Hanford Dose Overview Program: Standardized Methods and Data for Hanford Environmental Dose Calculations

W. D. McCormack

September 1982

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

**Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute**

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

PACIFIC NORTHWEST 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 from
National Technical Information Service
United States Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151

NTIS Price Codes
Microfiche A01

Printed Copy

Pages	Price Codes
001-025	A02
026-050	A03
051-075	A04
076-100	A05
101-125	A06
126-150	A07
151-175	A08
176-200	A09
201-225	A010
226-250	A011
251-275	A012
276-300	A013

3 3679 00048 5419

HANFORD DOSE OVERVIEW PROGRAM:
STANDARDIZED METHODS AND DATA
FOR HANFORD ENVIRONMENTAL
DOSE CALCULATIONS

W.D. McCormack

September 1982

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

Pacific Northwest Laboratory
Richland, Washington 99352

100

100

PREFACE

The Hanford Dose Overview Program is a Hanford site-wide service administered by the Pacific Northwest Laboratory (PNL) for the U.S. Department of Energy (DOE). The program was established at the request the DOE Richland Operations Office (DOE-RL) to provide a method of assuring the consistency of Hanford-related environmental dose assessments.

This document serves as a guide to the Hanford contractors for obtaining or performing Hanford-related environmental dose calculations. It is structured in two parts. The first section provides a background description of the Hanford Dose Overview Program, its objectives, scope, and review services. The second section is a description and listing of the calculations, models, and data standardized for use at Hanford.

Because environmental dose estimation techniques are state-of-the-art and are continually evolving, the data and standard methods presented herein will require periodic revision. This document is scheduled to be updated annually, but actual changes to the program will be made more frequently if required. For this reason, PNL's Environmental Evaluations Section should be contacted before any Hanford-related environmental dose calculation is performed.

CONTENTS

PREFACE	iii
HANFORD DOSE OVERVIEW PROGRAM	1
OBJECTIVES AND SCOPE	1
DOSE OVERVIEW SERVICES	2
CALCULATIONS, MODELS, AND DATA	5
CALCULATIONS	5
Chronic Releases	6
Acute Releases	9
MODELS	10
DATA	13
Meteorologic Data	13
Demographic Data	14
Terrestrial and Aquatic Pathway Data	14
Population Exposure Data	22
REFERENCES	25
APPENDIX A - JOINT FREQUENCY DATA	A.1

FIGURES

1	Environmental Dose Pathways	7
2	80 km Grid Around the 200 Areas	11

TABLES

1	Maximum Individual Locations	8
2	Programs for Calculating Radiation Doses	12
3	Annual Average Atmospheric Dispersion Around the 100-N Area for an 82-m Release Height (units are sec/m^3)(a)	15
4	Annual Average Atmospheric Dispersion Around the 200 Areas for an 89-m Release Height (units are sec/m^3)(a)	15
5	Annual Average Atmospheric Dispersion Around the 300 and 400 Areas for a Ground-Level Release Height (units are sec/m^3)(a)	16
6	Distribution of Population in 80-km Radius of the 100-N Reactor by Population Grid Sector for 1980	17
7	Distribution of Population in 80-km Radius of 200 Area Hanford Meteorological Tower by Population Grid Sector for the Year 1980	18
8	Distribution of Population in 80-km Radius of 300 Area by Population Grid Sector for the Year 1980	19
9	Distribution of Population in 80-km Radius of the FFTF by Population Grid Sector for the Year 1980	20
10	Pathway Parameters	21
11	Dietary Parameters	23
12	Residency Parameters	24
13	Recreational Activities	25
A.1	Joint Frequency Data for Ground-Level Releases, 100-N Area	A.2
A.2	Joint Frequency Data for Elevated Releases, 100-N Area	A.2
A.3	Joint Frequency Data for Ground-Level Releases, 200 Area	A.3
A.4	Joint Frequency Data for Elevated Releases, 200 Area	A.3
A.5	Joint Frequency Data for Ground-Level Releases, 300 Area	A.4

HANFORD DOSE OVERVIEW PROGRAM

The Hanford Dose Overview Program was established in response to DOE-RL's request that PNL provide a means of improving the consistency and accuracy of all documented Hanford-related environmental dose calculations. This program is funded through the service assessment pool and is administered at PNL by the Environmental Evaluations Section of the Occupational and Environmental Protection Department. The program's decision-making body is the Hanford Dose Overview Committee staffed by individuals from PNL's Atmospheric Sciences, Environmental Sciences, Radiological Sciences, and Occupational and Environmental Protection Departments as well as a representative from each of the Hanford contractors involved in calculation of environmental doses.

OBJECTIVES AND SCOPE

The Hanford Dose Overview Program's objective is to provide DOE-RL with a means of assuring that Hanford environmental doses are calculated using consistent methods and data such that an appropriate level of comparability exists between calculational results. The program serves as a focal point for Hanford environmental dose calculation activities and provides a number of services for Hanford contractors involved in calculation of environmental doses.

A set of computer programs, recommended for calculating Hanford environmental doses is maintained on Boeing Computer Services Richland (BCSR) System B. These programs are documented and contain approved and internally consistent models and data files. They are accessible in a protected "use-only" mode and possess built-in output features that document the primary calculation inputs, the program and data files used, and their revision dates. The data files are updated as necessary and all modifications to the programs are controlled and documented. While alternate methods may be used to calculate Hanford environmental doses, their adequacy will be evaluated by comparison with the recommended programs and models.

Site specific input data and assumptions have been compiled and are maintained for use by the contractors in calculating Hanford environmental

doses. The data and assumptions, to the extent they apply, should be used in Hanford calculations. These data are not all inclusive and will be modified should additional or more appropriate information become available.

The Hanford Dose Overview Program provides an environmental dose calculation review which documents the methods, data, and assumptions used in the calculation. All Hanford-related environmental dose calculations should undergo the review which is conducted by a member of the Dose Overview Committee. The documentation generated by this review should become an integral part of the calculational results and be included in any reporting of the doses.

Environmental dose calculations considered to be within the scope of the Hanford Dose Overview Program's standardized methods and review are those that address Hanford's facilities, actions, or conditions both present and future. Routine operations as well as actual and hypothetical accident situations are also considered. Hanford environmental doses that have been calculated by inappropriate methods or have not been subjected to review and documentation may not receive approval by DOE-RL. Those aspects of an environmental dose calculation that pertain to facility conditions and generation of environmental releases are not within the scope of this program, but are the responsibility of the facility contractor.

DOSE OVERVIEW SERVICES

Dose overview services (planning or review of calculated results) are obtained by contacting the Hanford Dose Overview Program Manager (376-0287). Because this program is funded through the service assessment pool, there are no additional charges for dose overview services.

Dose calculation planning involves selection of appropriate models and assumptions consistent with the objective of the calculation. Calculational techniques will vary depending upon the specific situation being addressed. Review of calculated results is initiated by providing the Hanford Dose Overview Program Manager with a description of the doses being calculated, a copy of the quality assurance page, which is created by the computer program,

and a copy of the calculational results. Documentation provided to the calculation originator by the Hanford Dose Overview Program review will include a summary of the information contained on the quality assurance page. In the case of manual dose calculations, a description of the methods and equations used and the calculation results should be provided to the reviewer. Discrepancies discovered during this review will be resolved with the originator.

CALCULATIONS, MODELS, AND DATA

The type and purpose of an environmental dose evaluation will determine the specific doses calculated and methods used. At Hanford, environmental doses are calculated for a variety of reasons. For example, environmental impact statements and safety analysis reports use dose calculations to evaluate the impact of projected operational and accident releases. Environmental doses are also calculated as a basis for emergency planning and each year doses are calculated to evaluate the offsite impact of Hanford operations and effluents.

These calculations are often complex requiring the use of computerized models that facilitate calculation of environmental doses for a variety of conditions and situations. Transport models are used to predict the movement of radionuclides through terrestrial and aquatic pathways and subsequent individual and population exposure. Dosimetry models predict biologic uptake, retention and removal of radionuclides in exposed individuals and estimate potential radiation dose.

