PNNL-11067
UC-810
Project Technical Information

Final Technical Report: Atmospheric Emission Analysis for the Hanford Waste Vitrification Plant

G. L. Andrews
K. C. Rhoads

March 1996

Prepared for
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest National Laboratory
Richland, Washington 99352

Battelle

DISCLAIMER

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RLO 1830

Printed in the United States of America

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831;
prices available from (615) 576-8401.

Available to the public from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161

The document was printed on recycled paper.

DISCLAIMER

PNNL-11067
UC-810
Project Technical Information

Final Technical Report: Atmospheric Emission Analysis for the Hanford Waste Vitrification Plant

G. L. Andrews
K. C. Rhoads

March 1996

Prepared for
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest National Laboratory
Richland, Washington 99352

Reprint of historical document HWVP-89-IVR0010101C, dated February 1989. Data, formatting, and other conventions reflect standards at the original date of printing. Technical peer reviews and editorial reviews may not have been performed.

SUMMARY

This report is an assessment of chemical and radiological effluents that are expected to be released to the atmosphere from the Hanford Waste Vitrification Plant (HWVP). The report is divided into two sections. In the first section, the impacts of carbon monoxide (CO) and nitrogen oxides as NO_2 have been estimated for areas within the Hanford Site boundary. A description of the dispersion model used to estimate CO and NO_2 average concentrations and Hanford Site meteorological data has been included in this section. In the second section, calculations were performed to estimate the potential radiation doses to a maximally exposed off-site individual. The model used to estimate the horizontal and vertical dispersion of radionuclides is also discussed.

The calculations performed for the emissions analysis were based upon February 1989 estimates of HWVP effluent releases at a glass production rate of 220 lb/h (WHC 1989). As a result of a better understanding of HWVP feed and the HWVP emissions abatement equipment, the 1989 projected effluent release estimates are substantially different from the estimates that appear in the 1987 Hanford Defense Waste Environmental Impact Statement (HDW-EIS). Consequently, the projected impacts to the environment in this report would be expected to vary significantly from those estimates in the EIS.

In this report, the 1989 HWVP release estimates were used as the source terms for NO_2 and CO in the Environmental Protection Agency's (EPA) Industrial Source Complex Long-Term (ISCLT) atmospheric dispersion model. From the model, the average annual ground-level air concentrations of these chemical effluents were calculated at various locations within and along the Hanford Site boundary. For radiological effluents, the AIRDOS-EPA model was used to calculate the radiation dose to a maximally exposed individual, taking into consideration radionuclide deposition rates, intake rates via inhalation and ingestion, and exposure from suspended radionuclides in the air. Hanford meteorological data from 1955 to 1970 on wind speed, wind direction, and atmospheric stability also served as input to the ISCLT and AIRDOS models.

The numerical results from the emissions analysis have been compared to previous HWVP emission estimates in the 1987 HDW-EIS. In addition, where data were available, the calculated results were compared to ambient conditions on the Hanford Site to assess the relative impacts of the projected HWVP effluent releases. Finally, the calculated HWVP emissions were compared to federal and Washington state regulatory standards.

The primary conclusions from the 1989 emissions analysis are as follows:

- upon comparing the emissions analysis results to regulatory standards, it appears that atmospheric releases associated with HWVP will not present a threat to human health or the environment

- projected HWVP contributions to ambient NO_2 emission concentrations from HWVP are four to five orders of magnitude lower than those measured on the Hanford Site between 1983 and 1987, and five to six orders of magnitude below federal and state annual average ambient air concentration standards

- the maximum projected whole body and critical organ radiological doses from estimated HWVP releases are three to four orders of magnitude below regulatory standards

- the maximum total body dose calculated from the 1989 source term is approximately fifty times greater than that estimated in the 1987 HDW EIS due to increases in the quantities of tritium and carbon-14 projected to be released from HWVP

- projected doses from HWVP releases were approximately 20% of those reported for the Hanford Site during 1987.

CONTENTS

TABLES

1.0 CHEMICAL EMISSIONS ANALYSIS

1.1 INTRODUCTION

The atmospheric chemical emission analysis task of the Hanford Waste Vitrification Plant (HWVP) program involves the assessment of air quality impacts associated with the projected nonradiological effluent released from the HWVP. Specifically, annual air concentrations for nitrogen dioxide (NO_2) and carbon monoxide (CO) are computed at the Hanford Site boundary using the Environmental Protection Agency's (EPA) Industrial Source Complex Long-Term (ISCLT) atmospheric dispersion model. Hourly meteorological data from the Hanford Meteorological Station (HMS) are summarized into climatological values for ISCLT meteorological input. The use of the ISCLT model is consistent with the atmospheric assessment contained in the Hanford Defense Waste Environmental Impact Statement (U.S. DOE 1987).

This section discusses the ISCLT model, gives background information on the meteorological data, presents annual air concentrations for NO_2 and CO at the Hanford Site boundary, compares NO_2 model concentrations with current monitoring data and federal and Washington state standards, and provides a brief conclusion.

1.2 ISCLT ATMOSPHERIC DISPERSION MODEL

The ISCLT atmospheric dispersion model is an EPA-approved model for assessing air quality impacts of nonradioactive material (e.g., NO_x, CO, etc.). The model computes ground-level concentrations and/or deposition for grid nodes and specific locations on the grid. It has the capability of handling single stack sources and multiple sources. For the HWVP project, the ISCLT model is used to compute annual ground-level air concentrations at areas of public access: the Hanford Site boundary and along Highway 240. The source is a single stack (release height 150-ft/46-m) emitting the following nonradiological pollutants: NO_2 and CO.

The model is a sector-averaged model. That is, it assumes effluent concentrations are evenly distributed across a 22.5° direction sector radiating from the source. A steady-state Gaussian plume equation for a continuous source is used to compute ground-level concentrations for stack sources (Cramer 1979). Other features include:

- downwash of the plume
- building wake dispersion
- modifications to concentrations and/or deposition due to terrain
- plume rise
- buoyancy induced dispersion for stack releases.

All features are used except the building wake feature and the modifications due to terrain. The building wake is not included in the computations because the criteria for including building wake were not met. The modification due to terrain is not included because the terrain between the source and the Hanford Site boundary and Highway 240 is relatively homogeneous.

The most recent version of the ISCLT model (January 1988) was used for the final calculations of air concentrations at the Hanford Site boundary. This version was obtained from the EPA regional office in Seattle.

1.3 METEOROLOGICAL DATA

The meteorological data are obtained from the meteorological data base located at the HMS. The HMS is located between the 200 West and 200 East areas in the northern part of the Hanford Site (Figure 1.1). The HMS maintains and collects meteorological data recorded from sensors mounted on a 410-ft tower (see Glantz and Islam 1988 for a detailed description of the HMS monitoring system); the tower is located approximately one-quarter mile east of the HMS. Wind direction and speed are measured at the 30-ft, 50-ft, 100-ft, 200-ft, 300-ft, and 400-ft levels. Air temperatures are measured at the 30-ft, 50-ft, 100-ft, 200-ft, 250-ft, 300-ft, and 400-ft levels. Meteorological data measured at the HMS can be applied to the HWVP site because of the close proximity (HMS is approximately 3 miles west of the proposed HWVP) and because the terrain is relatively homogeneous between the two sites.

