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Unit Dose Calculation Methods and Summary of Facility Effluent Monitoring Plan Determinations

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Prepared for the U.S. Department of Energy
Assistant Secretary for Environment,
Safety and Health

Westinghouse
Hanford Company Richland, Washington

Hanford Operations and Engineering Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930

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UNIT DOSE CALCULATION METHODS AND SUMMARY OF FACILITY EFFLUENT MONITORING PLAN DETERMINATIONS

ABSTRACT

In accordance with the Westinghouse Hanford Company guidance document, WHC-EP-0438, all Hanford Site facilities were evaluated for the need to prepare a facility effluent monitoring plan. A facility effluent monitoring plan determination was performed for 138 individual Westinghouse Hanford facilities (including auxiliary and operations support buildings) and documented by area in six reports. These reports are: (1) WHC-EP-0439, "Facility Effluent Monitoring Plan Determinations for 100 Area Facilities;" (2) WHC-EP-0440, "Facility Effluent Monitoring Plan Determinations for 200 Area Facilities;" (3) WHC-EP-0441, "Facility Effluent Monitoring Plan Determinations for 300 Area Facilities;" (4) WHC-EP-0442, "Facility Effluent Monitoring Plan Determinations for 400 Area Facilities;" (5) WHC-EP-0443, "Facility Effluent Monitoring Plan Determinations for 600 Area Facilities;" (6) WHC-EP-0444, "Facility Effluent Monitoring Plan Determinations for Operations Support Services Facilities." Of these, 24 individual facilities require an actual facility effluent monitoring plan and are documented in 15 reports. The determinations and the subsequent preparation of actual facility effluent monitoring plans will identify deficiencies and aid in achieving compliance with the U.S. Department of Energy orders and Clean Air Act of 1977 *final rule on National Emissions Standards for Hazardous Air Pollutants for radionuclides (Title 40 Code of Federal Regulations Part 61, Subpart H, U.S. Environmental Protection Agency).*

A list of the Westinghouse Hanford facilities evaluated, a summary of these determinations, and the methodology for determining the offsite dose to the public is provided.

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LIST OF TERMS

CFR	Code of Federal Regulations
DOE	U.S. Department of Energy
DOP	diocryl phthalate
EPA	U.S. Environmental Protection Agency
FEMP	Facility Effluent Monitoring Plan
HEPA	High-Efficiency Particulate Air
NESHAP	National Emission Standards for Hazardous Air Pollutants
PFP	Plutonium Finishing Plant
PNL	Pacific Northwest Laboratories
PUREX	plutonium/uranium extraction
TRUSAF	Transuranic Waste Storage and Assay Facility
Westinghouse Hanford	Westinghouse Hanford Company

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1.0 UNIT DOSE CALCULATIONS FOR WESTINGHOUSE HANFORD FACILITY EFFLUENT MONITORING PLANS

Evaluation against the offsite dose limits in the new National Emission Standards for Hazardous Air Pollutants (NESHAP) of the registered sources of airborne radionuclide emissions for all Westinghouse Hanford Company (Westinghouse Hanford) permitted stacks (95 of the total 130 Hanford Site) is included in the Facility Effluent Monitoring Plan (FEMP) determinations. Seven facility stacks exceeded the 0.1 mrem threshold and will need to be evaluated for monitoring upgrades to comply with the requirements of the *Clean Air Act of 1977*.

The stacks requiring a point-by-point evaluation against the U.S. Environmental Protection Agency (EPA) regulations are: (1) 291-A-1 Plutonium/Uranium Extraction Plant (PUREX) main stack, (2) 291-B-1 B Plant main stack, (3) 291-Z-1 Plutonium Finishing Plant (PFP) main stack, (4) 291-A-22 242-A Evaporator, (5) 296-A-40 AP Tank Farms, (6) 340-NT-EX 340 Waste Handling Facility (7) 291-T-1 T Plant main stack. These evaluations are included in the actual FEMPs.

Pacific Northwest Laboratories (PNL) was contracted to provide dose conversion factors, for both airborne and liquid pathways, for all Hanford facilities. Atmospheric releases were modeled using the CAP-88 (Beres 1990) EPA approved code package, and confirming calculations were performed with the GENII (Napier et, al 1988) code as required by the Hanford Environmental Dose Overview Panel. In most cases, the 1989 annual report data or preliminary 1990 release data was used to determine the quantities released. A treatment factor, to adjust the data for the assumption that no engineering controls are in place, was multiplied by the CAP-88 dose conversion factors and the quantities released (WHC 1990a, WHC 1990b, WHC 1990c), to derive the offsite dose to a maximum exposed individual. The liquid releases were modeled using the GENII package, specific to Hanford, and the offsite dose is determined to be what is discharged directly to the Columbia River. Liquid effluent releases are described in the FEMP determinations and actual FEMPs and were compared to the drinking water standards and DOE Order 5400.5, which requires monitoring if radionuclide constituents exist in the liquid discharges.

The unit dose conversion factors were developed by PNL for one curie radionuclide releases. The list of radionuclides was based upon the facility inventories identified in the FEMP determinations. Airborne releases from generic locations in the 100, 200 East, 200 West, and 300 Areas were modeled for both elevated (up to 200 ft/89 m high) and ground level releases (less than 60 ft/10 m). The 400 Area releases were modeled for ground level only (no stack exists above 60 ft). Impacts of liquid releases were also evaluated for individuals at Ringold (100 and 200 area effluents) and Riverview (300 and 400 area effluents).

The EPA approved CAP-88 (Beres 1990) and GENII (Napier et. al 1988) code packages were used to model atmospheric releases in order to satisfy the EPA requirements (40 Code of Federal Regulations [CFR] 61). The GENII code was also used to model liquid releases where appropriate.

1.1 METHODS FOR UNIT DOSE CONVERSION FACTORS

Standard input parameters for the Hanford dose calculations were included in the calculations where possible (McCormack, et. al 1984). Meteorology data were collected at weather stations in each of the Hanford operating areas (i.e., 100, 200, 300, 400, and 600 areas) and represent the 5-yr average of data taken between 1983 and 1987. The location of the maximally exposed individual at the Hanford Site boundary for each area is included in the Attachment C Tables C-1 through C-11 with results of the dose conversion factor calculations. Individual locations were based on the site boundary location having the greatest radionuclide air concentration under average atmospheric conditions. The Ringold location (Hanford Site Boundary) was selected as the area where the offsite dose from all air pathways would be the highest from the 100 and 200 Areas. The selection is based on the fact that nearly all of the dose from air releases in recent years has been contributed by radionuclides from the PUREX stack. The Ringold area is the closest inhabited and farming area to PUREX, and matches the assumption that the maximum exposed individual diet consists of 100% home grown food. The Ringold area has historically been capable of producing all of the items in the maximum exposed individual diet with possible exception of cereal grain. In addition, the Ringold area also is directly across the Columbia River from the Hanford Site and it also lies very nearly in the path of the prevailing winds from the 200 East Area. The atmospheric dispersion factor (X/Q), where X is the concentration in curies per cubic meter at the downwind point and Q is the source strength of curies per second, at Ringold is historically within 10 to 20% of the maximum offsite X/Q value associated with 200 Area releases. The maximum value usually occurs in an adjacent sector where there is no habitation and/or farming (see Table 1). Likewise, Riverview was chosen as the area where the offsite dose from all air pathways (Hanford Site Boundary) would be the highest from the 300 and 400 Areas. This location is the closest publicly occupied area south of the Hanford Site.

Doses were calculated as 50-yr committed effective dose equivalents for all internal deposition pathways using the EPA model specified in 40 CFR 61. Default solubility classes were used for all radionuclides in these calculations. These are appropriate for most Hanford facilities evaluated, except where plutonium or uranium are released in soluble form and contribute substantially to the overall dose from a given facility. Default classes for uranium and plutonium assume these radionuclides are released as insoluble compounds; this will result in a lower overall dose than would be the case if they were released in more soluble form.

1.2 RESULTS OF UNIT DOSE CONVERSION FACTORS

Results of the PNL evaluation are presented in Attachment C Tables 1 through 11, and represent the 50-yr committed dose equivalent following a chronic annual release of 1 Ci of each radionuclide at risk. The doses calculated using the GENII code are reported as rem to the maximum individual from an annual release; those from CAP-88 are reported in mrem. Values in the tables were taken directly from code outputs, and have been left in the units reported by each code to avoid transcription errors.

Table 1. Contributions to Dose from Air Pathways (Hanford Site Boundary) at Ringold.

Contributor	mrem/yr EDE	Percent
CAP-88 (AIRDOS) (All Pathways and all Nuclides)		
All Hanford stacks, all paths and nuclides	0.0093	100
All 200 Areas stacks, all paths and nuclides	0.0088	95
PUREX Plant stack, all paths and nuclides	0.0081	87
PUREX Plant stack, ^{129}I, all paths	0.0076	82
GENII		
All Hanford stacks, all paths and nuclides	0.014	100
All 200 Areas stacks, all paths and nuclides	0.014	100
PUREX stack ^{129}I		
All paths	0.013	93
All foods	0.013	93
Milk	0.0071	51
Fruit and vegetables	0.0045	32
Cereal	0.0006	5
Meat	0.0005	4

The CAP-88 and GENII codes handle ingrowth of long-lived radioactive daughter products differently, as noted in the tables. GENII calculates doses for all radionuclides in each decay chain, therefore, the doses reported in Attachment C Tables C-1 through C-6 include contributions from both parent and ingrown daughters. CAP-88 does not calculate activities for ingrowth of daughter radionuclides following release of the parent, but will estimate the dose from very short-lived daughters where the parent-to-daughter activity ratio is effectively 1:1. CAP-88 doses reported in Attachment C Tables C-7 through C-11 are for the parent nuclide only, except in the case where very short-lived daughters have been included in the parent dose as noted. CAP-88 doses, including contributions from daughter ingrowth, should be estimated using the fractional contribution from the parent nuclide reported in the GENII results.

2.0 OFFSITE EFFECTIVE DOSE EQUIVALENT DETERMINATION

The unit dose conversion factors (rem/Ci GENII or mrem/Ci CAP-88) are used in calculating the overall offsite effective dose equivalent by multiplying the factor by the quantity released in Curies for each radionuclide. In addition, the CAP-88 calculations require a treatment factor to be applied to adjust for no engineering controls.

On February 12, 1991, EPA, Region Ten, was contacted for clarification regarding the methods recognized by EPA for use in assessing sources of radioactive air emissions relative to applicability of EPA continuous measurement requirements in 40 CFR Part 61, Subpart H, Section 61.93 (b) (4) (ii). The EPA responded by listing the three recognized methods in order of preference. These methods are: (1) estimate potential emissions using past measurements taken from the flue upstream of the filter system, (2) estimate potential emissions using past measurements of first stage filter (HEPA) loading, (3) estimate potential emissions by extrapolating from past measurements by continuous air sampling downstream of the filter system. The third method was chosen because of the overall reliability of existing sampling systems and the difficulties in identifying source terms (historical or potential).

Attachment 2 summarizes the results of the airborne emissions offsite dose calculations for the registered stacks. The total dose expected from emissions at a given facility were obtained by multiplying the release quantity in Ci for each radionuclide by the corresponding unit dose factor in the tables (GENII and CAP-88). For determining potential dose for comparison with the 0.1 mrem EPA threshold, the CAP-88 doses were also multiplied by a treatment factor, and the contributions, for all nuclides in the effluent were summarized. The GENII conversion factors in units of rem were converted to mrem for ease in the calculations. The quantity released in Ci was obtained from the 1989 annual report release data because the 1990 preliminary release data was not made available. However, in the B Plant and PUREX FEMP determination reports preliminary 1990 data was also used to assess the current shutdown operating condition. In addition, the FEMP for UO_3 contains dose calculations using 1988 and 1989 campaign release data.