The calculated doses are site specific through the appropriate selection and use of data needed as input to the calculations. These data describe site-specific meteorology, demography, environmental pathway accumulation and transfer, and exposure of the local population.

The calculations, models, and data determined to be appropriate for use at Hanford are described in the sections that follow. While these data and models are not all inclusive, they do address the needs of the majority of dose calculations performed at Hanford. Calculation of environmental doses due to special release situations may require data and models in addition to those presented here.

CALCULATIONS

Environmental doses are calculated to evaluate the offsite impact of Hanford facilities and operations that involve radioactive materials. The doses may be compared with appropriate limits for offsite dose, historic

Hanford dose impacts, or doses from other common sources of exposure to radiation. In some cases, doses may be calculated in order to allow estimation of possible health effects in the exposed population. Calculations are made of the potential dose to a maximum individual (MI)* and the population residing within 80 km of the release point. In the case of radioiodine releases, the potential dose to the thyroid of an infant is also calculated.

The specific doses calculated for most situations are first-year dose (dose during year of exposure) and 50-year dose commitment (first year plus internal committed dose for next 49 years) to the whole body and other critical organs. When assessing the potential dose due to long-term exposure situations (longer than 1 year) it may be appropriate to calculate a maximum annual dose and/or an accumulated dose in order to account for continued uptake beyond the first year. An additional specialized calculation is performed for the 70-year accumulated dose (or lifetime dose). This dose is calculated when it is necessary to estimate potential health effects in the exposed population.

There are two primary situations for which environmental dose calculations are performed: chronic releases of radioactive material to the environment and acute releases. Chronic releases are on the order of months to years in duration while acute releases may range from seconds to weeks. The general methods of performing environmental dose calculations for these situations are discussed below.

Chronic Releases

The MI for chronic release is a hypothetical member of the public assumed to reside in a habitable location such that his overall exposure is maximized. In the event of multiple release locations (e.g., releases from the 100 and 200 Areas), a single MI location is selected to maximize the combined exposure to both releases. Potential pathways of MI exposure to chronic releases of radioactive material are shown in Figure 1. Table 1 lists MI locations for various onsite release points.

---

* The MI is a hypothetical member of the public whose location, diet, and living habits tend to maximize his dose.

FIGURE 1. Environmental Dose Pathways

TABLE 1. Maximum Individual Locations

<u>Release Point</u>	<u>Maximum Individual Location</u>
100 N	
Airborne Release	8.9 km, NW
Liquid Release	Riverview Dist., Pasco
200 E	26 km, SE
200 W	44 km, SE
300	1.6 km, E
400	8.9 km, E

Collective population doses (man-rem) due to chronic releases are calculated for the population living within 80 km of the release point. The MI exposure pathways depicted in Figure 1 are also assumed to be available to the offsite population. However, in the case of releases to the Columbia River, effluents are confined rather than dispersed and only a portion of full 80-km population is exposed. The river-related exposure pathways are drinking water, irrigated foodstuff, fish consumption and river recreation. Descriptions of river-related pathways are as follows:

- Drinking Water -- The cities of Richland and Pasco obtain their municipal water from the Columbia River downstream from Hanford. The city of Kennewick began drawing a portion of its municipal water from the river in late 1980. During 1981, 40% of Kennewick drinking water was drawn from the Columbia River. The total affected population was approximately 70,000 during 1981.
- Irrigated Foodstuff -- Columbia River water is withdrawn for irrigation of extensive home vegetable gardens in the Riverview District of Franklin County of Pasco. Approximately 2,000 people are estimated to be affected.

- River Recreation -- These activities include swimming, boating, and shoreline recreation. The population residing adjacent to the river within 80 km of Hanford is assumed to be effected by these pathways and is estimated to number 125,000.
- Fish Consumption -- Population doses due to consumption of fish obtained locally from the Columbia River are calculated based on the estimated total annual catch of 15,000 kg/yr without reference to a specific population group.

Population exposure to chronic atmospheric releases of radioactive material is calculated using population weighted atmospheric dispersion. The distributions of population within 80 km of the four Hanford operating areas are broken down by the 16 primary compass sectors subdivided further by 5 annular rings out to 80 km, as illustrated in Figure 2. For each of the 80 resultant sector/annular ring subdivisions an annual average atmospheric dispersion parameter $(X/Q)^*$ is calculated. The weighted X/Q is derived by summing the 80 products of population times X/Q for each sector/annular ring.

Acute Release

Environmental dose calculations for acute releases of radioactive material differ significantly from those performed for chronic releases. Public exposure during acute release situations is relatively short and special assumptions are required in order to estimate potential public dose.

Maximum individual doses are calculated for the uncontrolled point of public access that maximized potential MI exposure during the release. The exposure pathways normally considered for acute releases are inhalation and air submersion. Short term meteorologic conditions used in the dispersion portion of the calculations are selected based on the type of acute release. In response to actual atmospheric releases of radioactive material, actual meteorologic conditions are used. When calculating the potential impact of hypothetical releases (as in an SAR or EIS accident analysis), adverse meteorologic conditions are assumed.

---

* X/Q is an air concentration per unit release rate factor derived as $Ci/m^3 \div Ci/sec = sec/m^3$.

FIGURE 2. 80 km Grid Around the 200 Areas

Adverse meteorologic conditions for calculation of MI doses from ground level releases (building vents, short stacks, etc.) are a moderately stable atmosphere (generally equivalent to Pasquill Class F stability) with a constant direction 1-m/sec wind. In the case of stack releases, an evaluation must be made to determine which atmospheric stability classification is adverse. For a maximum individual located near the stack, an unstable atmosphere is likely to be adverse while moderately stable would be adverse for a distant MI.

Collective population doses due to inhalation and air submersion following an acute release are calculated for the population in effected downwind locations. For actual releases, the actual meteorologic conditions and downwind population are used in the calculations. Collective doses for hypothetical releases are calculated assuming a moderately stable atmosphere, a 1-m/sec wind and uniform dispersion over the affected 22-1/2° compass sector. The doses are calculated using a population-weighted E/Q* for the effected sector as described in the section on chronic releases. The compass sector is selected to maximize the weighted E/Q.

MODELS

A set of computer programs recommended for use in calculating Hanford-related environmental doses is listed in Table 2. These programs use internally consistent models, share common data libraries, and provide the computational capabilities most commonly needed at Hanford. The majority of the programs contain built-in quality assurance output that provides documentation of the current program and data library revision dates and primary inputs used in the calculations. Because they are lengthy and complex, program descriptions are limited to the brief statements contained in Table 2 and reference is made to the detailed program documentation. The referenced program documents contain program listings, model descriptions and full user instructions. The PNL contact for instructions on accessing these programs is B. A. Napier at 376-4217.

---

* E/Q is an integrated exposure per unit release factor derived as
$$\frac{Ci \cdot sec}{m^3} \div Ci = sec/m^3.$$

TABLE 2. Programs for Calculating Radiation Doses

<u>Program</u>	<u>Description</u>	<u>Reference</u>
KRONIC	One-year air submersion dose from chronic releases, individual and collective	Streng 1973
SUBDOS	One-year individual air submersion doses from acute release (finite cloud model)	Streng 1975a
HADOC	One-year individual and collective air submersion and inhalation dose commitments from acute releases (semi-infinite cloud model for external doses)	Streng 1980a
DACRIN	Individual and collective inhalation doses from chronic or acute releases, one-year doses, dose commitments, and accumulated doses	Streng 1974 Streng 1975a
ARRRG	Individual and collective doses from contaminated water and aquatic foods and aquatic recreation, one-year dose and dose commitment	Napier 1980a
FOOD	Individual and collective doses from contaminated farm products, from either air deposition or irrigation, one-year dose and dose commitment	Napier 1980a
PABLM	A combination of the capabilities of ARRRG and FOOD to calculate accumulated doses	Napier 1980b
MAXI	A calculational package to calculate individual maximum annual dose from residual radioactivity following nuclear facility decommissioning	Murphy 1980 Napier 1979 Kennedy 1979
ALLDOS	A report generator using the output from SUBDOS or HADOC, DACRIN, and PABLM	Streng 1980b

DATA

The data used in environmental dose calculations describe meteorology, demography, environmental pathway accumulation and transfer, population exposure, and dosimetry. Because the numerical results of a dose calculation strongly depend upon these data, they have been standardized for use in Hanford calculations and to the extent possible include values specific to the Hanford Site.