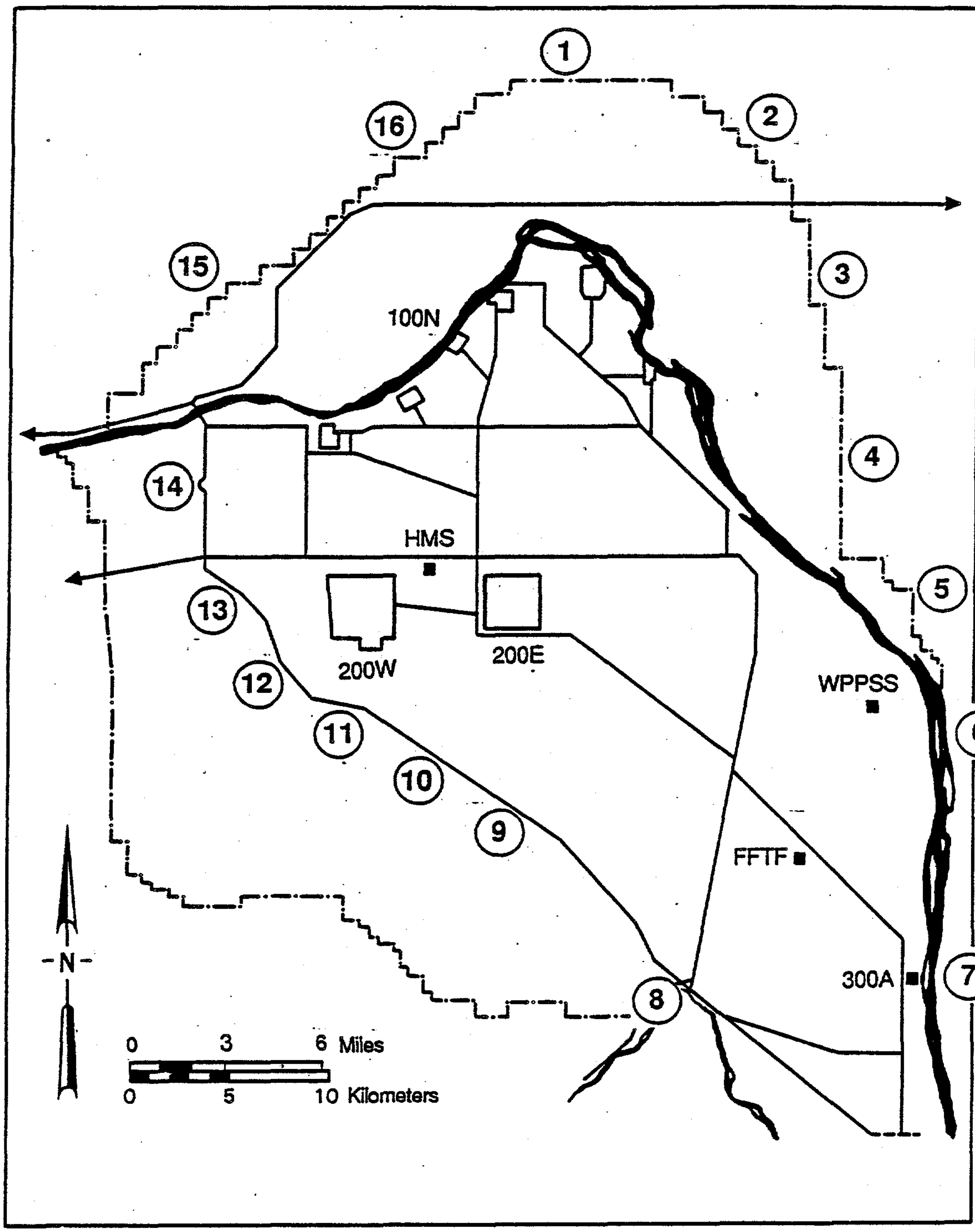

FIGURE 1.1. Map of the Hanford Site Indicating Locations of Modeled Ground-Level Air Concentrations

The following site specific meteorological data are needed as input to the ISCLT atmospheric model:

- joint frequency distribution of wind speed, wind direction, and atmospheric stability
- mean category wind speed from the joint frequency distribution
- ambient temperature as a function of stability and season
- mixing height as a function wind speed, stability, and season.

These data provide site specific meteorological characteristics that are important for a proper assessment of HWVP's impact on the Hanford Site's air quality. The joint frequency distribution of wind speed, wind direction, and atmospheric stability is generated from fifteen years (1955 through 1970) of hourly 200-ft level wind direction and speed. Wind speed is classified into six categories:

- 0 - 1.5 m/s
- 1.6 - 3.1 m/s
- 3.2 - 5.1 m/s
- 5.2 - 8.2 m/s
- 8.3 - 10.8 m/s
- > 10.9 m/s.

The mean wind speed for each range is 0.75, 2.5, 4.3, 6.8, 9.5, 12.5 m/s, respectively.

Atmospheric stabilities are computed from the hourly vertical temperature gradient between the 200-ft and 30-ft levels (i.e., $T_{200} - T_{30}$) for the same period of time. The vertical temperature gradients are categorized into atmospheric stability categories as done by standard Nuclear Regulatory Commission methods (Snell 1982). Atmospheric stabilities are usually classified in one of two ways: numeric or alpha-character. For example,

- very unstable 1 or A
- unstable 2 or B

- slightly unstable 3 or C
- neutral 4 or D
- stable 5 or E
- very unstable 6 or F.

This classification method is typically used to categorize atmospheric stabilities. Appendix A presents a listing of the joint frequency distribution of wind direction, wind speed, and atmospheric stability.

The ambient temperature as a function of stability and season is generated from five years (1983 through 1987) of hourly 200-ft level temperature data. Appendix B presents a listing of these ambient temperatures.

Mixing height, the vertical extent of mixing within the atmosphere, as function of wind speed, wind direction, and atmospheric stability are generated from five years (1983 through 1987) of hourly mixing height data. Mixing heights are measured at the HMS by an acoustic sounder on an hourly basis. Appendix C presents a listing of these mixing heights.

1.4 CALCULATIONS

Annual air concentrations at the Hanford Site boundary and Highway 240 are presented in Table 1.1 for NO_2 and CO. See Figure 1.1 for corresponding location at the Hanford Site boundary and Highway 240.

The source term used for each pollutant is:

- 7.1 ton/year or .204 grams/sec for NO_2
- 2.5 ton/year or .072 grams/sec for CO.

It is assumed the release rate is constant throughout the year. In addition, the effluent release is through a stack with the following characteristics:

- stack diameter 8-ft (2.4-m)
- stack height 150-ft (46-m)
- exhaust temperature 104°F (313K)
- exhaust flux 95600 SCFM or 9.6 m/s exhaust velocity.