3.0 TREATMENT FACTOR

Three treatment factors were used in the airborne emissions offsite effective dose equivalent to account for the differences in the engineering controls in situ at the facilities. Any of three different types of particulate filtration may exist in the facility stacks as an engineering control: (1) High-Efficiency Particulate Air (HEPA) filters (2) charcoal filters, and (3) sand filters. Each type of filter has its own specific fibrous medium which produces a particle removal efficiency (efficiency factor) for adequately filtering particulate radionuclides. The HEPA filters used at the Hanford Site have a manufacturer's rating of 99.97% efficiency for removal of particulates equal to 0.3 microns (micrometers) $\pm$ 0.03 microns in size. The minimum acceptable maintenance testing and operating efficiency

for Hanford Site HEPA filter systems is 99.95%. Charcoal filters have an efficiency of 95% for removal of radioiodine particulates. Sand filters have an efficiency of 99.8% for particulate radiation.

To determine a treatment factor for each of these three types of particulate filters used as engineering controls, the inverse of one minus the operating efficiencies was calculated. The applicable treatment factor was then applied as a multiplier of the actual reported curies emitted from each stack in question. That result was then used to represent the potential emissions, and calculate the potential offsite dose, from that stack assuming the treatment system or engineering control was not in place, but operations were otherwise normal. This method provides the potential offsite effective dose equivalent for each stack according to the guidance in 40 CRF 61, Subpart H (EPA 1989).

The Appendix D method for determining offsite effective dose equivalent is intended for use in evaluating new or modified facilities where source terms are estimated and the offsite dose can be calculated by projecting away from the facility inventory at risk and applying the Table 1, Appendix D values. The method used to evaluate stacks at the Hanford Site, described in this document, is more appropriate for the existing aging Hanford facilities because of the difficulties in identifying source terms within these facilities. In the method used in this document for HEPA filters with a minimum operating efficiency of 99.95%, the inverse of one minus 99.95% is 2,000. For charcoal filters, the inverse of one minus 95% is 20 and for sand filters the inverse of one minus 99.8% is 500.

$$\text{Treatment Factor} = \frac{1}{1 - .9995} = 2{,}000$$

Early 1991 Westinghouse Hanford Regulatory Analysis discussions with EPA Region Ten indicated verbal acceptance by EPA on this method for determining offsite dose. At that time, EPA Region Ten cited the preliminary results of other U.S. Department of Energy (DOE) sites (i.e., Idaho Falls) *Clean Air Act of 1977* assessments in the region. Initially, the minimum acceptance criteria of 99.95% for HEPA efficiency was to be used to provide the treatment factor of 2,000. Some facilities such as, Transuranic Waste Storage and Assay Facilities (TRUSAF), Central Waste Complex, and Low Level Burial Grounds used this factor in the FEMP determination report. These results were compared to the use of 3,000 used for all registered permitted stacks and the differences were found to be insignificant. Following discussions with EPA, as stated above, the decision was made to use a factor of 3,000 instead of 2,000. Westinghouse Hanford felt it would be more appropriate by being consistent with other DOE sites in the region (i.e., Idaho Falls). This position was communicated to EPA in subsequent conversation.

The HEPA filters are routinely acceptance tested before use on the Hanford Site. An approved aerosol source for testing HEPA filters is transformed under controlled conditions to produce an essentially monodispersed aerosol, with droplet-size distribution between 0.2 and 0.3 microns. The polydisperse dioctyl phthalate (di-2-ethyl hexyl phthalate or DOP) or an equivalent aerosol used for in-place leak testing of systems at Hanford must not be confused with the monodisperse DOP or an equivalent aerosol used for efficiency testing of individual HEPA filters by the manufacturers or by Hanford acceptance testing. This latter aerosol is produced by very large equipment that cannot be used for field testing.

The treatment factor was applied to HEPA systems as a whole (whether single or multiple banks of filters are present). Several scientists in the field were consulted to address multiple filters or filters in series. General conclusion was that not enough scientific data on submicron particle filtration has been collected and documented, and the difference between single and multiple filtration would be a small effect on the overall filtration, therefore, the effects to the overall calculation would be minimal. The reason is that "particles passing through a HEPA filter are generally less than 0.3 microns." While multiple banks of filters may eventually stop these submicron particles, the treatment factor would be a small fraction of that for particles greater than 0.3 microns.

4.0 REFERENCES

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ATTACHMENT 1.

WESTINGHOUSE HANFORD COMPANY FACILITY EFFLUENT MONITORING PLAN DETERMINATION RESULTS

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Westinghouse Hanford Company Facilities Effluent Monitoring Plan Determination Results.

Facility	FEMP Required?		
100 Areas			
N Reactor	yes		
KE/KW Reactors	yes		
Retired Reactors (B, C, D, DR, F, H)	no		
1706-KE Lab	yes		
200/600 Areas			
B Plant	yes		
PUREX	yes		
UO_3	yes		
U Plant (202-S, 233-S)	no		
PFP	yes		
T Plant	yes		
Powerhouses (284-E and W)	yes		
222-S Laboratory	yes		
2703-E CEL	no		
2711-E	no		
Fabrication Shops	no		
Laundry	yes		
Grout Facilities	no		
224-T TRUSAF	no		
Solid Waste Facilities Compactor	no		
616	no		
212-P	no		
East and West Tank Farms			
*Single-Shell Tank Farms			
241-A 241-AX 241-B	yes	no	no
241-BX 241-BY 241-C	no	no	yes
241-S 241-SX 241-U	no	yes	no
241-TX 241-TY	no	no	

Westinghouse Hanford Company Facilities Effluent Monitoring Plan Determination Results.

Facility	FEMP Required?		
East and West Tank Farms (Continued)			
*Double-Shell Tank Farms			
241-AN 241-AP 241-AW	no	yes	yes
241-SY 244-A 244-TX	yes	no	no
244-U 244-S 244-BX	no	no	no
241-AY 241-AZ	yes	yes	
*Vaults			
204-AR 244-AR 244-CR	no	no	no
*Evaporators			
242-A 242-S 242-T	yes	no	no
Low-Level Burial Grounds	no		
PWSF 600 Area	no		
213 J & K Storage Vaults (600 Area)	no		
General Area Services (200 Area)	no		
300 Area			
303 A, B, C, E, F, G, J, K	no		
303-M Oxide Facility	no		
313 Fuels Fab	yes		
333 Fuel Fab	yes		
334-A Spent Acid Storage	no		
305 Hotcell Verification	no		
306-E Fab and Testing Lab	no		
308 Fuels Lab	no		
309 SP-100	no		
315 Water Plant	no		
384 Powerhouse	no		
321 Shutdown	no		
328 Tech Shops	no		
337 High Temp Sodium Facility	no		
338 Maintenance	no		
340 Waste Handling	yes		
3718-F Alkali Metal	no		

Westinghouse Hanford Company Facilities Effluent Monitoring Plan Determination Results.

Facility	FEMP Required?		
300 Area (Continued)			
3705 Photo Lab	no		
3709 Paint Shop	no		
3717-B Standards Lab	no		
400 Area			
FFTF	yes		
MASF	no		
FMEF	no		
4713-B Maintenance	no		
4722 B, C Maintenance	no		
4734-B Maintenance	no		
4831 Flammable Storage	no		
4843 Alkali Metal Storage	no		
1100/3000 Areas			
1154-A Radio Maintenance	no		
1162 Flammable Storage	no		
1164 Hazardous Material Storage	no		
1169 Chemical Storage	no		
1171 Shop	no		
1172-A Service Station	no		
1176 Tire Storage	no		
1171-A Vehicle Wash	no		

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ATTACHMENT 2.

WESTINGHOUSE HANFORD COMPANY OFFSITE DOSE CALCULATIONS FOR THE REGISTERED PERMITTED STACKS

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Westinghouse Hanford Airborne Discharges

PUREX Stack #	Radionuclide	1989 Ci	mrem/Ci dose factors		Treatment factor CAP 88	mrem dose/yr	
			GENII	CAP 88		GENII	CAP 88
291-A-1*	^{3}H	1.75 E+02	7.00 E-06	5.42 E-06	1 E+00	1.22 E-03	9.48 E-04
	^{90}Sr	8.93 E-06	1.20 E-02	1.20 E-02	3 E+03	1.07 E-07	3.21 E-04
	^{106}Ru	3.83 E-03	4.70 E-03	5.71 E-03	3 E+03	1.80 E-05	6.56 E-02
	^{129}I	1.04 E-01	2.90 E-01	1.84 E-01	2 E+01	3.02 E-02	3.83 E-01
	^{220}Rn	1.60 E+03		6.42 E-21	1 E+00	0.00 E+00	1.03 E-17
	^{239}Pu	4.44 E-06	2.20 E+00	2.37 E+00	3 E+03	9.77 E-06	3.16 E-02
	Total					3.14 E-02	4.81 E-01
296-A-1*	^{239}Pu	3.20 E-06	2.20 E+00	2.37 E+00	3 E+03	7.04 E-06	2.28 E-02
	^{241}Am	1.10 E-06	3.40 E+00	3.59 E+00	3 E+03	3.74 E-06	1.18 E-02
	Total					1.08 E-05	3.46 E-02
296-A-2*	Gr. Alpha	2.20 E-07	2.20 E+00	2.37 E+00	3 E+03	4.84 E-07	1.56 E-03
	Gr. Beta	7.02 E-07	1.20 E-02	1.20 E-02	3 E+03	8.42 E-09	2.53 E-05
	Total					4.92 E-07	1.59 E-03
296-A-3*	Gr. Beta	5.07 E-07	1.20 E-02	1.20 E-02	3 E+03	6.08 E-09	1.83 E-05
296-A-5A*	Gr. Beta	1.78 E-06	1.20 E-02	1.20 E-02	3 E+03	2.14 E-08	6.41 E-05
296-A-5B*	Gr. Alpha	4.57 E-06	2.20 E+00	2.37 E+00	3 E+03	1.01 E-05	3.25 E-02
	Gr. Beta	2.03 E-06	1.20 E-02	1.20 E-02	3 E+03	2.44 E-08	7.31 E-05
	Total					1.01 E-05	3.26 E-02
206-A-7*	Gr. Alpha	1.08 E-06	2.20 E+00	2.37 E+00	3 E+03	2.38 E-06	7.68 E-03
296-A-8*	Gr. Beta	2.06 E-06	1.20 E-02	1.20 E-02	3 E+03	2.47 E-08	7.42 E-05
296-A-10	Gr. Beta	7.00 E-07	3.40 E-02	4.38 E-02	3 E+03	2.38 E-08	9.20 E-05
296-A-14	Gr. Alpha	2.42 E-04	6.40 E+00	8.67 E+00	3 E+03	1.55 E-06	6.29 E-03
	Gr. Beta	6.44 E-06	3.40 E-02	4.38 E-02	3 E+03	2.19 E-07	8.46 E-04
	Total					1.77 E-06	7.14 E-03
296-A-35	Gr. Beta	1.76 E-06	3.40 E-02	4.38 E-02	1 E+00	5.98 E-08	7.71 E-08
296-A-36	Gr. Beta	1.86 E-06	3.40 E-02	4.38 E-02	1 E+00	6.32 E-08	8.15 E-08
296-A-38	Gr. Alpha	2.12 E-07	6.40 E+00	8.67 E+00	1 E+00	1.36 E-06	1.84 E-06
	Gr. Beta	1.29 E-06	3.40 E-02	4.38 E-02	1 E+00	4.39 E-08	5.65 E-08
	Total					1.40 E-06	1.89 E-06
*Stacks above 40 ft				PUREX Total		3.14 E-02	5.65 E-01