Much of the data are stored in the computer in data libraries that are accessed by the programs when they are run. These data, which include bio-accumulation factors and radionuclide physical and metabolic data, are described in the computer program documents (see Table 2). Other data, required to be input each time the programs are run are described below.

Meteorologic Data

Radioactive material released to the atmosphere becomes diluted as it is carried by the wind, away from the point of release. The degree of dilution and magnitude of resultant air concentrations are predicted through the use of atmospheric dispersion models. The model used for predicting atmospheric dispersion at Hanford is described in ERDA-1538, Final Environmental Impact Statement Waste Management Operations, Hanford Reservation, and is often referred to as the "Hanford dispersion model." This model predicts downwind concentrations of released materials on the basis of wind speed, direction, and atmospheric stability during the release as well as release height, release duration, and distance from the source. The Hanford model considers four atmospheric stability categories:

- very stable
- moderately stable
- neutral
- unstable

Dispersion during stable conditions is based on past experiments conducted at Hanford (Fuquay, Simpson and Hinds, 1964) and dispersion during neutral and unstable conditions is calculated using Sutton's equations (U.S. Weather Bureau, 1955).

In predicting dispersion of chronically released materials, site specific annual average joint frequency data for wind speed, direction, and stability class should be used to predict atmospheric conditions during the release. The product of the dispersion model that is used for dose calculation is an air concentration per unit release rate factor, X/Q , with units sec/m^3 ($\text{Ci}/\text{m}^3 \div \text{Ci}/\text{sec}$). The numerical product of X/Q (sec/m^3) times average release rate (Ci/sec) is average air concentration (Ci/m^3).

Dispersion following an acute release to the atmosphere is predicted using short-term meteorologic data. For actual short-term atmospheric releases, the meteorologic data should describe actual atmospheric conditions during the release. In the case of predictive dose calculations for hypothetical short-term releases (as in accident safety analyses), potential dispersion is conservatively predicted by assuming that adverse atmospheric conditions exist during the release.

Annual average joint frequency data for the 100, 200, and 300/400 Areas is presented in Appendix A. Values of annual average X/Q for elevated releases from the 100 and 200 Areas and for 300/400 Area ground level releases are contained in Tables 3 through 5 respectively. The X/Q values are calculated for each compass sector at the midpoints of 5 equally spaced annular rings out to 80 km. Annual average X/Q s for release heights other than specified in Tables 3 through 5 can be calculated from the joint frequency data contained in Appendix A.

Demographic Data

Geographic distributions of population residing within an 80-km radius of the four operating areas are listed in Tables 6 through 9. These distributions are based on 1980 Bureau of Census data (Sommer, Rau, and Robinson, 1981).

Terrestrial and Aquatic Pathway Data

Following release and initial transport through the environment, radioactive materials may enter terrestrial or aquatic pathways that lead to public exposure. These potential pathways, which include fish consumption, drinking water, and consumption of foodstuffs, are generally composed of

TABLE 3. Annual Average Atmospheric Dispersion Around the 100-N Area for an 82-m Release Height (units are sec/m³)(a)

Direction	Range in Miles (km)									
	0.5 (0.8)	1.5 (2.4)	2.5 (4.0)	3.5 (5.6)	4.5 (7.2)	7.5 (12)	15 (24)	25 (40)	35 (56)	45 (72)
N	3.68E-08	1.60E-08	9.02E-09	5.69E-09	4.05E-09	2.49E-09	1.91E-09	1.44E-09	1.10E-09	8.69E-10
NNE	5.24E-08	2.05E-08	1.08E-08	6.64E-09	4.62E-09	1.94E-09	1.94E-09	1.46E-09	1.12E-09	8.90E-10
NE	1.44E-07	4.84E-08	2.35E-08	1.39E-08	9.39E-09	5.02E-09	3.30E-09	2.44E-09	1.87E-09	1.48E-09
ENE	1.21E-07	5.50E-08	2.81E-08	1.70E-08	1.17E-08	6.65E-09	4.72E-09	3.56E-09	2.73E-09	2.17E-09
E	1.14E-07	6.79E-08	3.60E-08	2.20E-08	1.54E-08	9.31E-09	7.43E-09	5.95E-09	4.70E-09	3.79E-09
ESE	1.20E-07	7.12E-08	3.76E-08	2.29E-08	1.59E-08	9.18E-09	6.87E-09	5.41E-09	4.27E-09	3.45E-09
SE	7.91E-08	4.84E-08	2.60E-08	2.60E-08	1.10E-08	5.95E-09	3.81E-09	2.74E-09	2.07E-09	1.63E-09
SSE	7.94E-08	4.40E-08	2.27E-08	1.37E-08	9.28E-09	4.73E-09	2.72E-09	1.85E-09	1.36E-09	1.05E-09
S	9.41E-08	4.26E-08	2.14E-08	1.27E-08	8.58E-09	4.25E-09	2.32E-09	1.55E-09	1.13E-09	8.70E-10
SSW	1.61E-07	5.84E-08	2.82E-08	1.65E-08	1.10E-08	5.38E-09	2.89E-09	1.93E-09	1.41E-09	1.09E-09
SW	7.78E-08	3.33E-08	1.77E-08	1.08E-08	7.49E-09	4.13E-09	2.67E-09	1.89E-09	1.41E-09	1.10E-09
WSW	5.39E-08	2.74E-08	1.62E-08	1.04E-08	7.39E-09	4.34E-09	2.99E-09	2.14E-09	1.59E-09	1.24E-09
W	7.20E-08	3.48E-08	1.97E-08	1.25E-08	8.81E-09	5.20E-09	3.64E-09	2.62E-09	1.95E-09	1.52E-09
WNW	8.53E-08	3.75E-08	2.07E-08	1.29E-08	9.02E-09	5.09E-09	3.39E-09	2.41E-09	1.80E-09	1.40E-09
NW	8.32E-08	3.48E-08	1.90E-08	1.18E-08	8.24E-09	4.62E-09	3.60E-09	2.19E-09	1.64E-09	1.28E-09
NNW	4.68E-08	2.07E-08	1.18E-08	7.43E-09	5.22E-09	2.99E-09	2.04E-09	1.48E-09	1.11E-09	8.69E-10

(a) Calculated from meteorological data collected at 100-N Area for the period 2-70 through 1-71.