TABLE 1.1. Annual Ground-Level Air Concentrations for NO_2 and CO

Map Position	Bearing (Degrees from North)	Distance from Source (meters)	Annual Ground-Level Air Concentrations ($\mu g/m^3$)	
			NO_2	CO
1	360.0	25267	9.26E-4	3.27E-4
2	22.0	26220	8.66E-4	3.06E-4
3	45.0	21453	1.55E-3	5.49E-4
4	67.0	17639	2.30E-3	8.11E-4
5	90.0	20023	3.00E-3	1.06E-3
6	112.0	23360	3.95E-3	1.39E-3
7	135.0	29081	3.73E-3	1.32E-3
8	157.0	20023	2.76E-3	9.72E-4
9	180.0	9058	4.28E-3	1.51E-3
10	202.0	7151	3.75E-3	1.32E-3
11	225.0	7627	3.58E-3	1.26E-3
12	247.0	10488	1.82E-3	6.43E-4
13	270.0	12395	1.86E-3	6.57E-4
14	292.0	15732	1.70E-3	6.02E-4
15	315.0	16685	2.24E-3	7.90E-4
16	337.0	20976	1.18E-3	4.18E-4

1.5 COMPARISON OF CALCULATIONS WITH MONITORING DATA AND FEDERAL AND STATE STANDARDS

Currently, annual air concentrations for NO_2 are routinely monitored on the Hanford Site, while CO air concentrations are not monitored. The monitoring and analysis are conducted by the Hanford Environmental Health Foundation (HEHF). The monitoring results are published on an annual basis in a PNL report (e.g., for 1987, PNL-6464). The current NO_2 monitoring network consists of nine stations located within the Hanford Site boundary. A point-by-point comparison can not be made due to the different locations between model receptors and the monitoring receptors. However, an overall comparison can be made. Table 1.2 gives annual ground-level air concentrations for NO_2 at the nine monitoring stations from 1983 though 1987 (Jacquish and Mitchell 1984, 1985, 1986, 1987, and 1988). The values are converted from parts-per-million (ppm) to micrograms-per-cubic-meter ($\mu g/m^3$).

A comparison of NO_2 air concentrations from model receptors listed in Table 1.1 with air concentrations from monitoring receptors listed in

TABLE 1.2. NO_2 Air Concentrations from the Hanford Monitoring Network

Station	Annual Ground-Level Air Concentrations ($\mu g/m^3$) 1983	1984	1985	1986	1987
ALE	7.5	9.4	11.3	13.2	13.2
100-B	7.5	7.5	11.3	11.3	11.3
100-D	7.5	7.5	11.3	13.2	11.3
Old Hanford	9.4	9.4	13.2	13.2	7.5
Army Barricade	9.4	9.4	13.2	15.0	11.3
WYE Barricade	11.3	15.0	16.9	16.9	15.0
FFTF	9.4	7.5	13.2	13.2	9.4
Highway 240	11.3	7.5	N/A	N/A	N/A
Sullivan Barn	9.4	9.4	15.0	16.9	13.2
200W	N/A	N/A	N/A	11.3	11.3

Table 1.2 indicates the projected air concentrations of NO_2 from the HWVP are four to five orders of magnitude lower than the measured NO_2 concentrations. In addition, the concentrations listed in Table 1.1 are five to six orders of magnitude lower than the applicable federal and Washington state annual average ambient air standard for NO_2, which is 100 $\mu g/m^3$ (0.05ppm) (see Jacquish and Mitchell 1988, page 3.9).

A comparison of model concentrations of CO and monitoring data is not presented because the current (and past) monitoring network at the Hanford Site does not include the pollutant CO. Federal and Washington state standards for CO do not include annual average standards, but do list standards for an 8- and a 1-hour period of time not to be exceeded once per year. The 8-hour standard is 10,000 $\mu g/m^3$ (9 ppm) and the 1-hour standard is 40,000 $\mu g/m^3$ (35 ppm) (Department of Energy 1987). These standards exceed the annual modeled ground-level air concentrations of CO, given in Table 1.1, by seven to eight orders of magnitude. Processing rates at the HWVP are expected to be relatively continuous and limited by the geometry of the melter cavity. At the maximum design processing rate (220 lb/hr), 90% of the molten glass surface is covered by a cold cap, which limits heat transfer to incoming feed and thereby limits the resultant gas generation rates. Moreover, it has been estimated that the probability of a 10X surge in noncondensible melter off-gas flows is only one occurrence in 17 years (Kessler and Randall 1984). Thus, the source term of CO is expected to be relatively continuous, and it is not expected to increase by orders of magnitude. Using this argument, it is reasonable not to expect the CO air concentrations to exceed the 1-hr and 8-hr standards previously given. In addition, 1- and 8-hour maximum background ambient air concentrations of CO were measured in Kennewick, Washington (U.S. Nuclear Regulatory Commission 1982). The values were 11,795 and 6,525 ($\mu g/m^3$), respectively, and are well below the 1-hr and 8-hr regulatory standards. Furthermore, the concentrations measured in Kennewick are orders of magnitude greater than Hanford Site boundary concentrations projected for the HWVP source.

1.6 CONCLUSIONS

Given the projected stack characteristics and source terms associated with the HWVP, the ISCLT model indicates annual ground-level air concentrations for NO_2 to be well within federal and Washington state standards. In addition, the projected air concentrations for NO_2 are four to five orders of magnitude below measured values. The annual CO air concentrations are not compared to monitoring data, for reasons given in the previous section. However, it is unlikely that processing at the HWVP will significantly change to yield a large increase (orders of magnitude) in the CO source term over a short period of time. Consequently, it is reasonable to assume that under the worst meteorological conditions, CO air concentrations would not have a significant impact on air quality conditions.

1.7 REFERENCES

Cramer, H. E. Co. 1979. Industrial Source Complex (ISC) Dispersion Model User Guide Volume 1. Environmental Protection Agency, Research Triangle Park, North Carolina.

Glantz, C. S., and M. M. Islam. 1988. The Data Collection Component of the Hanford Meteorology Monitoring Program. PNL-6684, Pacific Northwest Laboratory, Richland, Washington.

Jacquish, R. E., and P. J. Mitchell. 1984. Environmental Monitoring at Hanford for 1983. PNL-5038, Pacific Northwest Laboratory, Richland, Washington.

Jacquish, R. E., and P. J. Mitchell. 1985. Environmental Monitoring at Hanford for 1984. PNL-5407, Pacific Northwest Laboratory, Richland, Washington.

Jacquish, R. E., and P. J. Mitchell. 1986. Environmental Monitoring at Hanford for 1985. PNL-5817, Pacific Northwest Laboratory, Richland, Washington.

Jacquish, R. E., and P. J. Mitchell. 1987. Environmental Monitoring at Hanford for 1986. PNL-6120, Pacific Northwest Laboratory, Richland, Washington.

Jacquish, R. E., and P. J. Mitchell. 1988. Environmental Monitoring at Hanford for 1987. PNL-6464, Pacific Northwest Laboratory, Richland, Washington.

Kessler, J. L., and C. T. Randall. 1984. "Performance of a Large Scale Melter and OFf-Gas Systems Utilizing Simulated SRP DWPF Waste." In Proceedings of the Symposium on Waste Management, Waste Management '84, March 11-15, 1984, Tucson, Arizona.

Snell, W. G. 1982. Nuclear Regulatory Commission Computer Programs for Use with Meteorological Data. NUREG-0917, U.S. Nuclear Regulatory Commission, Washington, D.C.

U.S. Department of Energy. 1987. Final Environmental Impact Statement Disposal of Hanford Defense High-Level, Transuranic and Tank Wastes Hanford Site Richland, Washington. U.S. Department of Energy - Richland Office, Richland, Washington.