Westinghouse Hanford Airborne Discharges

B Plant Stack #	Radionuclide	Potential Ci**	mrem/Ci dose factors		Treatment factor CAP 88	mrem dose/yr	
			GENII	CAP 88		GENII	CAP 88
291-B-1*	^{90}Sr	6.76 E-03	1.20 E-02	1.20 E-02	3 E+03	8.11 E-05	2.43 E-01
	^{137}Cs	1.01 E-02	7.70 E-03	6.54 E-03	3 E+03	7.78 E-05	1.98 E-01
	^{239}Pu	3.22 E-06	2.20 E+00	2.37 E+00	3 E+03	7.08 E-06	2.29 E-02
	^{241}Am	9.60 E-07	3.40 E+00	3.59 E+00	3 E+03	3.26 E-06	1.03 E-02
	Total					1.69 E-04	4.75 E-01
296-B-5	Gr. Beta	1.20 E-06	3.40 E-02	4.38 E-02	3 E+03	4.08 E-08	1.58 E-04
296-B-10*	Gr. Beta	1.60 E-03	1.20 E-02	1.20 E-02	3 E+03	1.92 E-05	5.76 E-02
296-B-13	Gr. Beta	3.00 E-07	3.40 E-02	4.38 E-02	3 E+03	1.02 E-08	3.94 E-05
296-B-14	^{239}Pu	1.20 E-08	6.40 E+00	8.67 E+00	3 E+03	7.68 E-08	3.12 E-04
	^{241}Am	3.58 E-09	9.70 E+00	1.31 E+01	3 E+03	3.48 E-08	1.41 E-04
	Gr. Beta	8.90 E-06	3.40 E-02	4.38 E-02	3 E+03	3.03 E-07	1.17 E-03
	Total					4.14 E-07	1.62 E-03
*Stacks above 40 ft **DATA used was not 1989 Annual Report data but preliminary 1990 data submitted by facility.				B Plant Total		1.89 E-04	5.34 E-01

AR & CR Vent Stack #	Radionuclide	1989 Ci	mrem/Ci dose factors		Treatment factor CAP 88	mrem dose/yr	
			GENII	CAP 88		GENII	CAP 898
296-A-13*	Gr. Beta	9.37 E-07	1.20 E-02	1.20 E-02	3 E+03	1.12 E-08	3.37 E-05
296-C-5*	Gr. Beta	1.90 E-06	1.20 E-02	1.20 E-02	3 E+03	2.28 E-08	6.84 E-05
*Stacks above 40 ft				AR & CR Total		3.40 E-08	1.02 E-04

Westinghouse Hanford Airborne Discharges

200 East Tank Farm Stack & Vent Emissions	Radionuclide	1989 Ci	mrem/Ci dose factors		Treatment factor CAP 88	mrem dose/yr	
			GENII	CAP 88		GENII	CAP 88
296-A-17*	^{90}Sr	3.90 E-06	1.20 E-02	1.20 E-02	3 E+03	4.68 E-08	1.40 E-04
	^{137}Cs	3.20 E-05	7.70 E-03	6.54 E-03	3 E+03	2.46 E-07	6.28 E-04
	^{106}Ru	1.10 E-05	4.70 E-03	5.71 E-03	3 E+03	5.17 E-08	1.88 E-04
					Total	3.45 E-07	9.57 E-04
296-A-20	Gr. Beta	1.90 E-07	3.40 E-02	4.38 E-02	3 E+03	6.46 E-09	2.50 E-05
296-A-27	^{106}Ru	6.40 E-04	1.40 E-02	2.09 E-02	3 E+03	8.96 E-06	4.01 E-02
296-A-28	Gr. Beta	6.85 E-06	3.40 E-02	4.38 E-02	3 E+03	2.33 E-07	9.00 E-04
296-A-30	Gr. Beta	1.15 E-06	3.40 E-02	4.38 E-02	3 E+03	3.91 E-08	1.51 E-04
296-A-40	^{106}Ru	9.20 E-03	1.40 E-02	2.09 E-02	3 E+03	1.29 E-04	5.77 E-01
296-P-17	Gr. Alpha	3.86 E-08	6.40 E+00	8.67 E+00	3 E+03	2.47 E-07	1.00 E-03
	Gr. Beta	2.18 E-06	3.40 E-02	4.38 E-02	3 E+03	7.41 E-08	2.86 E-04
					Total	3.21 E-07	1.29 E-03
*Stacks above 40 ft			200 East TK Farm Total			1.39 E-04	6.20 E-01

242A Evaporator Vent #	Radionuclide	4 mo 1989 Ci	mrem/Ci dose factors		Treatment factor CAP 88	mrem dose/yr	
			GENII	CAP 88		GENII	CAP 88
296-A-22	^{90}Sr	1.70 E-08	3.40 E-02	4.38 E-02	3 E+03	5.78 E-10	2.23 E-06
	^{137}Cs	4.50 E-08	2.20 E-02	2.39 E-02	3 E+03	9.90 E-10	3.23 E-06
	^{106}Ru	5.80 E-04	1.40 E-02	2.09 E-02	3 E+03	8.12 E-06	3.64 E-02
					Total	8.12 E-06	3.64 E-02
2 E Evaporator Vent Total CAP 88 x 3 qtrs remaining/yr = 1.09 E-01							

2E Grout Vent #	Radionuclide	1989 Ci	mrem/Ci dose factors		Treatment factor CAP 88	mrem dose/yr	
			GENII	CAP 88		GENII	CAP 88
296-G-1	Gr. Beta	2.19 E-07	3.40 E-02	4.38 E-02	3 E+03	7.45 E-09	2.88 E-05

Westinghouse Hanford Airborne Discharges

2W S-Plant Stack #	Radionuclide	1989 Ci	mrem/Ci dose factors		Treatment Factor	mrem dose/yr	
			GENII	CAP 88		GENII	CAP 88
291-S-1	Gr. Alpha	8.08 E-07	1.50 E+00	1.55 E+00	5 E+02	1.21 E-06	6.26 E-04
	Gr. Beta	2.60 E-06	8.00 E-03	7.82 E-03	5 E+02	2.08 E-08	1.02 E-05
	Total					1.23 E-06	6.36 E-04
296-S-2*	Gr. Beta	1.24 E-07	8.00 E-03	7.82 E-03	3 E+03	9.92 E-10	2.91 E-06
296-S-4*	Gr. Alpha	2.96 E-07	1.50 E+00	1.55 E+00	3 E+03	4.44 E-07	1.38 E-03
	Gr. Beta	1.88 E-06	8.00 E-03	7.82 E-03	3 E+03	1.50 E-08	4.41 E-05
	Total					4.59 E-07	1.42 E-03
296-S-6*	Gr. Alpha	7.57 E-07	1.50 E+00	1.55 E+00	1 E+00	1.14 E-06	1.17 E-06
	Gr. Beta	4.19 E-06	8.00 E-03	7.82 E-03	1 E+03	3.35 E-08	3.28 E-08
	Total					1.17 E-06	1.21 E-06
296-S-7W	^{241}Am	3.60 E-07	5.60 E+00	7.79 E+00	3 E+03	1.96 E-06	8.18 E-03
*Stack above 40 ft				200 West S-Plant		4.82 E-06	1.02 E-02

2W T-Plant Stack #	Radionuclide	1989 Ci	mrem/Ci dose factors		Treatment factor CAP 88	mrem dose/yr	
			GENII	CAP 88		GENII	CAP 88
291-T-1*	^{239}Pu	3.20 E-05	1.50 E-02	1.55 E+00	3 E+03	4.80 E-05	1.49 E-01
	^{241}Am	2.80 E-06	2.30 E+00	2.35 E+00	3 E+03	6.44 E-06	1.97 E-02
	Total					5.44 E-05	1.69 E-01
296-T-11	Gr. Beta	2.60 E-06	2.00 E-02	2.60 E-02	3 E+03	5.20 E-08	2.03 E-04
296-T-12	Gr. Beta	3.70 E-06	2.00 E-02	2.60 E-02	3 E+03	7.40 E-08	2.89 E-04
296-T-13*	Gr. Alpha	4.11 E-06	1.50 E+00	1.55 E+00	3 E+03	6.16 E-06	1.91 E-02
	Gr. Beta	3.84 E-04	8.00 E-03	7.82 E-02	3 E+03	3.07 E-06	9.01 E-03
	Total					9.24 E-06	2.81 E-02
*Stacks above 40 ft				200 West T-Plant Total		6.38 E-05	5.67 E-02

Westinghouse Hanford Airborne Discharges

U-Plant Stack #	Radionuclide	1989 Ci	mrem/Ci dose factors		Treatment factor CAP 88	mrem dose/yr	
			GENII	CAP 88		GENII	CAP 88
291-U-1*	^{90}Sr	7.00 E-05	8.00 E-03	7.82 E-03	5 E+02	5.60 E-07	2.74 E-04
	^{137}Cs	7.40 E-04	5.20 E-03	4.28 E-03	5 E+02	3.85 E-06	1.58 E-03
	^{239}Pu	8.50 E-07	1.50 E+00	1.55 E+00	5 E+02	1.28 E-06	6.59 E-04
					Total	5.68 E-06	2.52 E-03
296-U-2*	Gr. Alpha	8.43 E-08	1.50 E+00	1.55 E+00	3 E+03	1.26 E-07	3.92 E-04
	Gr. Beta	2.02 E-07	8.00 E-03	7.82 E-03	3 E+03	1.62 E-09	4.74 E-06
					Total	1.28 E-07	3.97 E-04
296-U-4*	^{239}Pu	4.70 E-07	1.50 E+00	1.55 E+00	1 E+00	7.05 E-07	7.28 E-07
296-U-13	Gr. Alpha	4.26 E-07	3.60 E+00	5.15 E+00	3 E+03	1.53 E-06	6.58 E-03
	Gr. Beta	9.09 E -07	2.00 E-02	2.60 E-02	3 E+03	1.82 E-08	7.09 E-05
					Total	1.55 E-06	6.65 E-03
			200 West U-Plant Total			8.07 E-06	9.57 E-03

PFP Stack #	Radionuclide	1989 Ci	mrem/Ci dose factors		Treatment factor CAP 88	mrem dose/yr	
			GENII	CAP 88		GENII	CAP 88
291-Z-1*	^{239}Pu	2.90 E-04	1.50 E+00	1.55 E+00	3 E+03	4.35 E-04	1.35 E+00
	^{241}Am	5.00 E-05	2.30 E+00	2.35 E+00	3 E+03	1.15 E-04	3.53 E-01
					Total	5.50 E-04	1.70 E+00
296-Z-3	^{239}Pu	2.50 E-07	3.60 E+00	5.15 E+00	3 E+03	9.00 E-07	3.86 E-03
	^{241}Am	1.20 E-07	5.60 E+00	7.79 E+00	3 E+03	6.72 E-07	2.80 E-03
					Total	1.57 E-06	6.67 E-03
			Plutonium Finishing Plant Total			5.52 E-04	1.71 E+00

200 West Tank Farm Stack & Vent Emissions	Radionuclide	1989 Ci	mrem/Ci dose factors		Treatment factor CAP 88	mrem dose/yr	
			GENII	CAP 88		GENII	CAP 88
296-P-22	Gr. Beta	8.05 E-08	2.00 E-02	2.60 E-02	3 E+03	1.61 E-09	6.28 E-06
296-P-23	Gr. Beta	6.54 E-07	2.00 E-02	2.60 E-02	3 E+03	1.31 E-08	5.10 E-05
*Stacks above 40 ft			200 West TK Farm Total			1.47 E-08	5.73 E-05