TABLE 4. Annual Average Atmospheric Dispersion Around the 200 Areas for an 89-m Release Height (units are sec/m³)(a)

Direction	Range in Miles (km)									
	0.5 (0.8)	1.5 (2.4)	2.5 (4.0)	3.5 (5.6)	4.5 (7.2)	7.5 (12)	15 (24)	25 (40)	35 (56)	45 (72)
N	3.29E-08	1.76E-08	1.04E-08	6.91E-09	4.87E-09	2.29E-09	1.08E-09	7.81E-10	6.23E-10	5.10E-10
NNE	4.70E-08	1.90E-08	1.05E-08	6.82E-09	4.76E-09	2.22E-09	1.08E-09	8.11E-10	6.60E-10	5.47E-10
NE	8.05E-08	3.02E-08	1.54E-08	9.44E-09	6.40E-09	2.92E-09	1.50E-09	1.19E-09	9.86E-10	8.26E-10
ENE	7.61E-08	2.84E-08	1.45E-08	3.94E-09	6.07E-09	2.85E-09	1.64E-09	1.37E-09	1.15E-09	9.64E-10
E	4.61E-08	2.28E-08	1.32E-08	8.72E-09	6.17E-09	3.18E-09	2.22E-09	1.95E-09	1.65E-09	1.39E-09
ESE	7.97E-08	4.00E-08	2.17E-08	1.36E-08	9.38E-09	4.77E-09	3.60E-09	3.37E-09	2.93E-09	2.50E-09
SE	1.67E-07	7.60E-08	4.02E-08	2.49E-08	1.70E-08	7.97E-09	4.54E-09	3.73E-09	3.12E-09	2.62E-09
SSE	8.34E-08	4.19E-08	2.47E-08	1.64E-08	1.16E-08	5.42E-09	2.40E-09	1.60E-09	1.22E-09	9.76E-10
S	8.65E-08	4.38E-08	2.55E-08	1.68E-08	1.18E-09	5.40E-09	2.14E-09	1.33E-09	9.81E-10	7.71E-10
SSW	7.93E-08	3.88E-08	2.19E-08	1.42E-08	9.89E-09	4.43E-09	1.65E-09	9.59E-10	6.90E-10	5.35E-10
SW	6.89E-08	4.06E-08	2.36E-08	1.54E-08	1.08E-08	4.82E-09	1.73E-09	9.64E-10	6.79E-10	5.19E-10
WSW	3.74E-08	2.39E-08	1.49E-08	1.01E-08	7.20E-09	3.30E-09	1.24E-09	7.20E-10	5.18E-10	4.02E-10
W	3.72E-08	2.57E-08	1.64E-08	1.13E-08	8.13E-09	3.76E-09	1.44E-09	8.57E-10	6.24E-10	4.87E-10
WNW	3.42E-08	2.37E-08	1.58E-08	1.12E-08	8.09E-09	3.84E-09	1.63E-09	1.07E-09	8.20E-10	6.56E-10
NW	4.17E-08	2.69E-08	1.82E-08	1.29E-08	9.41E-09	4.55E-09	2.08E-09	1.45E-09	1.13E-09	9.10E-10
NNW	2.68E-08	1.57E-08	1.03E-08	7.27E-09	5.27E-09	2.56E-09	1.22E-09	8.79E-10	6.94E-10	5.64E-10

(a) Calculated from meteorological data collected at the Hanford Meteorological Station from 1955 through 1970.

TABLE 5. Annual Average Atmospheric Dispersion Around the 300 and 400 Areas for a Ground-Level Release Height (units are sec/m³)(a)

Direction	Range in Miles (km)									
	0.5 (0.8)	1.5 (2.4)	2.5 (4.0)	3.5 (5.6)	4.5 (7.2)	7.5 (12)	15 (24)	25 (40)	35 (56)	45 (72)
N	5.7E-06	8.7E-07	3.9E-07	2.4E-07	1.6E-07	7.9E-08	3.1E-08	1.6E-08	1.0E-08	7.4E-09
NNE	5.0E-06	7.6E-07	3.4E-07	2.1E-07	1.4E-07	6.9E-08	2.7E-08	1.3E-08	8.7E-09	6.3E-09
NE	3.9E-06	5.9E-07	2.6E-07	1.6E-07	1.1E-07	5.3E-08	2.1E-08	1.0E-08	6.7E-09	4.9E-09
ENE	3.6E-06	5.5E-07	2.5E-07	1.5E-07	1.0E-07	5.0E-08	1.9E-08	9.8E-09	6.4E-09	4.6E-09
E	3.4E-06	5.1E-07	2.3E-07	1.4E-07	9.4E-08	4.6E-08	1.8E-08	9.0E-09	5.9E-09	4.3E-09
ESE	5.8E-06	8.8E-07	4.0E-07	2.4E-07	1.7E-07	8.0E-08	3.1E-08	1.6E-08	1.0E-08	7.5E-09
SE	7.2E-06	1.1E-06	4.9E-07	3.0E-07	2.1E-07	1.0E-07	3.9E-08	2.0E-08	1.3E-08	9.3E-09
SSE	7.2E-06	1.1E-06	4.7E-07	2.9E-07	2.0E-07	9.6E-08	3.8E-08	1.9E-08	1.2E-08	9.0E-09
S	5.5E-06	8.4E-07	3.8E-07	2.4E-07	1.6E-07	7.8E-08	3.0E-08	1.5E-08	1.0E-08	7.3E-09
SSW	4.4E-06	6.8E-07	3.1E-07	1.9E-07	1.3E-07	6.3E-08	2.5E-08	1.3E-08	8.2E-09	6.0E-09
SW	3.8E-06	5.9E-07	2.7E-07	1.7E-07	1.1E-07	5.5E-08	2.2E-08	1.1E-08	7.2E-09	5.2E-09
WSW	3.0E-06	4.6E-07	2.1E-07	1.3E-07	8.8E-08	4.3E-08	1.7E-08	8.5E-09	5.6E-09	4.0E-09
W	2.6E-06	4.1E-07	1.8E-07	1.2E-07	7.8E-08	3.8E-08	1.5E-08	7.5E-09	4.9E-09	3.6E-09
WNW	2.9E-06	4.4E-07	2.0E-07	1.2E-07	8.2E-08	4.0E-08	1.5E-08	7.8E-09	5.1E-09	3.7E-09
NW	3.6E-06	5.4E-07	2.4E-07	1.5E-07	1.0E-07	4.9E-08	1.9E-08	9.5E-09	6.2E-09	4.5E-09
NNW	5.4E-06	8.2E-07	3.7E-07	2.2E-07	1.5E-07	7.4E-08	2.9E-08	1.5E-08	9.5E-09	6.9E-09

(a) Calculated from meteorological data collected at the Washington Public Power Supply System WNP-2 reactor during the period 4-74 through 3-76.

TABLE 6. Distribution of Population in 80-km Radius of the
100-N Reactor by Population Grid Sector for 1980

Compass Direction	Number of People					Totals
	0-10 mi	10-20 mi	20-30 mi	30-40 mi	40-50 mi	
NORTH	36	953	420	1,492	7,583	10,484
NNE	5	285	561	18,531	1,350	20,732
NE	0	624	1,013	2,691	259	4,587
ENE	0	620	5,884	1,129	429	8,062
EAST	0	294	625	2,742	605	4,266
ESE	0	306	1,493	596	247	2,642
SE	0	54	2,113	28,922	5,001	36,090
SSE	0	0	35,127	50,292	3,354	88,773
SOUTH	0	127	4,592	2,041	176	6,936
SSW	0	258	1,676	12,603	625	15,162
SW	0	547	4,946	16,747	469	22,709
WSW	0	680	1,699	8,297	15,274	25,950
WEST	18	395	936	5,149	75,686	82,184
WNW	54	573	377	490	1,598	3,092
NW	74	277	425	515	683	1,974
NNW	64	277	438	1,030	4,696	6,505
TOTALS	251	6,270	62,325	153,267	118,035	340,148

TABLE 7. Distribution of Population in 80-km Radius of
200 Area Hanford Meteorological Tower by
Population Grid Sector for the Year 1980

Compass Direction	Number of People					Totals
	0-10 mi	10-20 mi	20-30 mi	30-40 mi	40-50 mi	
NORTH	0	174	1,124	772	1,957	4,027
NNE	0	92	656	5,547	14,822	21,117
NE	0	262	5,930	2,963	596	9,751
ENE	0	235	773	2,366	435	3,809
EAST	0	340	1,329	1,659	588	3,916
ESE	0	283	1,374	230	652	2,539
SE	0	6,757	48,661	50,519	3,474	109,411
SSE	0	1,997	13,161	2,717	5,218	23,093
SOUTH	0	1,532	1,489	195	1,799	5,015
SSW	0	905	5,283	652	129	6,969
SW	0	1,190	19,786	2,182	459	23,617
WSW	5	1,840	5,063	15,088	4,573	26,569
WEST	32	648	949	6,874	78,635	87,138
WNW	73	444	802	833	2,833	4,985
NW	0	555	398	493	1,454	2,900
NNW	0	246	456	864	4,521	6,087
TOTALS	110	17,500	107,234	93,954	122,145	340,943