U.S. Nuclear Regulatory Commission. 1982. Draft Environmental Impact Statement Related to the Construction of Skagit/Hanford Nuclear Project, Units 1 and 2. Docket Nos. STN 50-522 and STN 50-523. NUREG-0894, Washington, D.C., and Washington State Energy Facility Site Evaluation Council, Olympia, Washington.

2.0 RADIOLOGICAL EMISSIONS ANALYSIS

2.1 INTRODUCTION

Estimates have been prepared for a maximum individual exposed to routine releases from the Hanford Waste Vitrification Plant (HWVP). These estimates are made to demonstrate compliance of the proposed facility with radiological emission standards of the U.S. Environmental Protection Agency, and to provide a perspective on the radiological impact of the new plant compared to existing facilities. The AIRDOS-EPA computer code was used to calculate doses for both the receipt and lag storage tank/waste hold tank (RLST/WHT) and vitrification facilities, and these are reported in Table 2.1. The maximum offsite exposure location was approximately 24 km (15 mi) SE of the 200 Area. Reference information on doses from the entire Hanford Site operations (Jacquish and Mitchell 1988) and from the HWVP as projected in the Hanford Defense Waste Environmental Impact Statement (HDW-EIS) (U.S. DOE 1987) are also provided for comparison.

The AIRDOS-EPA computer code (Moore et al. 1979), developed at Oak Ridge National Laboratory, was used to perform the calculations based on source term information supplied by the sponsor, and on local population and meteorology data. This code calculates either maximum individual or population doses from airborne releases of up to 36 radionuclides, and is currently the only software approved by EPA for environmental compliance calculations. Background information on the code and input data are provided in the following sections.

2.2 AIRDOS-EPA COMPUTER CODE

AIRDOS-EPA uses a modified Gaussian plume model to estimate horizontal and vertical dispersion of radionuclides from 1 to 6 stacks or area sources. The code calculates radionuclide concentrations in air, rates of deposition on ground surfaces, ground surface concentrations, intake rates via inhalation and ingestion, and radiation doses via airborne releases. The exposure pathways considered include immersion in air containing suspended radionuclides, exposure from radionuclides deposited on ground, inhalation of airborne radionuclides, and ingestion of local food contaminated by released

TABLE 2.1. Dose Estimates for an Individual Receiving Maximum Exposure to Radiological Emissions from HWVP Facilities

	Current Estimates		Previous Estimates	
	HWVP Facilities		HWVP	Hanford Site
	RLST/WHT	Vitrification	HDW-EIS	All Facilities
50-year Committed Dose From One Year of Operation (effective dose equivalent, rem)				
Total Body	1.1E-08	1.1E-05	2.0E-07[(a)]	5.0E-05
Critical Organ				
Red Marrow	1.1E-08	1.9E-05		7.0E-05
Endosteal Surface	1.9E-08	2.1E-05		1.0E-04
Thyroid	1.0E-08	5.8E-06		8.0E-04
Lung	1.0E-08	5.5E-06		2.0E-05
Lower Large Intestine	1.0E-08	8.9E-06		3.0E-05
Percent of Total Body Dose				
Critical Pathway				
Ingestion	85	94	90	67
Inhalation/External	15	6	10	33
Critical Radionuclides				
C-14		88		
H-3	92	3.4		
Cs-134	1.9	4.6		
Am-241	3.4	1.4		
Cs-137		1.2		
Sr-90	1.4	0.54		

(a) These values represent "lifetime" doses to the maximum individual from emissions during 1 year of facility operation, calculated by ICRP-2 methodology; the remainder of the doses reported are 50-year dose commitments from 1 year of operation, calculated by ICRP-30 methods.

material. Ingestion doses are estimated using the U.S. Nuclear Regulatory Commission Regulatory Guide 1.109 terrestrial food chain models.

The code provides for input of local population (Sommer, Rau and Robinson 1981) and meteorology data, and of external and internal dose factors (DOE 1988a,b). Doses are estimated for the whole body and 11 organs from these data and source terms provided for a specific installation. Because the HWVP source term included 71 radionuclides (WHC 1989), these were split into two separate runs for a preliminary screening, and a final run was made using only those isotopes that contributed significantly to the total dose in the screening. In the absence of specific information about the chemical form of the released material, and due to the relatively small particle size expected in releases from the emission control devices, dose factors for the more soluble forms of each isotope were used. In most cases, these provided a conservative (i.e., maximum) estimate for the radiation doses resulting from an airborne release. Doses were estimated at a distance of 24 km, which represents the nearest populated site downwind from the 200 Areas. Output data from the AIRDOS-EPA computations are provided in Appendix D.

2.3 METEOROLOGY DATA

Meteorological data input to the AIRDOS-EPA code include mixing height, rainfall rate, average air temperature, vertical temperature gradient, wind direction frequency, wind speed, and atmospheric stability. This information was obtained from the data base compiled by the Hanford Meteorological Station (HMS). HMS data on airspeed, direction, and temperature are collected at a 410-ft tower located on the Hanford Site between the 200 East and 200 West Areas, and approximately 3 miles from the proposed HWVP. Wind speed and direction are based on hourly data collected at the 200-ft level during the years 1955-1970. Atmospheric stability was estimated from the temperature gradient between the 30-ft and 200-ft levels for the same period using standard methods of the U.S. Nuclear Regulatory Commission. Air temperature and mixing height are also 15-year averages of hourly data taken during 1955-1970. Temperature is measured at the tower 200-ft level, and mixing height data are collected by onsite acoustic sounders.

Joint frequency data as reported by the HMS are modified for input into AIRDOS by conversion to true average and reciprocal average wind speeds for each direction and stability class. These converted input data are included in Appendix D. The meteorological data are then used to calculate Chi\Q values (atmospheric dispersion factors) for each radionuclide, which are also a function of radiological half-life and dry deposition velocity. For purposes of this calculation, deposition velocities are assigned as follows:

1.0E-3 m/s for all particulate materials, 1.0E-2 m/s for iodine isotopes, and 0 for all gaseous components. Chi/Q values for each class of isotope are listed in Appendix E.

2.4 CONCLUSIONS

Dose estimates to an individual from exposure to radiological emissions from HWVP are provided in Table 2.1. In addition, previous dose estimates from the HDW-EIS and from the entire Hanford Site are included in Table 2.1 for comparison.

Current estimates for doses from the vitrification building are higher than those from the RLST/WHT facility; however, neither exceeds the EPA limit of 25 mrem to the whole body or 75 mrem to a critical organ. They are also somewhat greater than previous estimates reported in the HDW-EIS because of higher projected releases for critical radionuclides and differences in the dose calculation methods. Doses from RLST/WHT were mainly due to tritium, whereas the vitrification building estimates were dominated by C-14. As would be expected, both nuclides produced a relatively uniform dose distribution throughout all organs. Ingestion of food contaminated by airborne transport of the radionuclides was the predominant exposure pathway.

Projected doses from the HWVP facilities were approximately 20% of those reported for the Hanford Site during 1987. It should be noted, however, that operations at a number of onsite facilities were shut down or severely curtailed during this reporting period, resulting in substantially lower sitewide release rates compared to previous years.

2.5 REFERENCES

Jacquish, R. E., and P. J. Mitchell, 1988. Environmental Monitoring at Hanford for 1987. PNL-6464, Pacific Northwest Laboratory, Richland, Washington.