Westinghouse Hanford Airborne Discharges

200 West Evaporator Emissions	Radionuclide	1989 Ci	mrem/Ci dose factors		Treatment factor CAP 88	mrem dose/yr	
			GENII	CAP 88		GENII	CAP 88
296-S-18	Gr. Alpha	1.16 E-06	3.60 E+00	5.15 E+00	3 E+03	4.18 E-06	1.79 E-02
	Gr. Beta	4.04 E-06	2.00 E-02	2.60 E-02	3 E+03	8.08 E-08	3.15 E-04
	Total					4.26 E-06	1.82 E-02
296-T-17	Gr. Beta	4.33 E-07	2.00 E-02	2.60 E-02	3 E+03	8.66 E-09	3.38 E-05
*Stacks above 40 ft			2 West Evaporator Vent Total			4.27 E-06	1.83 E-02

222-S Lab Stack #	Radionuclide	1989 Ci	mrem/Ci dose factors		Treatment factor CAP 88	mrem dose/yr	
			GENII	CAP 88		GENII	CAP 88
296-S-16	Gr. Beta	3.32 E-08	2.00 E-02	2.60 E-02	3 E+03	6.64 E-10	2.59 E-06
296-S-21	Gr. Beta	1.78 E-05	2.00 E-02	2.60 E-02	3 E+03	3.56 E-07	1.39 E-03
			222-S Laboratory Total			3.57 E-07	1.39 E-03

200 West Waste Compactor Emissions	Radionuclide	1989 Ci	mrem/Ci dose factors		Treatment factor CAP 88	mrem dose/yr	
			GENII	CAP 88		GENII	CAP 88
296-W-3	Gr. Beta	3.00 E-07	2.00 E-02	2.60 E-02	3 E+03	6.00 E-09	2.34 E-05
			Waste Compactor Total			6.00 E-09	2.34 E-05

200 West Laundry Emissions	Radionuclide	1989 Ci	mrem/Ci dose factors		Treatment factor CAP 88	mrem dose/yr	
			GENII	CAP 88		GENII	CAP 88
296-W-1	Gr. Alpha	1.67 E-06	3.60 E+00	5.15 E+00	1 E+00	6.01 E-06	8.60 E-06
	Gr. Beta	1.46 E-05	2.00 E-02	2.60 E-02	1 E+00	2.92 E-07	3.80 E-07
			200 West Laundry Total			6.30 E-06	8.98 E-06

Westinghouse Hanford Airborne Discharges

100 Area Stacks & Vents Emissions	Radionuclide	1989 Ci	mrem/Ci dose factors		Treatment factor CAP 88	mrem dose/yr	
			GENII	CAP 88		GENII	CAP 88
116-N-ST*	^{60}Co	4.70 E-04	4.70 E-03	1.29 E-02	3 E+03	2.21 E-06	1.82 E-02
	^{90}Sr	3.70 E-07	1.80 E-02	1.94 E-02	3 E+03	6.66 E-09	2.15 E-05
	^{137}Cs	2.00 E-04	1.10 E-02	1.06 E-02	3 E+03	2.20 E-06	6.36 E-03
	^{238}Pu	7.10 E-08	3.20 E+00	3.56 E+00	3 E+03	2.27 E-07	7.58 E-04
	^{239}Pu	1.00 E-07	3.30 E+00	3.85 E+00	3 E+03	3.30 E-07	1.15 E-03
	Total					4.97 E-06	2.65 E-02
109-N-Z-1	^{54}Mn	1.00 E-04	1.80 E-03	8.11 E-03	1 E+00	1.80 E-07	8.11 E-07
	^{60}Co	5.30 E-04	1.60 E-02	4.28 E-02	1 E+00	8.48 E-06	2.27 E-05
	^{90}Sr	2.10 E-06	5.90 E-02	6.45 E-02	1 E+00	1.24 E-07	1.35 E-07
	^{137}Cs	1.10 E-04	3.80 E-02	3.53 E-02	1 E+00	4.18 E-06	3.88 E-06
	^{155}Eu	1.70 E-04	2.00 E-03	2.73 E-03	1 E+00	3.40 E-07	4.64 E-07
	^{238}Pu	2.60 E-08	1.10 E+01	1.18 E+01	1 E+00	2.86 E-07	3.07 E-07
	^{239}Pu	5.70 E-08	1.10 E+01	1.28 E+01	1 E+00	6.27 E-07	7.30 E-07
	Total					1.42 E-05	2.90 E-05
109-N-C-6	^{54}Mn	1.60 E-05	1.80 E-03	8.11 E-03	1 E+00	2.88 E-08	1.30 E-07
	^{60}Co	2.30 E-04	1.60 E-02	4.28 E-02	1 E+00	3.68 E-06	9.84 E-06
	^{90}Sr	7.20 E-07	5.90 E-02	6.45 E-02	1 E+00	4.25 E-08	4.64 E-08
	^{137}Cs	1.50 E-05	3.80 E-02	3.53 E-02	1 E+00	5.70 E-07	5.29 E-07
	^{155}Eu	2.10 E-05	2.00 E-03	2.73 E-03	1 E+00	4.20 E-08	5.73 E-08
	^{238}Pu	1.30 E-08	1.10 E+01	1.18 E+01	1 E+00	1.43 E-07	1.53 E-07
	^{239}Pu	7.80 E-08	1.10 E+01	1.28 E+01	1 E+00	8.58 E-07	9.98 E-07
	Total					5.36 E-06	1.18 E-05
*Stacks above 40 ft			100 N Area Emission Total			2.46 E-05	2.65 E-02

Westinghouse Hanford Airborne Discharges

100-KE/W Vent #	Radionuclide	1989 Ci	mrem/Ci dose factors		Treatment factor CAP 88	mrem dose/yr	
			GENII	CAP 88		GENII	CAP 88
105-KE-VT	^{60}Co	3.70 E-05	1.60 E-02	4.28 E-02	1 E+00	5.92 E-07	1.58 E-06
	^{90}Sr	1.90 E-05	5.90 E-02	6.45 E-02	1 E+00	1.12 E-06	1.23 E-06
	^{134}Cs	2.50 E-05	5.20 E-02	4.62 E-02	1 E+00	1.30 E-06	1.15 E-06
	^{137}Cs	4.40 E-05	3.80 E-02	3.53 E-02	1 E+00	1.67 E-06	1.55 E-06
	^{238}Pu	5.70 E-08	1.10 E+01	1.18 E+01	1 E+00	6.27 E-07	6.73 E-07
	^{239}Pu	3.20 E-07	1.10 E+01	1.28 E+01	1 E+00	3.52 E-06	4.10 E-06
					Total	8.83 E-06	1.03 E-05
105-KW-VT	^{60}Co	3.30 E-05	1.60 E-02	4.28 E-02	1 E+00	5.28 E-07	1.41 E-06
	^{90}Sr	4.10 E-07	5.90 E-02	6.45 E-02	1 E+00	2.42 E-08	2.64 E-08
	^{137}Cs	2.40 E-05	3.80 E-02	3.53 E-02	1 E+00	9.12 E-07	8.47 E-07
	^{238}Pu	6.00 E-09	1.10 E+01	1.18 E+01	1 E+00	6.60 E-08	7.08 E-08
	^{239}Pu	1.10 E-08	1.10 E+01	1.28 E+01	1 E+00	1.21 E-07	1.41 E-07
					Total	1.65 E-06	2.50 E-06
1706-KE LB	^{60}Co	3.20 E-06	1.60 E-02	4.28 E-02	3 E+03	5.12 E-08	4.11 E-04
	^{238}Pu	2.40 E-09	1.10 E+01	1.18 E+01	3 E+03	2.64 E-08	8.50 E-05
	^{239}Pu	3.00 E-09	1.10 E+01	1.28 E+01	3 E+03	3.30 E-08	1.15 E-04
					Total	1.11 E-07	6.11 E-04
			100 K Area Emission Total			1.06 E-05	6.24 E-04

Westinghouse Hanford Airborne Discharges

300 Area Stack & Vent Emissions	Radionuclide	1989 Ci	mrem/Ci dose factors		Treatment factor CAP 88	mrem dose/yr	
			GENII	CAP 88		GENII	CAP 88
306-E-ULAB	^{238}U	6.30 E-08	5.90 E+1	5.66 E+01	3 E+03	3.72 E-06	1.07 E-02
308-GL-EX	^{239}Pu	5.50 E-08	1.50 E+02	1.73 E+02	3 E+03	8.25 E-06	2.85 E-02
308-ET-EX	^{239}Pu	1.30 E-07	1.50 E+02	1.73 E+02	1 E+00	1.95 E-05	2.20 E-05
308-TRIGA	^{239}Pu	4.00 E-08	1.50 E+02	1.73 E+02	1 E+00	6.00 E-06	8.70 E-06
	^{90}Sr	1.10 E-07	8.10 E-01	8.72 E-01	1 E+00	8.91 E-08	1.20 E-07
	^{131}I	1.40 E-06	1.20 E+00	7.47 E-01	1 E+00	1.68 E-06	1.4 E-06
	Total					3.55 E-05	1.00 E-05
309-PRTR	^{239}Pu	1.60 E-07	1.50 E+02	1.73 E+02	3 E+03	2.40 E-05	8.30 E-02
	^{90}Sr	9.80 E-07	8.10 E-01	8.72 E-01	3 E+03	7.94 E-07	2.56 E-03
	Total					2.48 E-05	8.56 E-02
340-NT-EX	^{239}Pu	2.50 E-08	1.50 E+02	1.73 E+02	3 E+03	3.75 E-06	1.30 E-02
	^{90}Sr	1.20 E-07	8.10 E-01	8.72 E-01	3 E+03	9.72 E-08	3.14 E-04
	^{131}I	4.10 E-06	1.20 E+00	7.47 E-01	2 E+01	4.92 LE-06	6.13 E-05
340-DECON-EX	^{239}Pu	2.10 E-07	1.50 E+02	1.73 E+02	3 E+03	3.15 E-05	1.09 E-01
	^{90}Sr	5.50 E-07	8.10 E-01	8.72 E-01	3 E+03	4.46 E-07	1.44 E-03
	Total					4.07 E-05	1.24 E-01
*Stacks above 40 ft			300 Area Total			1.05 E-04	3.37 E-01

400 Area Stack #	Radionuclide	1989 Ci	mrem/Ci dose factors		Treatment factor CAP 88	mrem/dose/yr	
			GENII	CAP 88		GENII	CAP 88
FFTF-CB-EX	^{137}Cs	3.70 E-06	3.20 E-02	1.89 E-02	1 E+00	1.18 E-07	6.99 E-08
	^{3}H	1.20 E+00	3.00 E-05	2.83 E-05	1 E+00	3.60 E-05	3.40 E-05
	^{131}I	9.40 E-06	7.60 E-02	2.72 E-02	2 E+01	7.14 E-07	5.11 E-06
	^{41}Ar	2.20 E+01	9.60 E-06	1.65 E-05	1 E+00	2.11 E-04	3.63 E-04
	^{85}Kr	6.60 E+00	2.10 E-08	6.31 E-08	1 E+00	1.39 E-07	4.16 E-07
	Total					2.48 E-04	4.03 E-04
FFTF-RE-SB	^{137}Cs	5.10 E-06	3.20 E-02	3.17 E-02	1 E+00	1.63 E-07	1.62 E-07
FFTF-HT-TR	^{137}Cs	3.90 E-07	3.20 E-02	3.17 E-02	1 E+00	1.25 E-08	1.24 E-08
437-MN&ST	^{137}Cs	6.40 E-07	3.20 E-02	3.17 E-02	3 E+03	2.05 E-08	6.09 E-05
	FFTF Total					2.48 E-04	4.64 E-04
*Stacks above 40 ft			Hanford Site Total			4.10 E-01	3.92 E+00

ATTACHMENT 3. RADIONUCLIDE LISTS

UNIT DOSE CONVERSION FACTORS PREPARED BY PACIFIC NORTHWEST LABORATORY

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Table C-1. GENII Dose Estimates for One-Curie Radionuclide Releases - 100 Areas. Location to the Individual at the Hanford Site Boundary: 9,900 Meters West.