TABLE 8. Distribution of Population in 80-km Radius of 300
Area by Population Grid Sector for the Year 1980

Compass Direction	Number of People					Totals
	0-10 mi	10-20 mi	20-30 mi	30-40 mi	40-50 mi	
NORTH	289	241	989	5,655	5,317	12,491
NNE	307	475	841	1,950	2,269	5,842
NE	18	966	2,583	562	205	4,334
ENE	307	465	349	470	238	1,829
EAST	291	114	137	174	687	1,403
ESE	338	288	863	594	17,891	19,974
SE	2,549	26,150	2,922	877	1,235	33,733
SSE	7,161	30,357	1,114	1,117	1,113	40,862
SOUTH	15,561	6,651	96	17,223	5,127	44,658
SSW	11,124	4,034	99	1,209	2,038	18,504
SW	10,066	3,931	706	182	181	15,066
WSW	4,429	1,810	5,531	8,988	621	21,379
WEST	294	984	2,226	16,878	16,293	36,675
WNW	0	0	692	1,543	1,679	3,914
NW	0	0	74	923	785	1,782
NNW	0	0	8	875	1,212	2,095
TOTALS	52,734	76,466	19,230	59,220	56,891	264,541

TABLE 9. Distribution of Population in 80-km Radius of the FFTF by Population Grid Sector for the Year 1980

Compass Direction	Number of People					Totals
	0-10 mi	10-20 mi	20-30 mi	30-40 mi	40-50 mi	
NORTH	0	78	859	811	16,267	18,015
NNE	20	343	5,728	2,945	1,021	10,057
NE	114	377	760	1,033	217	2,501
ENE	211	1,041	2,644	492	451	4,839
EAST	229	600	183	169	183	1,364
ESE	229	442	544	292	1,060	2,567
SE	344	25,267	13,654	2,105	952	42,322
SSE	10,829	40,933	5,688	719	2,364	60,533
SOUTH	11,760	9,385	1,525	5,611	15,691	43,972
SSW	1,446	4,550	583	185	1,927	8,691
SW	179	1,538	5,234	535	239	7,725
WSW	0	1,206	7,748	14,956	481	24,391
WEST	0	190	3,339	6,089	17,171	26,789
WNW	0	0	932	1,221	3,176	5,329
NW	0	0	295	903	705	1,903
NNW	0	0	264	1,302	1,182	2,748
TOTALS	25,361	85,950	49,980	39,368	63,087	263,746

compartments between which the radionuclides move. For example, radioactive material released to the river is diluted (Compartment 1), after which it may be withdrawn at a given rate for irrigation (Compartment 2), deposited on plants and soil (Compartments 3 and 4), and taken into the plant (Compartment 5), via the roots and leaves. The compartment transfer factors used for Hanford environmental dose calculations are described in detail in the reference computer program documentation (see Table 2).

Other parameters affecting the movement of radionuclides within potential exposure pathways include irrigation rates, growing period, hold up (delay between harvest and consumption), etc. These parameters are listed in Table 10. Note that certain parameters are specific to maximum and average individuals.

TABLE 10. Pathway Parameters

	Holdup (days, except as noted)(a)		Growing Period (days)	Yield (Kg/m ²)	Irrigation Rate (l/m ² /month)
	Maximum Individual	Average Individual			
Leafy Veg.	1	14	90	1.5	150
Other above ground veg.	1	14	60	0.7	160
Potatoes	10	14	90	4	180
Other root veg.	1	14	90	5	150
Berries	1	14	60	2.7	150
Melons	1	14	90	0.8	150
Orch. Fruit	10	14	90	1.7	150
Wheat	10	14	90	0.72	0
Other Grains	1	14	90	1.4	150
Eggs	1	18	90	0.84	150
Milk	1	4	30	1.3	200
Beef	15	34	90	0.84	140
Pork	15	34	90	0.84	140
Poultry	1	34	90	0.84	140
Fish	24 hours	24	—	—	—
Drinking Water	24	24	—	—	—

(a) Holdup is the time between harvest and consumption.

Population Exposure Data

Potential radiation doses are directly related to the degree of exposure to or consumption of radionuclides in the environment. The data described in preceding sections are used to estimate environmental concentrations of radionuclides following their release. Population exposure data that include diet, residency durations, and river recreation are used to estimate the extent of exposure to the radionuclide concentrations. Tables 11, 12, and 13 list dietary, residency, and river recreation parameters respectively. Note that the data are listed for both maximum and average individuals.

TABLE 11. Dietary Parameters

	<u>Consumption (Kg/yr)</u>	
	<u>Maximum Individual</u>	<u>Average Individual</u>
Leafy Veg.	30	15
Other above- ground veg.	30	15
Potatoes	110	100
Other root veg.	72	17
Berries	30	6
Melons	40	8
Orch. Fruit	265	50
Wheat	80	72
Other grains	8.3	7.5
Eggs	30	20
Milk	274(a)(b)	230(a)
Beef	40	40
Pork	40	30
Poultry	18	8.5
Fish	40	(c)
Drinking Water	730(b)	438

(a) Units ℓ /yr.

(b) 330 ℓ /yr for infant.

(c) Radiation doses are calculated based on
estimated total annual catch of 15,000 kg.

TABLE 12. Residency Parameters

<u>Parameter</u>	<u>Exposure (hr/yr)</u>	
	<u>Maximum Individual</u>	<u>Average Individual</u>
Ground Contamination	4383	2920
Air Submersion	8766	8766
Inhalation(a)	8766	8766

(a) Inhalation Rates:

Adult--250 cm³/sec routine -- Infant--44 cm³/sec

TABLE 13. Recreational Activities

<u>Activity</u>	<u>Exposure (hr/yr)(a)</u>	
	<u>Maximum Individual</u>	<u>Average Individual</u>
Shoreline	500	17
Boating	100	5
Swimming	100	10

(a) Assumes 8 hours holdup for maximum individual and 13 hours for average.

REFERENCES

Fuquay, J., C. L. Simpson, and W. T. Hinds. 1964. "Prediction of Environmental Exposures from Sources near the Ground Based on Hanford Experimental Data," J. Appl. Meteorol., 3(6): 761-770.

Houston, J. R., D. L. Streng, and E. C. Watson. 1974. DACRIN - A Computer Program for Calculating Organ Dose from Acute or Chronic Radionuclide Inhalation. BNWL-B-389, Pacific Northwest Laboratory, Richland, Washington.

Kennedy, W. E., et. al. 1979. A Method for Determining Acceptable Residual Radioactive Contamination Levels. PNL-SA-7495, Presented at the 24th Annual Meeting of the Health Physics Society, Philadelphia, Pennsylvania.

Murphy, E. S., and G. M. Holter. 1980. Technology, Safety and Costs of Decommissioning and Reference Low-Level Waste Burial Ground. NUREG/CR-0570, Pacific Northwest Laboratory, Richland, Washington.

Napier, B. A., et. al. 1979. The Maximum Annual Dose Resulting from Residual Radioactive Contamination. PNL-SA-7496, Presented at the 24th Annual Meeting of the Health Physics Society, Philadelphia, Pennsylvania.

Napier, B. A., et. al. 1980a. ARRRG and FOOD - Computer Programs for Calculating Radiation Dose to Man from Radionuclides in the Environment. PNL-3180, Pacific Northwest Laboratory, Richland, Washington.

Napier, B. A., W. E. Kennedy, Jr., and J. K. Soldat. 1980b. PABLM - A Computer Program to Calculate Accumulated Radiation Dose from Radionuclides in the Environment. PNL-3209, Pacific Northwest Laboratory, Richland, Washington.

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.