U.S. Department of Energy. 1987. Final Environmental Impact Statement. Disposal of Hanford Defense High-level, Transuranic, and Tank Wastes, Hanford Site, Richland, Washington. DOE/EIS-0113, Vol. 2, Appendices A-L, U.S. Department of Energy, Washington D.C.

Moore, R. E., et al. 1979. AIRDOS-EPA: A Computerized Methodology for Estimating Environmental Concentrations and Dose to Man from Airborne Releases of Radionuclides. ORNL-5532, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Sommer, D. J., R. G. Rau, and D. C. Robinson. 1981. Population Estimates for the Areas Within a 50-mile Radius of Four Reference Points on the Hanford Site. PNL-4010, Pacific Northwest Laboratory, Richland, Washington.

U.S. Department of Energy. 1988a. Internal Dose-Rate Conversion Factors for Calculation of Dose to the Public. DOE/EH-0071, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy. 1988b. External Dose-Rate Conversion Factors for Calculation of Dose to the Public. DOE/EH-0070, U.S. Department of Energy, Washington, D.C.

Westinghouse Hanford Company. 1989. Data for Environmental Compliance Analysis. HWVP/PNL.V-89-010, Westinghouse Hanford Company, Richland, Washington.

APPENDIX A

JOINT FREQUENCY DISTRIBUTION OF WIND DIRECTION, WIND SPEED, AND ATMOSPHERIC STABILITY

APPENDIX A

JOINT FREQUENCY DISTRIBUTION OF WIND DIRECTION, WIND SPEED, AND ATMOSPHERIC STABILITY

TABLE A.1. Frequency of Occurrence of Wind Speed, Direction and Stability

STABILITY CATEGORY 1

WIND SPEED CATEGORY 1 (1.5000MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
0.00152905	0.00479103	0.00183486	0.00061162	0.00010194	0.00000000
0.00193680	0.00479103	0.00224261	0.00122324	0.00030581	0.00000000
0.00193680	0.00407747	0.00163099	0.00071356	0.00020387	0.00010194
0.00091743	0.00244648	0.00050968	0.00010194	0.00010194	0.00000000
0.00101937	0.00234455	0.00030581	0.00010194	0.00000000	0.00000000
0.00081549	0.00214067	0.00030581	0.00000000	0.00000000	0.00000000
0.00091743	0.00244648	0.00050968	0.00000000	0.00000000	0.00000000
0.00040775	0.00152905	0.00040775	0.00010194	0.00000000	0.00000000
0.00040775	0.00183486	0.00050968	0.00010194	0.00000000	0.00000000
0.00020387	0.00152905	0.00101937	0.00040775	0.00030581	0.00020387
0.00040775	0.00173293	0.00193680	0.00173293	0.00101937	0.00122324
0.00030581	0.00112130	0.00142712	0.00183486	0.00122324	0.00101937
0.00030581	0.00112130	0.00071356	0.00071356	0.00040775	0.00030581
0.00030581	0.00142712	0.00173293	0.00214067	0.00132518	0.00081549
0.00071356	0.00356779	0.00438328	0.00356779	0.00305810	0.00224261
0.00091743	0.00387360	0.00173293	0.00040775	0.00010194	0.00000000

STABILITY CATEGORY 2

WIND SPEED CATEGORY 1 (1.5000MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
0.00050968	0.00122324	0.00061162	0.00010194	0.00000000	0.00000000
0.00061162	0.00091743	0.00081549	0.00030581	0.00010194	0.00010194
0.00081549	0.00112130	0.00040775	0.00020387	0.00010194	0.00000000
0.00030581	0.00081549	0.00020387	0.00010194	0.00000000	0.00000000
0.00050968	0.00071356	0.00020387	0.00000000	0.00000000	0.00000000
0.00040775	0.00071356	0.00010194	0.00000000	0.00000000	0.00000000
0.00050968	0.00081549	0.00030581	0.00000000	0.00000000	0.00000000
0.00020387	0.00040775	0.00010194	0.00010194	0.00000000	0.00000000
0.00020387	0.00061162	0.00020387	0.00010194	0.00000000	0.00000000
0.00020387	0.00050968	0.00040775	0.00020387	0.00020387	0.00010194
0.00020387	0.00071356	0.00061162	0.00071356	0.00040775	0.00050968
0.00010194	0.00040775	0.00071356	0.00081549	0.00050968	0.00040775
0.00010194	0.00050968	0.00040775	0.00030581	0.00010194	0.00010194
0.00010194	0.00050968	0.00061162	0.00081549	0.00050968	0.00020387
0.00030581	0.00122324	0.00152905	0.00122324	0.00101937	0.00071356
0.00030581	0.00112130	0.00061162	0.00010194	0.00000000	0.00000000

TABLE A.1. (contd)

STABILITY CATEGORY 3

WIND SPEED CATEGORY 1 (1.5000MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
0.00071356	0.00122324	0.00061162	0.00020387	0.00000000	0.00000000
0.00050968	0.00101937	0.00050968	0.00030581	0.00010194	0.00000000
0.00081549	0.00101937	0.00050968	0.00010194	0.00010194	0.00010194
0.00050968	0.00061162	0.00020387	0.00000000	0.00000000	0.00000000
0.00071356	0.00081549	0.00020387	0.00000000	0.00000000	0.00000000
0.00050968	0.00071356	0.00010194	0.00000000	0.00000000	0.00000000
0.00050968	0.00091743	0.00020387	0.00000000	0.00000000	0.00000000
0.00020387	0.00050968	0.00020387	0.00010194	0.00000000	0.00000000
0.00020387	0.00050968	0.00020387	0.00010194	0.00000000	0.00000000
0.00020387	0.00061162	0.00050968	0.00030581	0.00020387	0.00020387
0.00020387	0.00061162	0.00081549	0.00071356	0.00050968	0.00071356
0.00020387	0.00050968	0.00081549	0.00101937	0.00061162	0.00050968
0.00020387	0.00050968	0.00050968	0.00040775	0.00010194	0.00020387
0.00020387	0.00061162	0.00071356	0.00101937	0.00050968	0.00030581
0.00030581	0.00112130	0.00173293	0.00132518	0.00081549	0.00081549
0.00030581	0.00132518	0.00061162	0.00010194	0.00000000	0.00000000

STABILITY CATEGORY 4

WIND SPEED CATEGORY 1 (1.5000MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
0.00723751	0.00682976	0.00244648	0.00122324	0.00040775	0.00010194
0.00499490	0.00438328	0.00244648	0.00173293	0.00050968	0.00020387
0.00662589	0.00479103	0.00163099	0.00071356	0.00050968	0.00020387
0.00468909	0.00305810	0.00081549	0.00020387	0.00010194	0.00000000
0.00560652	0.00377166	0.00081549	0.00010194	0.00000000	0.00000000
0.00611621	0.00428134	0.00101937	0.00010194	0.00000000	0.00000000
0.00611621	0.00570846	0.00163099	0.00050968	0.00010194	0.00000000
0.00285423	0.00316004	0.00142712	0.00071356	0.00030581	0.00010194
0.00265036	0.00305810	0.00142712	0.00122324	0.00071356	0.00061162
0.00193680	0.00275229	0.00275229	0.00254842	0.00203874	0.00244648
0.00214067	0.00366972	0.00458716	0.00540265	0.00479103	0.00550459
0.00163099	0.00316004	0.00499490	0.00723751	0.00499490	0.00305810
0.00295617	0.00417941	0.00489297	0.00530071	0.00214067	0.00081549
0.00316004	0.00611621	0.00897044	0.01080530	0.00805301	0.00530071
0.00530071	0.01162079	0.01508664	0.01141692	0.00825688	0.00774720
0.00652395	0.00835882	0.00407747	0.00112130	0.00020387	0.00000000