Nuclide	Ground level dose equivalent (REM)	89 m stack dose equivalent (REM)
^{3}H	3.5 E-08	1.0 E-08
^{24}Na	1.1 E-07	4.5 E-08
^{41}Ar	9.0 E-09	6.9 E-09
^{51}Cr	3.6 E-08	1.1 E-08
^{54}Mn	1.8 E-06	5.5 E-07
^{56}Mn	2.3 E-08	1.1 E-08
^{59}Fe	1.9 E-06	5.8 E-07
^{58}Co	1.5 E-06	4.5 E-07
^{60}Co	1.6 E-05	4.7 E-06
^{76}As	1.6 E-07	5.1 E-08
^{85M}Kr	1.9 E-09 (100)*	9.1 E-10 (100)
^{85}Kr	2.7 E-11	1.4 E-11
^{87}Kr	4.4 E-09	2.8 E-09
^{88}Kr	2.4 E-08	1.3 E-08
^{89}Sr	2.0 E-06	5.8 E-07
^{90}Sr	5.9 E-05 (94)	1.8 E-05 (94)
^{91}Sr	5.4 E-08 (73)	1.9 E-08 (76)
^{95}Zr	1.9 E-06 (75)	5.7 E-07 (75)
^{95}Nb	7.2 E-07	2.2 E-07
^{99}Mo	1.4 E-07 (98)	4.4 E-08 (98)
^{103}Ru	8.8 E-07 (100)	2.6 E-07 (100)
^{106}Ru	2.4 E-05	7.1 E-06
^{124}Sb	3.4 E-06	1.0 E-06
^{132}Te	5.8 E-07 (86)	1.7 E-07 (86)
^{131}I	9.0 E-05 (100)	2.6 E-05 (100)
^{132}I	3.6 E-08	1.7 E-08
^{133}I	1.4 E-06 (100)	4.1 E-07 (100)
^{135}I	9.6 E-08 (95)	3.5 E-08 (95)
^{133}Xe	6.9 E-10	3.0 E-10
^{135}Xe	3.4 E-09	1.5 E-09
^{134}Cs	5.2 E-05	1.6 E-05
^{137}Cs	3.8 E-05	1.1 E-05
^{138}Cs	5.2 E-09	5.0 E-09
^{140}Ba	1.7 E-06 (50)	5.1 E-07 (51)
^{140}La	2.2 E-07	7.3 E-08
^{141}Ce	6.9 E-07	2.0 E-07
^{144}Ce	1.8 E-05 (100)	5.4 E-06 (100)
^{153}Sm	9.4 E-08	2.8 E-08
^{154}Eu	1.5 E-05	4.3 E-06
^{155}Eu	2.0 E-06	5.8 E-07
^{238}Pu	1.1 E-02	3.2 E-03
^{239}Np	1.3 E-07 (100)	3.9 E-08 (100)
^{239}Pu	1.1 E-02	3.3 E-03

*Doses calculated with GENII include contributions from the parent nuclide, long-lived daughter chains, and short-lived daughters. Numbers in parenthesis indicate percent of the total dose attributable to the parent nuclide in chains with long-lived daughters.

Table C-2. GENII Dose Estimates for One-Curie Radionuclide Releases - 200 East Area. Location to the Individual at the Hanford Site Boundary: 16,000 Meters East. (2 sheets)

Nuclide	Ground-level dose equivalent (REM)[a]	89-m stack dose equivalent (REM)[a]
^{3}H	2.0 E-08	7.0 E-09
^{14}C	4.2 E-06	1.5 E-06
^{54}Mn	1.1 E-06	3.7 E-07
^{60}Co	9.0 E-06	3.2 E-06
^{79}Se	6.6 E-05	2.2 E-05
^{85}Kr	1.6 E-11	9.1 E-12
^{90}Sr	3.4 E-05 (94)[a]	1.2 E-05 (94)
^{90}Y	2.6 E-07	9.0 E-08
^{94}Nb	1.0 E-05	3.6 E-06
^{95}Zr	1.1 E-06 (75)	3.8 E-07 (76)
^{95}Nb	4.1 E-07	1.5 E-07
^{99}Tc	3.4 E-06	1.2 E-06
^{103}Ru	5.0 E-07 (100)	1.7 E-07 (100)
^{106}Ru	1.4 E-05	4.7 E-06
^{106}Rh	[b]	[b]
^{113}Sn	7.9 E-07	2.7 E-07
^{125}Sb	1.2 E-06	4.2 E-07
^{126}Sn	8.4 E-06 (74)	2.9 E-06 (73)
^{129}I	8.4 E-04	2.9 E-04
^{131}I	5.1 E-05 (100)	1.8 E-05 (100)
^{134}Cs	3.0 E-05	1.0 E-05
^{135}Cs	3.2 E-06	1.1 E-06
^{137}Cs[b]	2.2 E-05	7.7 E-06
^{144}Ce	1.0 E-05 (100)	3.6 E-06 (100)
^{147}Pm	9.8 E-07	3.4 E-07
^{220}Rn	[c]	[c]
^{216}Po	[c]	[c]
^{212}Pb	3.6 E-06 (93)	1.3 E-06 (95)
^{212}Bi	1.7 E-07	8.4 E-08
^{212}Po	[b]	[b]
^{208}Tl	[b]	[b]
^{226}Ra	3.1 E-04 (98)	1.0 E-04 (98)
^{230}Th	5.5 E-03 (100)	1.9 E-03 (100)
^{233}U	2.8 E-03 (100)	9.9 E-04 (100)
^{234}U	2.8 E-03	9.7 E-04
^{235}U	2.6 E-03 (100)	9.0 E-04 (100)
^{236}U	2.7 E-03	9.2 E-04
^{238}U	2.5 E-03 (100)	8.6 E-04 (100)
^{237}Np	1.4 E-02 (100)	5.0 E-03 (100)
^{238}Pu	6.0 E-03	2.1 E-03
^{239}Pu	6.4 E-03	2.2 E-03
^{240}Pu	6.4 E-03	2.2 E-03
^{241}Pu	1.0 E-04 (100)	3.6 E-05 (100)
^{241}Am	9.7 E-03	3.4 E-03

Table C-2. GENII Dose Estimates for One-Curie Radionuclide Releases - 200 East Area. Location to the Individual at the Hanford Site Boundary: 16,000 Meters East. (2 sheets)

Nuclide	Ground-level dose equivalent (REM)[a]	89-m stack dose equivalent (REM)[a]
^{243}Am	9.7 E-03 (100)	3.4 E-03 (100)
^{244}Cm	5.5 E-03 (100)	1.9 E-03 (100)

[a]Doses calculated with GENII include contributions from the parent nuclide, long-lived daughter chains, and short-lived daughters. Numbers in parenthesis indicate percent of the total dose attributable to the parent nuclide in chains with long-lived daughters.

[b]Short-lived daughters are included in dose from parent nuclide.

[c]Very short-lived; model as Pb212.

Table C-3. GENII Dose Estimates for One-Curie Radionuclide Releases - 200 West Area. Location to the Individual at the Hanford Site Boundary: 24,000 Meters East. (2 sheets)

Nuclide	Ground-level dose equivalent (REM)[a]	89-m stack dose equivalent (REM)[a]
^{3}H	1.2 E-08	4.7 E-09
^{14}C	2.4 E-06	1.0 E-06
^{54}Mn	6.0 E-07	2.4 E-07
^{60}Co	5.2 E-06	2.1 E-06
^{79}Se	3.8 E-05	1.5 E-05
^{85}Kr	1.0 E-11	5.8 E-12
^{90}Sr	2.0 E-05 (94)*	8.0 E-06 (94)
^{90}Y	1.5 E-07	6.0 E-08
^{94}Nb	5.8 E-06	2.4 E-06
^{95}Zr	6.3 E-07 (76)	2.6 E-07 (75)
^{95}Nb	2.4 E-07	9.8 E-08
^{99}Tc	2.0 E-06	7.8 E-07
^{103}Ru	2.9 E-07 (100)	1.2 E-07 (100)
^{106}Ru	7.7 E-06	3.2 E-06
^{106}Rh	[b]	[b]
^{113}Sn	4.5 E-07	1.8 E-07
^{125}Sb	6.8 E-07	2.8 E-07
^{126}Sn	4.7 E-06 (74)	1.9 E-06 (74)
^{129}I	4.9 E-04	2.0 E-04
^{131}I	2.9 E-05 (100)	1.2 E-05 (100)
^{134}Cs	1.7 E-05	7.1 E-06
^{135}Cs	1.8 E-06	7.3 E-07
^{137}Cs[b]	1.3 E-05	5.2 E-06
^{144}Ce	5.9 E-06 (100)	2.4 E-06 (100)
^{147}Pm	5.6 E-07	2.3 E-07
^{220}Rn	[c]	[c]
^{216}Po	[c]	[c]
^{212}Pb	2.1 E-06 (92)	8.6 E-07 (93)
^{212}Bi	6.1 E-08	4.3 E-08
^{212}Po	[b]	[b]
^{208}Tl	[b]	[b]
^{226}Ra	1.7 E-04 (98)	7.1 E-05 (98)
^{230}Th	3.2 E-03 (100)	1.3 E-03 (100)
^{233}U	1.6 E-03 (100)	6.6 E-04 (100)
^{234}U	1.6 E-03	6.5 E-04
^{235}U	1.5 E-03 (100)	6.1 E-04 (100)
^{237}U	1.5 E-03	6.2 E-04
^{238}U	1.4 E-03 (100)	5.8 E-04 (100)
^{237}Np	8.1 E-03 (100)	3.3 E-03 (100)
^{238}Pu	3.4 E-03	1.4 E-03
^{239}Pu	3.6 E-03	1.5 E-03
^{240}Pu	3.6 E-03	1.5 E-03
^{241}Pu	5.9 E-05 (100)	2.4 E-05 (100)
^{241}Am	5.6 E-03	2.3 E-03

Table C-3. GENII Dose Estimates for One-Curie Radionuclide Releases - 200 West Area. Location to the Individual at the Hanford Site Boundary: 24,000 Meters East. (2 sheets)

Nuclide	Ground-level dose equivalent (REM)[a]	89-m stack dose equivalent (REM)[a]
^{243}Am	5.6 E-03 (100)	2.3 E-03 (100)
^{244}Cm	3.2 E-03 (100)	1.3 E-03 (100)

[a]Doses calculated with GENII include contributions from the parent nuclide, long-lived daughter chains, and short-lived daughters. Numbers in parenthesis indicate percent of the total dose attributable to the parent nuclide in chains with long-lived daughters.

[b]Short-lived daughters are included in dose from parent nuclide.

[c]Very short-lived; model as Pb212.

Table C-4. GENII Dose Estimates for One-Curie Radionuclide Releases - 300 Area. Location to the Individual at the Hanford Site Boundary: 1,400 Meters Northeast.