Streng, D. L. 1975b. DACRIN - Modification for Gastrointestinal Tract Dose. BNWL-B-399, SUPP, Pacific Northwest Laboratory, Richland, Washington.

Streng, D. L., and E. C. Watson. 1973. KRONIC - A Computer Program for Calculating Annual Average External Doses from Chronic Atmospheric Releases of Radionuclides. BNWL-B-264, Pacific Northwest Laboratory, Richland, Washington.

Streng, D. L., and R. A. Peloquin. 1980a. HADOC - A Computer Code for Calculation of External and Inhalation Doses from Acute Radionuclide Releases. PNL-3503, Pacific Northwest Laboratory, Richland, Washington.

Streng, D. L., and E. C. Watson, and J. R. Houston. 1975a. SUBDOS - A Computer Program for Calculating External Doses from Accidental Atmospheric Releases of Radionuclides. BNWL-B0351, Pacific Northwest Laboratory, Richland, Washington.

Streng, D. L., et. al. 1980b. ALLDOS - A Computer Program for Calculation of Radiation Doses from Airborne and Waterborne Releases. PNL-3524, Pacific Northwest Laboratory, Richland, Washington.

U.S. Weather Bureau. 1955. Meteorology and Atomic Energy, USAEC Report AECU-3066.

APPENDIX A
JOINT FREQUENCY DATA

APPENDIX A

JOINT FREQUENCY DATA

Tables A.1 through A.5 list joint frequency meteorologic data for the 100, 200, and 300/400 Areas. These data are based on past measurements of occurrence frequency for wind speed, direction, and atmospheric stability at or near each of the operating areas. Tables A-1 and A-2 list 200 Area joint frequency data for ground level and elevated releases respectively. Releases are considered to be elevated when the release point is at least 2.5 times higher than adjacent structures. Tables A.3 and A.4 contain similar information for the 200 Areas while Table A.5 contains data for 300/400 Area ground level releases. Atmospheric stability classes indicated for the 100 and 200 Areas are:

- VS = Hanford Very Stable
- MS = Hanford Moderately Stable
- D = Pasquill Neutral
- B = Pasquill Moderately Unstable

The joint frequency data for 300/400 Area releases, collected by the Washington Public Power Supply System at their WNP-2 meteorology tower, uses the following Pasquill stability classifications:

- A = Extremely Unstable
- B = Moderately Unstable
- C = Slightly Unstable
- D = Neutral
- E = Slightly Stable
- F = Moderately Stable

TABLE A.1 Joint Frequency Data for Ground-Level Releases, 100-N Area

Stability Class		Wind Speed (m/s)	Percent of Time Wind is of Specified Direction, Speed, and Stability															
		Wind Direction: Sector:	NNE SSW	NE SW	ENE WSW	E W	ESE WNW	SE NW	SSE NNW	S N	SSW NNE	SW NE	WSW ENE	W E	WNW ESE	NW SE	NNW SSE	N S
Hanford	VS	0.78	.45	.38	.36	.44	.37	.34	.31	.36	.36	.44	.54	.58	.55	.52	.52	.48
	MS	0.78	.43	.41	.39	.54	.36	.35	.32	.31	.33	.62	.81	.77	.60	.65	.65	.51
	D	0.78	.20	.23	.24	.34	.27	.19	.15	.11	.14	.24	.34	.43	.34	.37	.35	.26
	B	0.78	.14	.12	.15	.22	.16	.07	.08	.06	.06	.09	.23	.33	.38	.45	.44	.22
	VS	2.5	.37	.39	.56	.84	.70	.54	.35	.22	.29	1.02	.95	.51	.30	.33	.34	.35
	MS	2.5	.65	.61	.80	.90	.80	.51	.42	.41	.53	2.04	1.91	1.44	1.03	.69	.61	.39
	D	2.5	.28	.22	.22	.26	.32	.22	.13	.07	.11	.43	.58	.68	.53	.35	.32	.25
	B	2.5	.43	.27	.39	.38	.36	.22	.16	.07	.09	.36	.23	.21	.23	.21	.33	.35
	VS	4.5	.01	.02	.11	.04	.16	.18	.05	.04	.00	.24	.20	.20	.03	.02	.01	.00
	MS	4.5	.18	.12	.12	.08	.23	.24	.20	.31	.39	1.21	1.81	2.08	.88	.33	.13	.06
	D	4.5	.09	.07	.03	.03	.11	.07	.06	.06	.12	.20	.32	.40	.25	.15	.13	.08
	B	4.5	.11	.05	.06	.04	.10	.08	.06	.08	.08	.13	.11	.20	.17	.11	.09	.06
	VS	6.9	.00	.00	.00	.00	.01	.02	.00	.00	.00	.00	.04	.07	.02	.00	.00	.00
	MS	6.9	.10	.00	.00	.00	.04	.10	.08	.17	.28	.31	.54	1.57	.80	.20	.06	.04
	D	6.9	.06	.02	.00	.00	.02	.07	.02	.04	.06	.14	.16	.42	.38	.11	.05	.03
	B	6.9	.04	.00	.00	.00	.04	.03	.01	.05	.04	.13	.10	.16	.15	.07	.12	.05
	VS	9.5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.01	.01	.00	.00	.00	.00
	MS	9.5	.13	.01	.00	.00	.00	.01	.02	.05	.19	.42	.26	1.07	1.04	.15	.10	.02
	D	9.5	.14	.06	.00	.00	.00	.01	.02	.04	.08	.21	.15	.74	.89	.21	.11	.04
	B	9.5	.10	.01	.00	.00	.00	.01	.00	.01	.05	.14	.06	.25	.44	.18	.06	.03
	VS	12.5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
	MS	12.5	.00	.01	.00	.00	.00	.00	.00	.00	.00	.06	.03	.10	.20	.01	.01	.00
	D	12.5	.01	.00	.00	.00	.00	.00	.01	.00	.00	.05	.00	.31	.20	.02	.01	.01
	B	12.5	.04	.00	.00	.00	.00	.00	.00	.00	.00	.01	.01	.17	.17	.03	.01	.01

TABLE A.2 Joint Frequency Data for Elevated Releases, 100-N Area

Stability Class		Wind Speed (m/s)	Percent of Time Wind is of Specified Direction, Speed, and Stability															
		Wind Direction: Sector:	NNE SSW	NE SW	ENE WSW	E W	ESE WNW	SE NW	SSE NNW	S N	SSW NNE	SW NE	WSW ENE	W E	WNW ESE	NW SE	NNW SSE	N S
	VS	0.78	.38	.46	.47	.53	.42	.41	.27	.33	.31	.28	.30	.34	.35	.36	.24	.30
	MS	0.78	.33	.45	.47	.54	.52	.45	.33	.33	.30	.40	.34	.40	.41	.37	.40	.37
	D	0.78	.21	.23	.31	.33	.31	.28	.20	.15	.14	.19	.26	.34	.35	.30	.22	.20
	B	0.78	.46	.29	.19	.30	.20	.18	.11	.11	.12	.27	.40	.46	.50	.50	.56	.54
	VS	2.5	.31	.43	.58	.62	.55	.42	.39	.36	.31	.39	.52	.94	.97	.63	.32	.22
	MS	2.5	.48	.49	.68	.90	.67	.61	.37	.34	.30	.55	1.09	1.65	1.56	.82	.42	.29
	D	2.5	.22	.17	.23	.26	.33	.28	.16	.10	.10	.22	.46	.60	.53	.37	.29	.16
	B	2.5	1.57	.71	.56	.77	.93	.82	.43	.32	.44	1.11	1.01	.59	.42	.42	.62	.91
	VS	4.5	.07	.06	.09	.08	.13	.19	.12	.06	.07	.07	.13	.34	.33	.10	.04	.05
	MS	4.5	.20	.10	.12	.16	.26	.22	.14	.17	.27	.50	1.21	2.16	1.54	.55	.17	.10
	D	4.5	.11	.07	.03	.02	.13	.07	.03	.03	.06	.10	.19	.50	.29	.13	.14	.09
	B	4.5	.57	.33	.18	.18	.29	.36	.29	.22	.27	.92	.52	.54	.49	.26	.15	.17
	VS	6.9	.01	.00	.01	.00	.02	.05	.03	.01	.01	.01	.05	.15	.14	.00	.01	.01
	MS	6.9	.15	.02	.00	.00	.06	.12	.09	.14	.18	.30	.54	1.83	1.31	.28	.08	.04
	D	6.9	.11	.01	.00	.00	.03	.06	.04	.01	.05	.11	.18	.34	.38	.14	.07	.02
	B	6.9	.21	.07	.02	.01	.08	.16	.03	.04	.15	.39	.25	.36	.42	.17	.09	.07
	VS	9.5	.00	.00	.00	.00	.00	.01	.02	.01	.00	.00	.00	.07	.07	.00	.00	.00
	MS	9.5	.19	.07	.00	.00	.01	.11	.09	.13	.20	.50	.36	1.66	2.18	.36	.06	.05
	D	9.5	.29	.07	.01	.00	.00	.06	.04	.02	.07	.17	.19	.55	1.15	.37	.07	.06
	B	9.5	.30	.08	.00	.00	.00	.04	.01	.02	.09	.40	.18	.42	.90	.33	.09	.04
	VS	12.5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.01	.00	.00	.00	.00	.00
	MS	12.5	.06	.03	.00	.00	.00	.00	.01	.02	.10	.33	.19	.20	.45	.12	.01	.06
	D	12.5	.08	.07	.00	.00	.00	.00	.01	.00	.04	.11	.06	.32	.48	.14	.01	.02
	B	12.5	.11	.03	.00	.00	.00	.00	.00	.00	.01	.07	.01	.12	.40	.05	.01	.01