TABLE A.1. (contd)

STABILITY CATEGORY 5

WIND SPEED CATEGORY 1 (1.5000MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
0.00366972	0.00448522	0.00234455	0.00101937	0.00010194	0.00000000
0.00234455	0.00234455	0.00152905	0.00091743	0.00020387	0.00000000
0.00244648	0.00183486	0.00132518	0.00050968	0.00020387	0.00000000
0.00203874	0.00152905	0.00091743	0.00020387	0.00010194	0.00000000
0.00254842	0.00183486	0.00101937	0.00040775	0.00000000	0.00000000
0.00336391	0.00254842	0.00122324	0.00020387	0.00000000	0.00000000
0.00438328	0.00387360	0.00214067	0.00071356	0.00010194	0.00000000
0.00254842	0.00254842	0.00224261	0.00122324	0.00040775	0.00010194
0.00234455	0.00234455	0.00132518	0.00101937	0.00071356	0.00050968
0.00163099	0.00214067	0.00183486	0.00173293	0.00132518	0.00183486
0.00193680	0.00285423	0.00336391	0.00428134	0.00356779	0.00265036
0.00183486	0.00387360	0.00662589	0.00744139	0.00366972	0.00132518
0.00326198	0.00744139	0.01264016	0.01080530	0.00203874	0.00040775
0.00316004	0.00866463	0.02222222	0.02945973	0.01090724	0.00285423
0.00438328	0.00998981	0.01773700	0.01885831	0.01049949	0.00387360
0.00366972	0.00693170	0.00499490	0.00183486	0.00020387	0.00000000

STABILITY CATEGORY 6

WIND SPEED CATEGORY 1 (1.5000MPS)	WIND SPEED CATEGORY 2 (2.5000MPS)	WIND SPEED CATEGORY 3 (4.3000MPS)	WIND SPEED CATEGORY 4 (6.8000MPS)	WIND SPEED CATEGORY 5 (9.5000MPS)	WIND SPEED CATEGORY 6 (12.5000MPS)
0.00295617	0.00295617	0.00091743	0.00020387	0.00000000	0.00000000
0.00163099	0.00163099	0.00050968	0.00030581	0.00000000	0.00000000
0.00214067	0.00142712	0.00040775	0.00010194	0.00000000	0.00000000
0.00112130	0.00112130	0.00020387	0.00010194	0.00000000	0.00000000
0.00163099	0.00122324	0.00020387	0.00010194	0.00000000	0.00000000
0.00203874	0.00142712	0.00030581	0.00000000	0.00000000	0.00000000
0.00336391	0.00265036	0.00122324	0.00050968	0.00010194	0.00000000
0.00183486	0.00234455	0.00152905	0.00091743	0.00020387	0.00010194
0.00203874	0.00244648	0.00091743	0.00040775	0.00020387	0.00010194
0.00173293	0.00193680	0.00101937	0.00040775	0.00020387	0.00010194
0.00183486	0.00254842	0.00152905	0.00061162	0.00020387	0.00010194
0.00173293	0.00346585	0.00377166	0.00234455	0.00040775	0.00010194
0.00275229	0.00632008	0.00764526	0.00397553	0.00040775	0.00000000
0.00214067	0.00672783	0.01111111	0.01019368	0.00101937	0.00000000
0.00316004	0.00713557	0.01508664	0.01600408	0.00244648	0.00010194
0.00326198	0.00570846	0.00540265	0.00163099	0.00000000	0.00000000

APPENDIX B

AMBIENT AIR TEMPERATURE

APPENDIX B

AMBIENT AIR TEMPERATURE

TABLE B.1. Ambient Air Temperatures (K) at the HMS

Season	Atmospheric Stability Classification					
	A	B	C	D	E	F
Winter	276	272	272	271	274	276
Spring	289	288	287	285	284	285
Summer	299	298	297	295	294	295
Fall	292	290	288	283	283	284

APPENDIX C

MIXING HEIGHT

APPENDIX C

MIXING HEIGHT

TABLE C.1. Mixing Heights (meters) at the HMS

Stability Class	Wind Speed Classification (meters/sec) (0-1.5)	(1.6-3.1)	(3.2-5.1)	(5.2-8.2)	(8.3-10.8)	(>10.9)
Winter						
A	202	270	321	321	321	321
B	266	315	466	1333	1333	1333
C	238	295	680	680	680	680
D	167	226	430	1147	1483	1500
E	149	185	323	850	1311	1500
F	148	198	213	559	1025	1025
Spring						
A	797	930	1116	1278	1476	1400
B	582	699	791	1182	1433	1250
C	522	659	621	1170	1283	1283
D	306	384	524	914	1220	1375
E	161	224	365	769	1277	1500
F	146	170	216	608	1000	1000
Summer						
A	991	1078	1102	1250	1422	1385
B	753	824	855	1132	1437	1333
C	581	685	763	1058	1278	1500
D	434	493	555	900	1323	1200
E	183	225	350	681	1216	1216
F	135	159	204	469	590	590
Fall						
A	802	961	1093	1251	1423	1500
B	583	732	755	1096	1500	1500
C	450	568	683	1162	1400	1500
D	279	372	517	924	1185	1500
E	142	207	360	738	1293	820
F	120	142	181	487	487	487

APPENDIX D

<u>INPUT/OUTPUT DATA TO/FROM AIRDOS CODE</u>

APPENDIX D

INPUT/OUTPUT DATA TO/FROM AIRDOS CODE

TABLE D.1. Input Data to AIRDOS-EPA Model

Source Term:	Projected annual releases supplied in reference attachments
Release Height:	RLST/WHT - 26.5 m (87 ft.) Vitrification Bldg. - 45.7 m (150 ft.)
Inhalation Rate:	8000 m^3/y
Meteorology:	Hanford Meteorological Tower Data, 200 ft. level, 1955-1970 average data.