Nuclide	Ground-level dose equivalent (REM)[a]	46-m stack dose equivalent (REM)[a]
^{3}H	4.8 E-07	8.4 E-08
^{14}C	1.0 E-04	1.7 E-05
^{22}Na	4.3 E-04	7.5 E-05
^{51}Cr	4.9 E-07	8.6 E-08
^{54}Mn	2.5 E-05	4.3 E-06
^{59}Fe	2.6 E-05	4.6 E-06
^{58}Co	2.0 E-05	3.6 E-06
^{60}Co	2.1 E-04	3.7 E-05
^{63}Ni	3.2 E-06	5.5 E-07
^{65}Zn	2.8 E-04	5.0 E-05
^{79}Se	1.5 E-03	2.7 E-04
^{85}Sr	8.8 E-06	1.6 E-06
^{90}Sr	8.1 E-04 (94)[a]	1.5 E-04 (94)
^{95}Zr	2.6 E-05 (76)	4.5 E-06 (75)
^{99M}Tc	3.1 E-08 (100)	9.5 E-09 (100)
^{99}Tc	8.3 E-05	1.4 E-05
^{106}Ru[b]	3.2 E-04	5.6 E-05
^{113}Sn	1.9 E-05 (86)	3.2 E-06 (87)
^{125}Sb	2.9 E-05 (87)	5.0 E-06 (86)
^{125}I	2.1 E-03	3.6 E-04
^{129}I	2.0 E-02	3.5 E-03
^{131}I	1.2 E-03 (100)	2.1 E-04 (100)
^{134}Cs	7.2 E-04	1.2 E-04
^{137}Cs[b]	5.3 E-04	9.2 E-05
^{144}Ce	2.5 E-04 (100)	4.3 E-05 (100)
^{153}Eu	1.5 E-04	2.7 E-05
^{154}Eu	2.0 E-04	3.5 E-05
^{155}Eu	2.6 E-05	4.6 E-06
^{232}Th	5.9 E-01 (100)	1.0 E-01 (100)
^{234}U	6.6 E-02	1.2 E-02
^{235}U	6.2 E-02 (100)	1.1 E-02 (100)
^{238}U	5.9 E-02 (100)	1.0 E-02 (100)
^{238}Np	3.4 E-01 (100)	5.9 E-02 (100)
^{238}Pu	1.4 E-01	2.5 E-02
^{239}Pu	1.5 E-01	2.6 E-02
^{241}Pu	2.5 E-03 (100)	4.3 E-04 (100)
^{241}Am	2.3 E-01	4.0 E-02
^{242}Cm	8.6 E-03 (100)	1.5 E-03 (100)
^{244}Cm	1.3 E-01 (100)	2.3 E-02 (100)

[a]Doses calculated with GENII include contributions from the parent nuclide, long-lived daughter chains, and short-lived daughters. Numbers in parenthesis indicate percent of the total dose attributable to the parent nuclide in chains with long-lived daughters.

[b]Short-lived daughters are included in dose from parent nuclide.

Table C-5. GENII Dose Estimates for One-Curie Radionuclide Releases - 400 Area. Location to the Individual at the Hanford Site Boundary: 8,100 Meters South.

Nuclide	Ground-level dose equivalent (REM)[a]
^{3}H	3.0 E-08
^{22}Na	2.6 E-05
^{41}Ar	9.6 E-09
^{51}Cr	3.0 E-08
^{54}Mn	1.5 E-06
^{59}Fe	1.6 E-06
^{57}Co	5.8 E-07
^{58}Co	1.3 E-06
^{60}Co	1.3 E-05
^{65}Zn	1.8 E-05
^{83M}Kr	2.3 E-11
^{85M}Kr	1.7 E-09 (100)[a]
^{85}Kr	2.1 E-11
^{87}Kr	5.0 E-09 (100)
^{88}Kr	2.1 E-08 (70)
^{90}Sr	5.0 E-05 (94)
^{95}Nb	6.1 E-07
^{131}I	7.6 E-05 (100)
^{131M}Xe	2.4 E-10
^{133M}Xe	5.0 E-10 (100)
^{133}Xe	5.4 E-10
^{135M}Xe	6.3 E-10 (89)
^{135}Xe	2.8 E-09
^{134}Cs	4.4 E-05
^{137}Cs[b]	3.2 E-05
^{182}Ta	3.0 E-06
^{239}Pu	9.4 E-03

[a]Doses calculated with GENII include contributions from the parent nuclide, long-lived daughter chains, and short-lived daughters. Numbers in parenthesis indicate percent of the total dose attributable to the parent nuclide in chains with long-lived daughters.

[b]Short-lived daughters are included in dose from parent nuclide.

Table C-6. GENII Dose Estimates for One-Curie Liquid Releases to Columbia River.

Nuclide	100 and 200 Areas MI at Ringold dose equivalent (REM)[a]	300 Area MI at Riverview dose equivalent (REM)[a]
^{3}H	6.4 E-10	
^{24}Na	2.7 E-08	
^{32}P	2.5 E-04	
^{51}Cr	3.3 E-09	
^{54}Mn	6.6 E-07	
^{59}Fe	6.1 E-06	
^{58}Co	5.4 E-07	
^{60}Co	2.4 E-06	
^{65}Zn	1.6 E-05	
^{89}Sr	3.1 E-07	
^{90}Sr	6.1 E-06	6.1 E-06
^{95}Zr	4.6 E-07	
^{99}Mo	1.7 E-08	
^{99}Tc	3.9 E-07	3.9 E-07
^{103}Ru	1.7 E-07	
^{106}Ru	1.6 E-06	
^{124}Sb	1.1 E-06	
^{125}Sb	4.0 E-07	
^{129}I	1.7 E-05	
^{131}I	1.8 E-06	
^{133}I	1.2 E-07	
^{133}Xe	1.4 E-10	
^{134}Cs	4.6 E-04	
^{137}Cs	3.2 E-04	
^{140}Ba	1.1 E-06	
^{141}Ce	6.6 E-07	
^{144}Ce	4.9 E-06	
^{234}U	8.9 E-07	8.9 E-07
^{235}U	9.6 E-07	9.6 E-07
^{238}U	9.5 E-07	9.5 E-07
^{238}Pu	5.8 E-06	
^{239}Pu	6.0 E-06	
^{241}Pu	9.7 E-08	
^{241}Am	2.0 E-04	
^{239}Np	2.8 E-06	

[a]Doses calculated with GENII include contributions from the parent nuclide, long-lived daughter chains, and short-lived daughters.

Table C-7. CAP-88 Dose Estimates for One-Curie Radionuclide Releases - 100 Areas. Location to the Individual at the Hanford Site Boundary: 9,900 Meters West.

Nuclide	10-m stack dose equivalent (mrem)[a]	89-m stack dose equivalent (mrem)[a]
^{3}H	3.36 E-05	8.85 E-06
^{24}Na	2.19 E-04	6.72 E-05
^{41}Ar	1.41 E-05	4.38 E-06
^{51}Cr	9.32 E-05	2.80 E-05
^{54}Mn	8.11 E-03	2.44 E-03
^{56}Mn	3.56 E-05	1.20 E-05
^{59}Fe	4.72 E-03	1.42 E-03
^{58}Co	4.75 E-03	1.43 E-03
^{60}Co	4.28 E-02	1.29 E-02
^{76}As	1.81 E-04	5.50 E-05
^{85M}Kr	2.62 E-06	7.35 E-07
^{85}Kr	7.49 E-08	1.97 E-08
^{87}Kr	7.18 E-06	2.41 E-06
^{88}Kr	3.11 E-05	9.07 E-06
^{89}Sr	3.11 E-03	9.35 E-04
^{90}Sr	6.45 E-02	1.94 E-02
^{91}Sr	5.39 E-05	1.67 E-05
^{95}Zr	3.90 E-03	1.17 E-03
^{95}Nb	2.60 E-03	7.81 E-04
^{99}Mo	2.41 E-04	7.28 E-05
^{103}Ru	2.10 E-03	6.31 E-04
^{106}Ru[b]	3.08 E-02	9.26 E-03
^{124}Sb	8.90 E-03	2.68 E-03
^{132}Te	6.29 E-04	1.90 E-04
^{131}I	1.84 E-02	1.65 E-02
^{132}I	2.48 E-05	2.54 E-05
^{133}I	1.72 E-04	1.56 E-04
^{135}I	5.99 E-05	5.62 E-05
^{133}Xe	7.71 E-07	2.04 E-07
^{135}Xe	4.73 E-06	1.28 E-06
^{134}Cs	4.62 E-02	1.39 E-02
^{137}Cs[b]	3.53 E-02	1.06 E-02
^{138}Cs	7.20 E-06	3.77 E-06
^{140}Ba	1.86 E-03	5.60 E-04
^{140}La	4.49 E-04	1.36 E-04
^{141}Ce	1.21 E-03	3.65 E-04
^{144}Ce	2.02 E-02	6.08 E-03
^{153}Sm	1.13 E-04	3.42 E-05
^{154}Eu	2.69 E-02	8.10 E-03
^{155}Eu	2.73 E-03	8.20 E-04
^{238}Pu	1.18 E+01	3.56 E+00
^{239}Np	1.70 E-04	5.13 E-05
^{239}Pu	1.28 E+01	3.85 E+00

[a] Doses calculated with CAP-88 are for the parent nuclide only, and do not include contributions from long-lived daughter chains.
[b] Short-lived daughters are included in dose from parent nuclide.

Table C-8. CAP-88 Dose Estimates for One-Curie Radionuclide Releases - 200 East Area. Location to the Individual at the Hanford Site Boundary: 16,000 Meters East. (2 sheets)

Nuclide	10-m stack dose equivalent (mrem)[a]	89-m stack dose equivalent (mrem)[a]
^{3}H	2.19 E-05	5.42 E-06
^{14}C	2.62 E-03	6.48 E-04
^{54}Mn	5.51 E-03	1.51 E-03
^{60}Co	2.90 E-02	7.94 E-03
^{79}Se	[b]	[b]
^{85}Kr	4.88 E-08	1.21 E-08
^{90}Sr	4.38 E-02	1.20 E-02
^{90}Y	3.77 E-04	1.04 E-04
^{94}Nb	2.58 E-02	7.05 E-03
^{95}Zr	2.65 E-03	7.24 E-04
^{95}Nb	1.76 E-03	4.82 E-04
^{99}Tc	1.09 E-03	2.97 E-04
^{103}Ru	1.42 E-03	3.89 E-04
^{106}Ru	2.09 E-02	5.71 E-03
^{106}Rh	[c]	[c]
^{113}Sn	1.18 E-03	3.23 E-04
^{125}Sb	4.15 E-03	1.14 E-03
^{126}Sn	8.63 E-03	2.36 E-03
^{129}I	2.91 E-01	1.84 E-01
^{131}I	1.68 E-02	1.06 E-02
^{134}Cs	3.13 E-02	8.56 E-03
^{135}Cs	2.15 E-03	5.87 E-04
^{137}Cs[c]	2.39 E-02	6.54 E-03
^{144}Ce	1.37 E-02	3.75 E-03
^{147}Pm	1.14 E-03	3.11 E-04
^{220}Rn	[d]	[d]
^{216}Po	[d]	[d]
^{212}Pb	3.32 E-03	9.42 E-04
^{212}Bi	2.66 E-04	1.14 E-04
^{212}Po	[c]	[c]
^{208}Tl	[c]	[c]
^{226}Ra	5.45 E-01	1.49 E-01
^{230}Th	5.69 E+00	1.55 E+00
^{233}U	3.23 E+00	8.83 E-01
^{234}U	3.19 E+00	8.72 E-01
^{235}U	2.96 E+00	8.10 E-01
^{236}U	3.02 E+00	8.26 E-01
^{238}U	2.84 E+00	7.77 E-01
^{238}Np	1.19 E+01	3.25 E+00
^{238}Pu	8.02 E+00	2.19 E+00
^{239}Pu	8.67 E+00	2.37 E+00
^{240}Pu	8.66 E+00	2.37 E+00
^{241}Pu	1.38 E-01	3.76 E-02
^{241}Am	1.31 E+01	3.59 E+00

Table C-8. CAP-88 Dose Estimates for One-Curie Radionuclide Releases - 200 East Area. Location to the Individual at the Hanford Site Boundary: 16,000 Meters East. (2 sheets)

Nuclide	10-m stack dose equivalent (mrem)[a]	89-m stack dose equivalent (mrem)[a]
^{245}Am	1.31 E+01	3.59 E+00
^{244}Cm	6.94 E+00	1.90 E+00

[a]Doses calculated with CAP-88 are for the parent nuclide only, and do not include contributions from long-lived daughter chains.
[b]Dose factors not included in code radionuclide library.
[c]Short-lived daughters are included in dose from parent nuclide.
[d]Very short-lived; model as Pb212.