TABLE A.3 Joint Frequency Data for Ground-Level Releases, 200 Area

Stability Class	Wind Speed (m/s)	Percent of Time Wind is of Specified Direction, Speed, and Stability																
		Wind Direction: Sector:	NNE SSW	NE SW	ENE WSW	E W	ESE WNW	SE NW	SSE NNW	S N	SSW NNE	SW NE	WSW ENE	W E	WNW ESE	NW SE	NNW SSE	N S
Hanford	VS	0.78	.07	.05	.06	.06	.07	.11	.07	.11	.06	.08	.07	.10	.09	.14	.10	.08
	MS	0.78	.33	.27	.32	.30	.36	.72	.45	.54	.44	.59	.54	.67	.68	.77	.63	.79
	D	0.78	.55	.54	.41	.42	.36	.48	.27	.25	.20	.27	.24	.25	.33	.41	.50	.54
	B	0.78	.79	.74	.33	.28	.44	.39	.17	.20	.15	.15	.21	.18	.15	.30	.39	.55
	VS	2.5	.04	.03	.01	.02	.02	.14	.15	.10	.17	.18	.26	.47	.44	.39	.15	.04
	MS	2.5	.24	.26	.20	.26	.44	.68	.62	.63	.56	.90	1.70	2.48	2.45	2.29	.93	.36
	D	2.5	.28	.21	.16	.20	.34	.28	.17	.20	.21	.25	.30	.45	.81	.96	.63	.39
	B	2.5	1.12	.78	.53	.54	.60	.66	.34	.35	.50	.52	.48	.43	.65	1.25	1.33	1.16
	VS	4.5	.00	.00	.00	.00	.00	.02	.03	.01	.02	.05	.39	.21	.78	.43	.01	.00
	MS	4.5	.07	.02	.03	.06	.11	.21	.39	.25	.28	.62	1.74	2.48	4.06	2.50	.46	.11
	D	4.5	.16	.05	.03	.04	.08	.10	.11	.09	.27	.32	.53	.65	1.23	1.02	.32	.14
	B	4.5	.46	.18	.08	.09	.06	.08	.08	.08	.27	.50	.76	.30	.75	1.33	.42	.34
	VS	6.9	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.00	.01	.00	.00	.00
	MS	6.9	.01	.01	.00	.00	.00	.03	.04	.11	.17	.43	.65	.34	1.42	.93	.04	.01
	D	6.9	.04	.05	.01	.00	.01	.01	.04	.08	.30	.60	.52	.38	1.33	.86	.09	.06
	B	6.9	.16	.06	.00	.00	.00	.00	.03	.02	.15	.48	.67	.25	.64	.80	.07	.06
	VS	9.5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
	MS	9.5	.00	.02	.00	.00	.00	.01	.03	.04	.11	.19	.09	.02	.25	.14	.00	.01
	D	9.5	.01	.02	.00	.00	.00	.00	.00	.05	.17	.35	.17	.05	.62	.65	.02	.01
	B	9.5	.01	.00	.00	.00	.00	.00	.00	.00	.06	.32	.29	.05	.32	.57	.01	.03
	VS	12.5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
	MS	12.5	.00	.00	.00	.00	.00	.00	.01	.00	.06	.09	.02	.00	.02	.00	.00	.00
	D	12.5	.00	.00	.00	.00	.00	.00	.00	.00	.01	.13	.06	.01	.08	.11	.00	.00
	B	12.5	.00	.00	.00	.00	.00	.00	.00	.00	.02	.17	.08	.01	.11	.21	.01	.00

TABLE A.4 Joint Frequency Data for Elevated Releases, 200 Area

Stability Class		Wind Speed (m/s)	Percent of Time Wind is of Specified Direction, Speed, and Stability															
		Wind Direction: Sector:	NNE SSW	NE SW	ENE WSW	E W	ESE WNW	SE NW	SSE NNW	S N	SSW NNE	SW NE	WSW ENE	W E	WNW ESE	NW SE	NNW SSE	N S
Hanford	VS	0.78	.24	.24	.17	.23	.30	.44	.26	.26	.23	.26	.25	.46	.39	.50	.43	.40
	MS	0.78	.20	.21	.19	.25	.39	.50	.24	.21	.14	.14	.15	.25	.26	.37	.33	.34
	D	0.78	.34	.39	.31	.38	.41	.50	.25	.17	.15	.13	.11	.21	.21	.38	.47	.47
	B	0.78	.54	.71	.40	.44	.34	.30	.13	.19	.11	.18	.11	.16	.16	.30	.41	.60
	VS	2.5	.21	.18	.14	.17	.20	.33	.28	.28	.24	.35	.50	.96	1.08	1.00	.69	.39
	MS	2.5	.17	.15	.13	.15	.22	.36	.21	.17	.15	.21	.24	.42	.50	.68	.47	.31
	D	2.5	.12	.13	.10	.12	.19	.26	.14	.10	.07	.10	.11	.16	.27	.55	.33	.18
	B	2.5	.97	.93	.57	.60	.55	.64	.38	.46	.46	.52	.38	.39	.49	1.16	1.14	1.21
	VS	4.5	.13	.11	.08	.07	.07	.13	.21	.11	.12	.24	.59	1.23	2.00	1.74	.60	.20
	MS	4.5	.11	.08	.03	.06	.10	.21	.19	.13	.20	.34	.50	.96	1.47	1.53	.38	.14
	D	4.5	.06	.04	.03	.03	.04	.09	.07	.04	.06	.09	.14	.14	.42	.78	.15	.06
	B	4.5	.48	.33	.12	.09	.09	.15	.11	.14	.34	.59	.56	.33	.59	1.42	.52	.45
	VS	6.9	.05	.03	.02	.02	.00	.04	.10	.03	.03	.09	.25	.43	1.25	1.53	.17	.05
	MS	6.9	.10	.05	.02	.02	.02	.07	.13	.15	.25	.54	.87	1.24	3.04	2.23	.18	.10
	D	6.9	.05	.01	.01	.01	.00	.03	.04	.05	.07	.14	.24	.16	.44	.58	.06	.04
	B	6.9	.26	.13	.03	.01	.01	.03	.04	.05	.18	.54	.68	.26	.64	.98	.09	.14
	VS	9.5	.00	.00	.00	.00	.00	.00	.01	.01	.01	.02	.04	.02	.06	.18	.00	.00
	MS	9.5	.04	.03	.01	.00	.00	.02	.06	.11	.21	.53	.50	.33	1.55	1.45	.03	.02
	D	9.5	.02	.02	.00	.00	.00	.01	.01	.03	.08	.15	.17	.05	.25	.34	.01	.02
	B	9.5	.06	.05	.01	.00	.00	.00	.01	.02	.11	.34	.41	.12	.32	.63	.01	.03
	VS	12.5	.00	.00	.00	.00	.00	.00	.00	.00	.01	.01	.00	.00	.00	.00	.00	.00
	MS	12.5	.01	.01	.00	.00	.00	.01	.02	.08	.30	.47	.22	.06	.55	.76	.00	.01
	D	12.5	.01	.01	.00	.00	.00	.00	.01	.02	.08	.17	.09	.03	.21	.30	.00	.01
	B	12.5	.02	.03	.01	.00	.00	.00	.00	.01	.09	.40	.31	.08	.17	.46	.01	.00