TABLE D.2. Output of AIRDOS-EPA Computer Code--Calculations for Vitrification Facility

Meteorological and Plant Information Supplied to Program	
Average air temperature (°K)	285.0
Average vertical temperature gradient of the air (°K/meter)	
In stability class E	0.0728
In stability class F	0.1090
In stability class G	0.1455
Rainfall rate (cm/year)	15.88
Height of lid (meters)	1000
Number of stacks in the plant	1
Stack Information	
Height (meters)	45.7000
Diameter (meters)	2.4000
Effluent velocity (meters/sec)	9.7000
Rate of heat emission (cal/second)	0.38E+07

TABLE D.3. Frequency of Atmospheric Stability Classes for Each Direction

Sector	Fraction of Time in Each Stability Class						
	A	B	C	D	E	F	G
1	0.0982	0.0386	0.0351	0.3333	0.2842	0.2105	0.0000
2	0.0848	0.0283	0.0353	0.2968	0.3145	0.2403	0.0000
3	0.0962	0.0405	0.0405	0.3494	0.2785	0.1949	0.0000
4	0.1147	0.0430	0.0466	0.4050	0.2581	0.1326	0.0000
5	0.1440	0.0545	0.0661	0.3930	0.2218	0.1206	0.0000
6	0.1770	0.0619	0.0575	0.3850	0.2080	0.1106	0.0000
7	0.2231	0.0682	0.0682	0.3727	0.1627	0.1050	0.0000
8	0.2531	0.0688	0.0590	0.3440	0.1769	0.0983	0.0000
9	0.1740	0.0480	0.0540	0.3580	0.2280	0.1380	0.0000
10	0.1075	0.0327	0.0358	0.3100	0.2695	0.2445	0.0000
11	0.0884	0.0303	0.0308	0.2996	0.3294	0.2215	0.0000
12	0.0470	0.0167	0.0204	0.2574	0.4691	0.1894	0.0000
13	0.0420	0.0180	0.0228	0.2386	0.4305	0.2482	0.0000
14	0.0921	0.0393	0.0488	0.3333	0.3293	0.1572	0.0000
15	0.1214	0.0476	0.0538	0.3932	0.2811	0.1029	0.0000
16	0.0973	0.0432	0.0541	0.3838	0.2784	0.1432	0.0000

TABLE D.4. Frequencies of Wind Directions and Reciprocal-Averaged Wind Speeds[(a)]

Wind Toward	Frequency	Wind Speeds for Each Stability Class (meters/sec)						
		A	B	C	D	E	F	G
1	0.028	2.18	2.07	2.01	1.88	1.86	1.60	0.00
2	0.028	2.07	1.82	2.01	1.62	1.83	1.86	0.00
3	0.040	1.78	1.60	1.58	1.35	1.46	1.38	0.00
4	0.028	1.73	1.52	1.41	1.19	1.32	1.17	0.00
5	0.026	1.68	1.48	1.37	1.17	1.37	1.21	0.00
6	0.023	1.85	1.91	1.43	1.20	1.39	1.33	0.00
7	0.038	1.94	1.67	1.69	1.33	1.50	1.20	0.00
8	0.041	2.13	2.09	2.05	1.60	1.68	1.43	0.00
9	0.050	2.11	1.96	1.80	1.45	1.65	1.37	0.00
10	0.064	2.32	2.26	2.30	1.62	2.04	2.07	0.00
11	0.195	4.18	3.96	4.00	3.39	3.76	3.47	0.00
12	0.162	4.29	4.31	3.88	3.81	4.33	3.36	0.00
13	0.083	3.17	3.26	2.99	2.71	3.16	2.58	0.00
14	0.074	4.36	4.61	4.16	4.06	3.63	2.50	0.00
15	0.065	3.95	3.75	4.06	3.82	3.40	1.82	0.00
16	0.037	3.20	2.73	3.00	2.96	2.74	1.66	0.00

(a) Wind directions are numbered counterclockwise starting at 1 for due north.

TABLE D.5. Frequencies of Wind Directions and True-Average Wind Speeds[a]

Wind Toward	Frequency	Wind Speeds for Each Stability Class (meters/sec) A	B	C	D	E	F	G
1	0.028	2.95	3.11	3.13	4.15	4.21	3.04	0.00
2	0.028	2.91	3.02	3.13	3.11	3.61	3.52	0.00
3	0.040	2.54	2.47	2.37	2.31	2.64	2.54	0.00
4	0.028	2.45	2.27	2.15	1.90	2.25	1.84	0.00
5	0.026	2.50	2.31	2.16	1.87	2.48	2.00	0.00
6	0.023	2.83	2.90	2.27	2.05	2.57	2.21	0.00
7	0.038	3.27	3.01	3.30	2.64	2.91	2.00	0.00
8	0.041	3.46	3.87	3.52	3.26	3.20	2.50	0.00
9	0.050	3.15	2.95	2.94	2.70	2.91	2.28	0.00
10	0.064	3.28	3.17	3.14	2.77	3.34	3.35	0.00
11	0.195	6.45	6.31	6.30	6.08	6.00	5.12	0.00
12	0.162	6.46	6.34	6.23	6.61	6.11	4.81	0.00
13	0.083	5.43	5.05	5.29	5.11	4.89	4.03	0.00
14	0.074	6.83	6.83	6.74	6.78	5.89	4.16	0.00
15	0.065	6.37	6.42	6.86	7.15	6.57	3.34	0.00
16	0.037	4.73	4.96	5.31	6.22	6.07	3.22	0.00

(a) Wind directions are numbered counterclockwise starting at 1 for due north.

APPENDIX E

GROUND-LEVEL Chi/q VALUES FOR RADIONUCLIDES AT VARIOUS DISTANCES FROM HWVP

TABLE E.1. Ground-Level Chi/q Values for H-3, C-14 and Noble Gases at Indicated Distances in Each Direction

Distance (meters)	Chi/q Toward Indicated Direction (sec/cubic meter)							
	N	NNW	NW	WNW	W	WSW	SW	SSW
800	0.214E-06	0.220E-06	0.425E-06	0.371E-06	0.358E-06	0.300E-06	0.459E-06	0.408E-06
2,400	0.121E-06	0.128E-06	0.228E-06	0.183E-06	0.161E-06	0.133E-06	0.189E-06	0.169E-06
4,000	0.732E-07	0.770E-07	0.134E-06	0.104E-06	0.897E-07	0.734E-07	0.105E-06	0.937E-07
5,600	0.509E-07	0.535E-07	0.921E-07	0.699E-07	0.600E-07	0.489E-07	0.702E-07	0.630E-07
7,200	0.385E-07	0.403E-07	0.689E-07	0.516E-07	0.441E-07	0.359E-07	0.517E-07	0.464E-07
12,000	0.214E-07	0.223E-07	0.378E-07	0.277E-07	0.235E-07	0.190E-07	0.276E-07	0.249E-07
24,000	0.975E-08	0.102E-07	0.170E-07	0.121E-07	0.102E-07	0.819E-08	0.119E-07	0.109E-07
40,000	0.551E-08	0.574E-08	0.948E-08	0.665E-08	0.557E-08	0.446E-08	0.653E-08	0.597E-08
56,000	0.379E-08	0.395E-08	0.649E-08	0.450E-08	0.376E-08	0.300E-08	0.441E-08	0.404E-08
72,000	0.287E-08	0.299E-08	0.489E-08	0.337E-08	0.281E-08	0.224E-08	0.329E-08	0.303E-08
	S	SSE	SE	ESE	E	ENE	NE	NNE
800	0.518E-06	0.491E-06	0.747E-06	0.515E-06	0.342E-06	0.284E-06	0.298E-06	0.209E-06
2,400	0.244E-06	0.266E-06	0.441E-06	0.356E-06	0.242E-06	0.167E-06	0.155E-06	0.112E-06
4,000	0.139E-06	0.159E-06	0.266E-06	0.217E-06	0.151E-06	0.100E-06	0.906E-07	0.670E-07
5,600	0.946E-07	0.110E-06	0.185E-06	0.151E-06	0.107E-06	0.697E-07	0.622E-07	0.464E-07
7,200	0.702E-07	0.827E-07	0.139E-06	0.114E-06	0.810E-07	0.525E-07	0.465E-07	0.349E-07
12,000	0.380E-07	0.456E-07	0.773E-07	0.632E-07	0.456E-07	0.292E-07	0.255E-07	0.193E-07
24,000	0.167E-07	0.206E-07	0.353E-07	0.292E-07	0.212E-07	0.134E-07	0.115E-07	0.873E-08
40,000	0.927E-08	0.115E-07	0.199E-07	0.166E-07	0.121E-07	0.757E-08	0.643E-08	0.492E-08
56,000	0.630E-08	0.791E-08	0.137E-07	0.115E-07	0.840E-08	0.521E-08	0.440E-08	0.338E-08
72,000	0.473E-08	0.597E-08	0.104E-07	0.869E-08	0.639E-08	0.395E-08	0.332E-08	0.255E-08