Table C-9. CAP-88 Dose Estimates for One-Curie Radionuclide Releases - 200 West Area. Location to the Individual at the Hanford Site Boundary: 24,000 Meters East. (2 sheets)

Nuclide	10-m stack dose equivalent (mrem)[a]	89-m stack dose equivalent (mrem)[a]
^{3}H	1.38 E-05	3.58 E-06
^{14}C	1.65 E-03	4.28 E-04
^{54}Mn	3.27 E-03	9.84 E-04
^{60}Co	1.72 E-02	5.19 E-03
^{79}Se	[b]	[b]
^{85}Kr	3.07 E-08	7.98 E-09
^{90}Sr	2.60 E-02	7.82 E-03
^{90}Y	2.22 E-04	6.73 E-05
^{94}Nb	1.53 E-02	4.61 E-03
^{95}Zr	1.57 E-03	4.73 E-04
^{95}Nb	1.05 E-03	3.15 E-04
^{99}Tc	6.45 E-04	1.94 E-04
^{103}Ru	8.45 E-04	2.54 E-04
^{106}Ru	1.24 E-02	3.73 E-03
^{106}Rh	[c]	[c]
^{113}Sn	7.02 E-04	2.11 E-04
^{125}Sb	2.47 E-03	7.42 E-04
^{126}Sn	5.12 E-03	1.54 E-03
^{129}I	1.14 E-01	1.09 E-01
^{131}I	6.53 E-03	6.29 E-03
^{134}Cs	1.86 E-02	5.60 E-03
^{135}Cs	1.28 E-03	3.84 E-04
^{137}Cs[c]	1.42 E-02	4.28 E-03
^{144}Ce	8.14 E-03	2.45 E-03
^{147}Pm	6.75 E-04	2.03 E-04
^{220}Rn	[d]	[d]
^{216}Po	[d]	[d]
^{212}Pb	1.85 E-03	5.91 E-04
^{212}Bi	9.88 E-05	5.81 E-05
^{212}Po	[e]	[e]
^{208}Tl	[e]	[e]
^{226}Ra	3.23 E-01	9.73 E-02
^{230}Th	3.38 E+00	1.02 E+00
^{233}U	1.92 E+00	5.77 E-01
^{234}U	1.89 E+00	5.70 E-01
^{235}U	1.76 E+00	5.30 E-01
^{236}U	1.79 E+00	5.40 E-01
^{238}U	1.69 E+00	5.08 E-01
^{237}Np	7.05 E+00	2.12 E+00
^{238}Pu	4.76 E+00	1.43 E+00
^{239}Pu	5.15 E+00	1.55 E+00
^{240}Pu	5.14 E+00	1.55 E+00
^{241}Pu	8.17 E-02	2.46 E-02
^{241}Am	7.79 E+00	2.35 E+00

Table C-9. CAP-88 Dose Estimates for One-Curie Radionuclide Releases - 200 West Area. Location to the Individual at the Hanford Site Boundary: 24,000 Meters East. (2 sheets)

Nuclide	10-m stack dose equivalent (mrem)[a]	89-m stack dose equivalent (mrem)[a]
^{243}Am	7.79 E+00	2.34 E+00
^{244}Cm	4.12 E+00	1.24 E+00

[a]Doses calculated with CAP-88 are for the parent nuclide only, and do not include contributions from long-lived daughter chains.
[b]Dose factors not included in code radionuclide library.
[c]Short-lived daughters are included in dose from parent nuclide.
[d]Very short-lived; model as Pb212.

Table C-10. CAP-88 Dose Estimates for One-Curie Radionuclide Releases - 300 Area. Location to the Individual at the Hanford Site Boundary: 1,400 Meters Northeast.

Nuclide	10-m stack dose equivalent (mrem)[a]	89-m stack dose equivalent (mrem)[a]
^{3}H	3.97 E-04	1.10 E-04
^{14}C	4.74 E-02	1.32 E-02
^{22}Na	3.86 E-01	1.09 E-01
^{51}Cr	1.26 E-03	3.56 E-04
^{54}Mn	1.10 E-01	3.10 E-02
^{59}Fe	6.38 E-02	1.80 E-02
^{58}Co	6.43 E-02	1.81 E-02
^{60}Co	5.79 E-01	1.63 E-01
^{63}Ni	4.05 E-03	1.14 E-03
^{65}Zn	1.86 E-01	5.24 E-02
^{79}Se	[b]	[b]
^{85}Sr	1.74 E-01	5.44 E-02
^{90}Sr	8.72 E-01	2.46 E-01
^{95}Zr	5.27 E-02	1.49 E-02
^{99m}Tc	7.12 E-05	2.02 E-05
^{99}Tc	2.16 E-02	6.11 E-03
^{106}Ru[c]	4.16 E-01	1.17 E-01
^{113}Sn	2.35 E-02	6.65 E-03
^{125}Sb	8.27 E-02	2.34 E-02
^{125}I	1.81 E-01	5.10 E-02
^{129}I	1.29 E+01	4.28 E+00
^{131}I	7.47 E-01	2.48 E-01
^{134}Cs	6.24 E-01	1.76 E-01
^{137}Cs[c]	4.77 E-01	1.35 E-01
^{144}Ce	2.73 E-01	7.71 E-02
^{152}Eu	3.07 E-01	8.67 E-02
^{154}Eu	3.64 E-01	1.03 E-01
^{155}Eu	3.68 E-02	1.04 E-02
^{232}Th	1.62 E+02	4.57 E+01
^{234}U	6.36 E+01	1.79 E+01
^{235}U	5.90 E+01	1.67 E+01
^{238}U	5.66 E+01	1.60 E+01
^{237}Np	2.37 E+02	6.68 E+01
^{238}Pu	1.60 E+02	4.51 E+01
^{239}Pu	1.73 E+02	4.87 E+01
^{241}Pu	2.74 E+00	7.74 E-01
^{241}Am	2.62 E+02	7.38 E+01
^{242}Cm	8.46 E+00	2.39 E+00
^{244}Cm	1.38 E+02	3.90 E+01

[a]Doses calculated with CAP-88 are for the parent nuclide only, and do not include contributions from long-lived daughter chains.
[b]Dose factors not included in code radionuclide library.
[c]Short-lived daughters are included in dose from parent nuclide.

Table C-11. CAP-88 Dose Estimates for One-Curie Radionuclide Releases - 400 Area. Location to the Individual at the Hanford Site Boundary: 8,100 Meters South.

Nuclide	10-m stack dose equivalent (mrem)[a]
^{3}H	2.83 E-05
^{22}Na	2.56 E-02
^{41}Ar	1.65 E-05
^{51}Cr	8.37 E-05
^{54}Mn	7.29 E-03
^{59}Fe	4.24 E-03
^{57}Co	1.63 E-03
^{58}Co	4.27 E-03
^{60}Co	3.85 E-02
^{65}Zn	1.23 E-02
^{83M}Kr	2.97 E-09
^{85M}Kr	2.53 E-06
^{85}Kr	6.31 E-08
^{87}Kr	9.48 E-06
^{88}Kr	3.25 E-05
^{90}Sr	5.80 E-02
^{95}Nb	2.33 E-03
^{131}I	2.72 E-02
^{131M}Xe	1.79 E-07
^{133M}Xe	5.65 E-07
^{133}Xe	6.57 E-07
^{135M}Xe	9.53 E-07
^{135}Xe	4.26 E-06
^{134}Cs	4.15 E-02
^{137}Cs[b]	3.17 E-02
^{182}Ta	[c]
^{239}Pu	1.15 E+01

[a]Doses calculated with CAP-88 are for the parent nuclide only, and do not include contributions from long-lived daughter chains.

[b]Short-lived daughters are included in dose from parent nuclide.

[c]Dose factors not included in code radionuclide library.

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ATTACHMENT 4. LETTER REPORT

UNIT DOSE CALCULATIONS FOR WESTINGHOUSE HANFORD COMPANY FACILITY EFFLUENT MONITORING PLANS

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UNIT DOSE CALCULATIONS FOR WHC FACILITY EFFLUENT MONITORING PLANS

K. Rhoads January 3, 1991

INTRODUCTION

Dose calculations for unit (1 Ci) radionuclide releases were performed in support of efforts by Westinghouse Hanford Company (WHC) to develop Effluent Monitoring Plans for all WHC facilities on the Hanford site. Atmospheric releases from generic locations in the 100, 200 E, 200 W, and 300 areas were modeled for both elevated and ground-level releases; 400 area releases were modeled for ground level only. Impacts of liquid releases were evaluated for individuals at Ringold (100 and 200 area effluents) and Riverview (300 Area effluents). Both the CAP-88 (Beres 1990) and GENII (Napier et al 1988) code packages were used to model atmospheric releases in order to satisfy requirements of the U. S. Environmental Protection Agency (USEPA 1989) and the U. S. Department of Energy. The GENII code was used to model liquid releases.

METHODS

Standard parameters for Hanford dose calculations were included in the calculations where possible (McCormack, et al 1984). Meteorology data were collected at weather stations in each of the Hanford operating areas and represent the five-year average of data taken between 1983 and 1987. The location of the maximally exposed individual for each area is included in the attached tables with results of the dose calculations. Individual locations were based on the site boundary location having the greatest radionuclide air concentration under average atmospheric conditions. Doses were calculated as 50-year committed effective dose equivalents for all internal deposition pathways using the EPA model specified in 40 CFR 61. Default solubility classes were used for all radionuclides in these preliminary calculations. These should be appropriate for most facilities evaluated, except where plutonium or uranium are released in soluble form and contribute substantially to the overall dose from a given facility. Default classes for uranium and plutonium assume these radionuclides are released as insoluble compounds; this will result in a lower overall dose than would be the case if they were released in more soluble form.

RESULTS

Results of the evaluation are presented in Tables 1 - 11, and represent the 50-year committed dose equivalent following a chronic annual release of 1 Ci of each radionuclide. The CAP-88 and GENII codes handle ingrowth of long-lived radioactive daughter products differently, as noted in the tables. GENII calculates doses for all radionuclides in each decay chain, therefore the doses reported in Tables 1 -6 include contributions from both parent and ingrown daughters. CAP-88 does not calculate activities for ingrowth of daughter radionuclides following release of the parent, but will estimate the dose from very short-lived daughters where the parent-to-daughter activity ratio is effectively 1:1. CAP-88 doses reported in Tables 7 - 11 are for the parent nuclide only, except in the case where very short-lived daughters have been included in the parent dose as noted. CAP-88 doses including contributions from daughter ingrowth should be estimated using the fractional contribution from the parent nuclide reported in the GENII results.

The total dose expected from emissions at a given facility can be obtained by multiplying the release quantity in Ci for each radionuclide by the corresponding unit dose factor in the tables, and summing the contributions for all nuclides in the effluent stream. Please note that doses calculated using the GENII code are reported as rem to the maximum individual from an annual release; those from CAP-88 are reported in mrem. Values in the tables were taken directly from code outputs, and have been left in the units reported by each code to avoid transcription errors.