TABLE A.5 Joint Frequency Data for Ground-Level Releases, 300 Area

Stability Class		Wind Speed (m/s)	Percent of Time Wind is of Specified Direction, Speed, and Stability															
			Wind Direction: Sector:	NNE SSW	NE SW	ENE WSW	E W	ESE WNW	SE NW	SSE NNW	S N	SSW NNE	SW NE	WSW ENE	W E	WNW ESE	NW SE	NNW SSE
Pasquill A	A	0.78	.01	.00	.00	.00	.00	.01	.00	.00	.00	.00	.00	.00	.00	.01	.01	.01
	B	0.78	.01	.00	.01	.01	.00	.01	.00	.01	.02	.01	.01	.01	.01	.01	.01	.01
	C	0.78	.05	.03	.01	.02	.03	.01	.01	.03	.01	.02	.03	.02	.03	.06	.07	.05
	D	0.78	.22	.17	.18	.19	.32	.31	.34	.23	.32	.34	.24	.23	.40	.42	.47	.35
	E	0.78	.25	.19	.15	.19	.26	.31	.28	.38	.27	.28	.32	.28	.49	.47	.42	.37
	F	0.78	.89	.80	.61	.60	.53	.43	.43	.48	.54	.49	.52	.42	.69	.83	1.06	1.02
Pasquill B	A	2.5	.09	.04	.04	.03	.02	.09	.07	.04	.05	.07	.02	.06	.05	.07	.13	.13
	B	2.5	.11	.08	.03	.03	.09	.10	.13	.08	.11	.11	.07	.15	.09	.11	.22	.19
	C	2.5	.27	.14	.11	.05	.13	.23	.42	.38	.24	.21	.16	.17	.17	.23	.32	.42
	D	2.5	.52	.24	.35	.30	.30	.67	.92	.82	.65	.36	.33	.35	.55	.96	.89	.54
	E	2.5	.18	.29	.27	.19	.19	.45	.89	.79	.59	.57	.53	.55	.93	1.26	.83	.39
	F	2.5	.75	.71	.43	.14	.23	.69	1.62	1.55	.99	.55	.45	.45	.74	1.48	1.40	.87
Pasquill C	A	4.5	.10	.06	.05	.01	.02	.04	.06	.27	.05	.03	.03	.06	.05	.10	.11	.11
	B	4.5	.08	.03	.00	.02	.05	.04	.08	.31	.10	.06	.06	.05	.02	.06	.07	.09
	C	4.5	.21	.08	.10	.06	.05	.08	.18	.58	.34	.14	.15	.16	.09	.09	.13	.28
	D	4.5	.25	.11	.12	.06	.05	.15	.39	.89	1.01	.40	.26	.28	.49	.64	.46	.37
	E	4.5	.07	.04	.05	.02	.05	.25	.85	.79	.56	.37	.40	.46	1.19	1.24	.47	.13
	F	4.5	.06	.05	.09	.01	.00	.12	.80	.96	.48	.15	.15	.27	.52	.54	.15	.07
Pasquill D	A	6.9	.03	.01	.00	.00	.00	.01	.02	.12	.10	.05	.05	.05	.05	.08	.03	.04
	B	6.9	.02	.00	.00	.00	.00	.00	.01	.07	.11	.03	.06	.05	.06	.05	.03	.06
	C	6.9	.05	.01	.00	.00	.00	.02	.01	.07	.24	.21	.14	.11	.06	.08	.07	.09
	D	6.9	.07	.02	.00	.00	.00	.05	.10	.38	.83	.58	.26	.27	.47	.54	.13	.13
	E	6.9	.02	.01	.01	.00	.00	.05	.17	.40	.73	.44	.14	.15	.75	.42	.07	.01
	F	6.9	.00	.02	.00	.00	.00	.00	.03	.14	.14	.03	.00	.01	.01	.03	.00	.00
Pasquill E	A	9.5	.00	.00	.00	.00	.00	.00	.00	.03	.00	.03	.03	.07	.05	.10	.01	.00
	B	9.5	.00	.00	.00	.00	.00	.00	.00	.01	.02	.03	.04	.03	.03	.05	.00	.00
	C	9.5	.00	.00	.00	.00	.00	.00	.00	.02	.05	.07	.07	.06	.03	.07	.02	.01
	D	9.5	.01	.01	.00	.00	.00	.01	.00	.05	.23	.29	.13	.09	.34	.31	.02	.00
	E	9.5	.04	.00	.00	.00	.00	.01	.02	.03	.32	.17	.07	.05	.17	.06	.00	.00
	F	9.5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.00	.00
Pasquill F	A	12.5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.03	.03	.02	.05	.01	.01
	B	12.5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.01	.01	.02	.03	.00	.00
	C	12.5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.03	.02	.03	.01	.05	.00	.00
	D	12.5	.07	.00	.00	.00	.00	.00	.00	.00	.11	.15	.05	.05	.06	.13	.00	.00
	E	12.5	.05	.00	.00	.00	.00	.00	.00	.00	.11	.06	.03	.01	.03	.00	.00	.00
	F	12.5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

DISTRIBUTION

No. of
Copies

No. of
Copies

OFFSITE

7 UNC Nuclear Industries, Inc.

27 DOE Technical Information Center

P. A. Carlson
T. E. Deobald
L. P. Diediker
J. J. Dorian
G. L. Smith
A. P. Vinther
UNC Files

ONSITE

13 DOE Richland Operations Office

R. E. Austin
D. R. Elle (6)
O. J. Elgert
R. E. Gerton
H. E. Ransom
J. L. Rhoades
D. M. Smith
M. W. Tiernan

6 Westinghouse Hanford Co.

E. T. Boulette
J. S. Davis
T. G. Halverson
D. E. Lucas
R. E. Peterson
A. R. Schade

14 Rockwell Hanford Operations

M. L. Bell
G. M. Christensen
E. N. Dodd, Jr.
H. J. Goldberg
A. W. Graves
C. J. Hall
D. B. Howe
G. S. Hunt
B. E. Knight
P. G. Lorenzini
T. J. McLaughlin
D. L. Uhl
R. E. Wheeler
RHO Files

38 Pacific Northwest Laboratory

P. E. Bramson
J. R. Brown
J. P. Corley
J. T. Denovan
J. J. Fuquay
W. A. Glass
G. R. Hoenes
W. E. Kennedy
H. V. Larson
W. D. McCormack (10)
M. A. McKinney
B. A. Napier
K. R. Price
J. V. Ramsdell
C. R. Richey
J. R. Soldat
D. J. Sommer
D. L. Streng
M. J. Sula
B. E. Vaughn
E. C. Watson
Technical Information (5)
P. E. Bramson--Historical File
Publishing Coordination (KC) (2)

2 Hanford Environmental Health
Foundation

R. D. Gilmore
L. J. Maas

10

11