TABLE E.2. Ground-Level Chi/q Values for I-129 at Indicated Distances in Each Direction

Distance (meters)	Chi/q Toward Indicated Direction (sec/cubic meter)							
	N	NNW	NW	WNW	W	WSW	SW	SSW
800	0.211E-06	0.217E-06	0.418E-06	0.364E-06	0.350E-06	0.294E-06	0.451E-06	0.401E-06
2,400	0.112E-06	0.118E-06	0.205E-06	0.162E-06	0.142E-06	0.118E-06	0.170E-06	0.155E-06
4,000	0.633E-07	0.660E-07	0.110E-06	0.824E-07	0.713E-07	0.586E-07	0.856E-07	0.789E-07
5,600	0.412E-07	0.429E-07	0.697E-07	0.505E-07	0.436E-07	0.359E-07	0.528E-07	0.494E-07
7,200	0.287E-07	0.299E-07	0.474E-07	0.335E-07	0.289E-07	0.238E-07	0.354E-07	0.336E-07
12,000	0.133E-07	0.139E-07	0.208E-07	0.141E-07	0.122E-07	0.102E-07	0.153E-07	0.150E-07
24,000	0.355E-08	0.379E-08	0.498E-08	0.317E-08	0.284E-08	0.244E-08	0.378E-08	0.403E-08
40,000	0.141E-08	0.152E-08	0.184E-08	0.113E-08	0.104E-08	0.913E-09	0.145E-08	0.162E-08
56,000	0.549E-09	0.587E-09	0.659E-09	0.407E-09	0.394E-09	0.356E-09	0.605E-09	0.700E-09
72,000	0.241E-09	0.243E-09	0.281E-09	0.186E-09	0.189E-09	0.174E-09	0.317E-09	0.367E-09
	S	SSE	SE	ESE	E	ENE	NE	NNE
800	0.510E-06	0.484E-06	0.742E-06	0.513E-06	0.339E-06	0.283E-06	0.296E-06	0.208E-06
2,400	0.222E-06	0.246E-06	0.424E-06	0.344E-06	0.232E-06	0.160E-06	0.149E-06	0.107E-06
4,000	0.116E-06	0.137E-06	0.247E-06	0.203E-06	0.138E-06	0.931E-07	0.834E-07	0.604E-07
5,600	0.730E-07	0.894E-07	0.166E-06	0.137E-06	0.933E-07	0.623E-07	0.548E-07	0.397E-07
7,200	0.496E-07	0.627E-07	0.120E-06	0.991E-07	0.674E-07	0.449E-07	0.389E-07	0.281E-07
12,000	0.219E-07	0.295E-07	0.609E-07	0.506E-07	0.337E-07	0.224E-07	0.189E-07	0.134E-07
24,000	0.555E-08	0.839E-08	0.213E-07	0.181E-07	0.111E-07	0.754E-08	0.603E-08	0.398E-08
40,000	0.214E-08	0.346E-08	0.101E-07	0.870E-08	0.501E-08	0.347E-08	0.269E-08	0.170E-08
56,000	0.849E-09	0.141E-08	0.505E-08	0.444E-08	0.229E-08	0.168E-08	0.129E-08	0.759E-09
72,000	0.406E-09	0.608E-09	0.264E-08	0.237E-08	0.108E-08	0.873E-09	0.693E-09	0.381E-09

TABLE E.3. Ground-Level Chi/q Values for Particulate Nuclides at Indicated Distances in Each Direction

Distance (meters)	Chi/q Toward Indicated Direction (sec/cubic meter)							
	N	NNW	NW	WNW	W	WSW	SW	SSW
800	0.214E-06	0.219E-06	0.424E-06	0.370E-06	0.357E-06	0.299E-06	0.459E-06	0.407E-06
2,400	0.120E-06	0.127E-06	0.225E-06	0.181E-06	0.159E-06	0.131E-06	0.187E-06	0.168E-06
4,000	0.721E-07	0.758E-07	0.131E-06	0.101E-06	0.876E-07	0.717E-07	0.103E-06	0.921E-07
5,600	0.499E-07	0.523E-07	0.896E-07	0.677E-07	0.581E-07	0.474E-07	0.682E-07	0.614E-07
7,200	0.373E-07	0.391E-07	0.663E-07	0.494E-07	0.423E-07	0.344E-07	0.497E-07	0.449E-07
12,000	0.204E-07	0.213E-07	0.356E-07	0.258E-07	0.220E-07	0.178E-07	0.260E-07	0.236E-07
24,000	0.879E-08	0.920E-08	0.149E-07	0.105E-07	0.891E-08	0.722E-08	0.106E-07	0.977E-08
40,000	0.478E-08	0.501E-08	0.799E-08	0.550E-08	0.465E-08	0.376E-08	0.552E-08	0.517E-08
56,000	0.306E-08	0.323E-08	0.503E-08	0.341E-08	0.289E-08	0.235E-08	0.345E-08	0.328E-08
72,000	0.212E-08	0.225E-08	0.343E-08	0.230E-08	0.195E-08	0.160E-08	0.235E-08	0.227E-08
	S	SSE	SE	ESE	E	ENE	NE	NNE
800	0.518E-06	0.490E-06	0.746E-06	0.515E-06	0.341E-06	0.284E-06	0.298E-06	0.209E-06
2,400	0.242E-06	0.264E-06	0.439E-06	0.355E-06	0.241E-06	0.166E-06	0.154E-06	0.112E-06
4,000	0.137E-06	0.157E-06	0.264E-06	0.215E-06	0.150E-06	0.996E-07	0.899E-07	0.663E-07
5,600	0.922E-07	0.108E-06	0.183E-06	0.149E-06	0.105E-06	0.690E-07	0.614E-07	0.456E-07
7,200	0.678E-07	0.805E-07	0.137E-06	0.112E-06	0.796E-07	0.517E-07	0.457E-07	0.341E-07
12,000	0.359E-07	0.437E-07	0.755E-07	0.618E-07	0.443E-07	0.284E-07	0.247E-07	0.186E-07
24,000	0.149E-07	0.188E-07	0.335E-07	0.278E-07	0.199E-07	0.126E-07	0.107E-07	0.803E-08
40,000	0.792E-08	0.102E-07	0.186E-07	0.155E-07	0.111E-07	0.698E-08	0.584E-08	0.438E-08
56,000	0.500E-08	0.660E-08	0.124E-07	0.104E-07	0.735E-08	0.461E-08	0.381E-08	0.284E-08
72,000	0.343E-08	0.464E-08	0.898E-08	0.757E-08	0.528E-08	0.332E-08	0.270E-08	0.199E-08