REFERENCES

Beres, D. A., 1990. The Clean Air Act Assessment Package -1988 (CAP-88). A Dose and Risk Assessment Methodology for Radionuclide Emissions to Air. Vols. 1-3, U. S. Environmental Protection Agency, Washington, D. C.

McCormack, W. D., J. V. Ramsdell, and B. A. Napier. 1984. Hanford Dose Overview Program: Standardized Methods and Data for Hanford Environmental Dose Calculations. PNL-3777, Rev. 1, Pacific Northwest Laboratory, Richland, Washington.

Napier, B. A., R. A. Peloquin, D. L. Strenge, and J. V. Ramsdell. 1988. GENII - The Hanford Environmental Radiation Dosimetry Software System. PNL-6584, Vols. 1-3. Pacific Northwest Laboratory, Richland, Washington.

U. S. Environmental Protection Agency. 1989. National Emission Standards for Hazardous Air Pollutants; Radionuclides; Final Rule and Notice of Reconsideration. 40 CFR Part 61, Federal Register 54 (240):51654-51715.

WHC-EP-0498

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September 12, 1991

Larry P. Diediker
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Richland, WA 99352

TRANSMITTAL OF QUALITY ASSURANCE DOCUMENTATION FOR FACILITIES EFFLUENT MONITORING PLAN DOSE CALCULATIONS

Dear Larry,

The enclosed information completes the package of results and quality assurance documentation for dose calculations performed in support of the Facilities Effluent Monitoring Plan Determinations. The package includes results transmitted to you in January via electronic mail as well as the Westinghouse Technical Review form, Quality Assurance forms required by our internal procedures, and other information to support the dose calculations. I trust this will give you an adequate paper trail to support the results, however if you find you need additional information, please contact me. My apologies for the long delay in getting the review completed.

Sincerely,

Kathy Rhoads

Kathy Rhoads
Environmental Health Physics Group
Occupational and Environmental Health
Protection Section
Health Physics Department

cc: (results only)
R. L. Aaberg
R. L. Hill, K3-51
W. E. Kennedy, Jr.
D. A. Lamar, P7-41
J. M. Nickels, WHC T1-30
L. H. Sawyer
R. G. Schreckhise
J. K. Soldat
C. E. Sowa, WHC H4-57
R. J. Thompson, WHC S6-01

CHECKLIST FOR CALCULATION REVIEW

Document Reviewed: GENII Dose Calculations for WHC Facility Effluent Monitoring Plans

Scope of Review:

Yes	No	N/A	
[X]	[ ]	[ ]	Previous reviews complete and cover analysis, up to scope of this review, with no gaps.
[X]	[ ]	[ ]	Problem completely defined.
[X]	[ ]	[ ]	Necessary assumptions explicitly stated and supported.
[X]	[ ]	[ ]	Computer codes and data files documented.
[X]	[ ]	[ ]	Data used in calculations explicitly stated in document.
[X]	[ ]	[ ]	Data checked for consistency with original source information as applicable.
[ ]	[ ]	[X]	Mathematical derivations checked including dimensional consistency of results.
[X]	[ ]	[ ]	Models appropriate and used within range of validity or use outside range of established validity justified.
[ ]	[ ]	[X]	Hand calculations checked for errors. Spreadsheet results should be treated exactly the same as hand calculations.
[X]	[ ]	[ ]	Code runstreams correct and consistent with analysis documentation.
[X]	[ ]	[ ]	Code output consistent with input and with results reported in analysis documentation.
[ ]	[ ]	[X]	Acceptability limits on analytical results applicable and supported. Limits checked against sources.
[ ]	[ ]	[X]	Safety margins consistent with good engineering practices.
[X]	[ ]	[ ]	Conclusions consistent with analytical results and applicable limits.
[X]	[ ]	[ ]	Results and conclusions address all points required in the problem statement.
[ ]		[X]	* Review calculations, comments, and/or notes are attached.

J.K. Soldat 1/25/91

Reviewer Approval (Printed Name and Signature) Date

HEDOP Review (Radiological and Toxicological Release Calculations)

[X]	[ ]	[ ]	GENII (current version) used for radiological calculations.
[X]	[ ]	[ ]	Appropriate receptor locations evaluated.
[X]	[ ]	[ ]	Appropriate models (finite plume vs. semi-infinite cloud, building wake, etc.) used.
[X]	[ ]	[ ]	Appropriate pathways evaluated for each receptor.
[X]	[ ]	[ ]	Analysis consistent with HEDOP Recommendations.
[ ]		[X]	* Review calculations, comments, and/or notes are attached.

J.K. Soldat 1/25/91

HEDOP Reviewer Approval (Printed Name and Signature) Date

* Any calculations, comments, or notes generated as part of this review should be signed, dated and attached to this checklist. Such material should be labeled and recorded in such a manner as to be intelligible to a technically qualified third party.

Software name and version GENII v. 1.485

APPLICATION REPORT

1) Project title and number WHC Facility Effluent Monitoring Program ED1167

2) Purpose of application package and relationship to other work:

   To perform dose calculations

3) List original sources of input data, assumptions and derivations used to obtain it, and justification for its use, as appropriate. (if input information has been previously reviewed, reference the documentation of this review.)

   - List of radionuclides in the Hanford Annual Environmental Monitoring Reports for 1986 - 1989, plus additional radionuclides requested in a memo from Joe Nichols dated December 5, 1990, and in a telephone conversation with Joe Nichols on December 11, 1990.
   - HEMP (11/30/90) controller program used radionuclide and template information files (Attachment 1) to create GENII input files (Attachment 2). Files stored on Diskette WHC_DOSES.1 12/13/90.
   - GENII Version 1.485 used the developed input files (Attachment 2) to calculate doses. GENII output data stored in WHC_DOSE.OUT 12/13/90 (see listing in Attachment 3). Files stored on Diskette WHC_DOSES.1 12/13/90.

4) Minor changes made in the software that produced the application run (see section 4.1).

   N/A

5) Describe interrelationships and dependencies of each application run in the application package.

   N/A

6) Summarize the overall output of the application package in relation of the purpose stated in item 2 above (including tables and graphs, as appropriate):

   See Application Record Log (Attachment 3).

7) Submitted for ITR by:

   Preparer _____ Date 1/22/91

8) Approved for reporting results to sponsor by:

   Reviewer _____ Date 1/25/91

Attachment 1
Page 1 of 1

APPLICATION RECORD LOG

1) Project title and number: WHC FACILITY EFFLUENT MONITORING PROGRAM

2) Files (on Diskette WHC_DOSES.1 12/13/90) used as input for HEMP controller program:

CASE.IN	12/10/90
AIR_EL.TPL	12/5/90
AIR_GL.TPL	12/5/90
LIQ.TPL	12/5/90
100N.INV	12/6/90
200E.INV	12/12/90
200W.INV	12/12/90
300A.INV	12/4/90
400A.INV	12/4/90
100N.LIN	12/12/90
300A.LIN	12/4/90

3) Robin J. Hill — 1/22/91
Preparer — Date

Attachment 2
Page 1 of 1

APPLICATION RECORD LOG

1) Project title and number: WHC FACILITY EFFLUENT MONITORING PROGRAM

2) Files (on Diskette WHC_DOSES.1 12/13/90) created by HEMP controller program and used as input to GENII Version 1.485:

E100N.IN	12/12/90
E200E.IN	12/12/90
E200W.IN	12/12/90
G100N.IN	12/12/90
G200E.IN	12/12/90
G200W.IN	12/13/90
G324B.IN	12/13/90
G331B.IN	12/6/90
G400A.IN	12/13/90
L100N.IN	12/12/90
L300A.IN	12/13/90
GENII.IN	12/13/90

3) Robin L. Stell 1/22/91
Preparer Date

CHECKLIST FOR CALCULATION REVIEW

Document Reviewed:
Unit Dose Calculations for WHC Facility Effluent Monitoring Plans

Scope of Review: K. Rhoads 1/3/91

Yes	No	N/A	
[ ]	[ ]	[✓]	Previous reviews complete and cover analysis, up to scope of this review, with no gaps.
[✓]	[ ]	[ ]	Problem completely defined.
[✓]	[ ]	[ ]	Necessary assumptions explicitly stated and supported.
[✓]	[ ]	[ ]	Computer codes and data files documented.
[✓]	[ ]	[ ]	Data used in calculations explicitly stated in document.
[✓]	[ ]	[ ]	Data checked for consistency with original source information as applicable.
[✓]	[ ]	[ ]	Mathematical derivations checked including dimensional consistency of results.
[✓]	[ ]	[ ]	Models appropriate and used within range of validity or use outside range of established validity justified.
[✓]	[ ]	[ ]	Hand calculations checked for errors. Spreadsheet results should be treated exactly the same as hand calculations.
[✓]	[ ]	[ ]	Code runstreams correct and consistent with analysis documentation.
[✓]	[ ]	[ ]	Code output consistent with input and with results reported in analysis documentation.
[ ]	[ ]	[✓]	Acceptability limits on analytical results applicable and supported. Limits checked against sources.
[ ]	[ ]	[✓]	Safety margins consistent with good engineering practices.
[ ]	[ ]	[✓]	Conclusions consistent with analytical results and applicable limits.
[✓]	[ ]	[ ]	Results and conclusions address all points required in the problem statement.
[ ]		[X]	* Review calculations, comments, and/or notes are attached.

[signature] 9/10/91

Reviewer Approval (Printed Name and Signature) Date

HEDOP Review (Radiological and Toxicological Release Calculations)

[✓]	[N/A]	[ ]	GENII (current version) used for radiological calculations. CAP-88 also
[✓]	[ ]	[ ]	Appropriate receptor locations evaluated.
[✓]	[ ]	[ ]	Appropriate models (finite plume vs. semi-infinite cloud, building wake, etc.) used.
[✓]	[ ]	[ ]	Appropriate pathways evaluated for each receptor.
[✓]	[ ]	[ ]	Analysis consistent with HEDOP Recommendations.
[ ]		[X]	* Review calculations, comments, and/or notes are attached.

[signature] 9/10/91

HEDOP Reviewer Approval (Printed Name and Signature) Date

* Any calculations, comments, or notes generated as part of this review should be signed, dated and attached to this checklist. Such material should be labeled and recorded in such a manner as to be intelligible to a technically qualified third party.

APPLICATION REPORT

1) Project title and number WHC Facility Effluent Monitoring Plan, ED-1167

2) Purpose of application package and relationship to other work:
Calculate unit dose factors for WHC facilities, to be used in screening for determination of requirements for individual facility effluent monitoring.

3) List original sources of input data, assumptions and derivations used to obtain it, and justification for its use, as appropriate. (If input information has been previously reviewed, reference the documentation of this review.)
Radionuclide lists based on DOE Annual Environmental monitoring reports for 1986 - 1989, with additions as requested by sponsor if needed. Additional sources as noted in attached letter report.

4) Minor changes made in the software that produced the application run (see section 4.1).
N/A

5) Describe interrelationships and dependencies of each application run in the application package.
Calculations to be performed for 100, 200E, 200W, 300 and 400 areas, elevated and ground level releases (except 400 area - ground level only). Liquid releases will be evaluated for maximally exposed individuals at Ringold and Riverview.

6) Summarize the overall output of the application package in relation to the purpose stated in item 2 above (including tables and graphs, as appropriate):
See attached letter report.

7) Submitted for ITR by:

Kathy Rhoads K Rhoads 1/3/91
Preparer Date

8) Approved for reporting results to sponsor by:

See attached review documentation.
Reviewer Date

Attachments:

1. Application Record Log
2. Letter Report
3. Radionuclide Lists
4. Spreadsheet Calculations

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