporting notes, calculations, comments, comment resolutions, or other information is attached. (Use the "Page 1 of X" page numbering format and sign and date each added page.)
[x]	[ ]		**10.**	**Approval is granted on behalf of the Hanford Environmental Dose Overview Panel.**

* All "NO" responses must be explained and use of nonstandard methods justified.

K Rhoads

K. Rhoads (approval contingent on resolution of attached comments) 8/12/94

HEDOP-Approved Reviewer (Printed Name and Signature) Date

COMMENTS (add additional signed and dated pages if necessary): see attached

Comments on Document: Page 1 of 1

Rittmann, P. D. August 1994. Dose Estimates for the Solid Waste Performance Assessment, WHC-SD-WM-TI-616, Westinghouse Hanford Co., Richland, WA.

The following are major issues that need to be resolved for HEDOP and peer review approval. See also editorial comments in the document text.

p. 1, par 1 - The introduction lists the need to include radionuclides not in the GENII library, and a desire to use DOE dose factors as justification for use of the spreadsheet model. These calculations are difficult to review and contain numerous opportunities for error, as well as involving trade-offs in the models that need to be explained or justified as insignificant. You go to a lot of extra effort for a 20-30% difference in the final result that adds nothing in terms of reducing the overall uncertainty in the analysis. I'm satisfied on the basis of your comparison that there aren't any gross errors in the calculations, but for the future I hope you'll consider a simpler approach, such as post-processing GENII output using a ratio of dose factors, rather than going to the trouble to re-invent the wheel.

p. 1, par 4 - The use of 50% consumption of contaminated animal products needs to be referenced or justified. 100% consumption of locally produced beef and milk is certainly a credible scenario.

p. 4, par. 5 - The regulatory basis for the 730 L/year water consumption rate should be mentioned. This is actually somewhat larger than the average consumption used in the Grout PA.

p. 5, par 2 - The fish consumption rate should include a reference to the Hanford Annual Environmental Report.

p. 24, section 4 - The tables report scenario dose factors with and without soil leaching, but nothing in the text explains the purpose of the calculations without leaching factors. Were these used for special cases in the PA, or were they just included as an academic exercise? Something should be said in this section about the purpose of the comparison.

p. 34, par 1 - The 500 person-rem/year collective dose guideline from RL 5820.2A is not really a regulatory limit, but a criterion below which RL considers that the ALARA provisions have been satisfied. Recommend you refer to your numerical criteria as performance objectives rather than limits.

p. 46, par 1 - You discuss an acute air transport case without saying why it may be important. The section starts with "If the burial ground release were of short duration...". You need to describe the conditions under which such a release could occur and why it might be significant.

K Rhoads

K Rhoads, 8/12/94