1. ECN	647503
Proj. ECN	

2. ECN Category (mark one)	3. Originator's Name, Organization, MSIN, and Telephone No.	4. USQ Required?	5. Date
Supplemental [ ] Direct Revision [x] Change ECN [ ] Temporary [ ] Standby [ ] Supersedure [ ] Cancel/Void [ ]	P. D. Rittmann, Nuclear Safety, R3-26, 373-7794	[ ] Yes [x] No	5-26-99
	6. Project Title/No./Work Order No. Spent Nuclear Fuel Project	7. Bldg./Sys./Fac. No. W-441	8. Approval Designator E, S^N, Q
	9. Document Numbers Changed by this ECN (includes sheet no. and rev.) HNF-SD-SNF-TI-059, Rev. 1	10. Related ECN No(s). 637174	11. Related PO No. N/A

12a. Modification Work	12b. Work Package No.	12c. Modification Work Complete	12d. Restored to Original Condition (Temp. or Standby ECN only)
[ ] Yes (fill out Blk. 12b) [x] No (NA Blks. 12b, 12c, 12d)	N/A	N/A ——————————— Design Authority/Cog. Engineer Signature & Date	N/A ——————————— Design Authority/Cog. Engineer Signature & Date

13a. Description of Change   13b. Design Baseline Document? [ ] Yes [X] No

This new revision shows joint frequency tables and wind roses for the 100 and 200 Areas of the Hanford Site using the average of nine years of data (1983 to 1991). Revision includes the overall site 95% values for air transport factors. Distances have been revised in each direction to follow the method given in NRC Regulatory Guide 1.145.

14a. Justification (mark one)

Criteria Change	[x]	Design Improvement	[ ]	Environmental	[ ]	Facility Deactivation	[ ]
As-Found	[ ]	Facilitate Const	[ ]	Const. Error/Omission	[ ]	Design Error/Omission	[ ]

14b. Justification Details

See box 13a.

15. Distribution (include name, MSIN, and no. of copies)

See attached distribution coversheet.

A-7900-013-2 (05/96) GEF095

A-7900-013-1
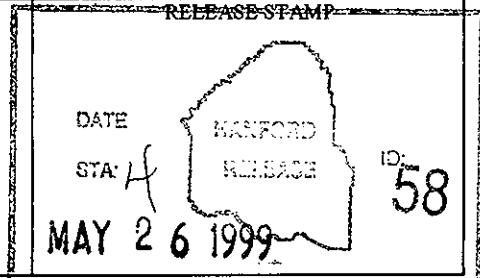
16. Design Verification Required	17. Cost Impact				18. Schedule Impact (days)		
	ENGINEERING		CONSTRUCTION				
[ ] Yes	Additional	[ ] N/A	Additional	[ ]	Improvement	[ ]	N/A
[x] No	Savings	[ ]	Savings	[ ]	Delay	[ ]	

19. Change Impact Review: Indicate the related documents (other than the engineering documents identified on Side 1) that will be affected by the change described in Block 13. Enter the affected document number in Block 20.

SDD/DD	[] N/A	Seismic/Stress Analysis	[] N/A	Tank Calibration Manual	[] N/A
Functional Design Criteria	[]	Stress/Design Report	[]	Health Physics Procedure	[]
Operating Specification	[]	Interface Control Drawing	[]	Spares Multiple Unit Listing	[]
Criticality Specification	[]	Calibration Procedure	[]	Test Procedures/Specification	[]
Conceptual Design Report	[]	Installation Procedure	[]	Component Index	[]
Equipment Spec.	[]	Maintenance Procedure	[]	ASME Coded Item	[]
Const. Spec.	[]	Engineering Procedure	[]	Human Factor Consideration	[]
Procurement Spec.	[]	Operating Instruction	[]	Computer Software	[]
Vendor Information	[]	Operating Procedure	[]	Electric Circuit Schedule	[]
OM Manual	[]	Operational Safety Requirement	[]	ICRS Procedure	[]
FSAR/SAR	[]	IEFD Drawing	[]	Process Control Manual/Plan	[]
Safety Equipment List	[]	Cell Arrangement Drawing	[]	Process Flow Chart	[]
Radiation Work Permit	[]	Essential Material Specification	[]	Purchase Requisition	[]
Environmental Impact Statement	[]	Fac. Proc. Samp. Schedule	[]	Tickler File	[]
Environmental Report	[]	Inspection Plan	[]		[]
Environmental Permit	[]	Inventory Adjustment Request	[]		[]

20. Other Affected Documents: (NOTE: Documents listed below will not be revised by this ECN.) Signatures below indicate that the signing organization has been notified of other affected documents listed below.
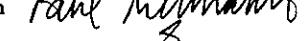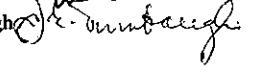
Document Number/Revision	Document Number/Revision	Document Number Revision
	N/A	

21. Approvals

	Signature	Date	Signature	Date
Design Auth.	J. J. Irwin	5-24-99		
Cog. Eng.	P. D. Rittmann	5-10-99		
Cog. Mgr.	L. J. Garvin	5/10/99		
QA	P. J. Chomentowski	5/26/99		
Safety	L. J. Garvin	5/10/99	DEPARTMENT OF ENERGY	
			Signature or a Control # that tracks Approval	N/A
Environ.	J. E. Turnbaugh	5/24/99	ADDITIONAL	

DISTRIBUTION SHEET

To	From		Page 1 of 1
Distribution	Nuclear Safety		Date 5-26-99
Project Title/Work Order			EDT No. N/A
HNF-SD-SNF-TI-059, Rev. 2			ECN No. 647503
A Discussion on the Methodology for Calculating Radiological and Toxicological Consequences for the Spent Nuclear Fuel Project at the Hanford Site			

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
J. R. Brehm	R3-26	X			
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T. B. Powers	R3-26	X			
P. D. Rittmann (2)	R3-26	X			
J. E. Turnbaugh	R3-26	X			
SNF Project Files	R3-11	X			

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A Discussion on the Methodology for Calculating Radiological and Toxicological Consequences for the Spent Nuclear Fuel Project at the Hanford Site

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U.S. Department of Energy Contract DE-AC06-96RL13200

Abstract: This report contains technical information used to determine accident consequences for the Spent Nuclear Fuel Project safety documents. It does not determine accident consequences or describe specific accident scenarios, but instead provides generic information used to calculate radiological consequences and toxicological exposures for postulated accident releases.

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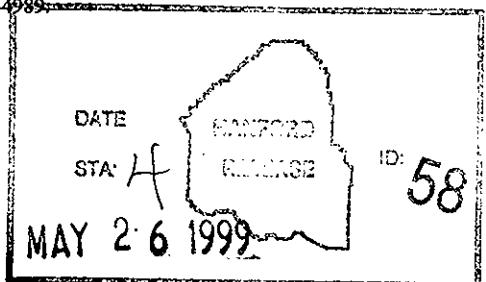
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RECORD OF REVISION		(1) Document Number HNF-SD-SNF-TI-059, Rev. 2	Page 1

(2) Title

A Discussion on the Methodology for Calculating Radiological and Toxicological Consequences for the Spent Nuclear Fuel Project at the Hanford Site

CHANGE CONTROL RECORD			
(3) Revision	(4) Description of Change - Replace, Add, and Delete Pages	Authorized for Release	
		(5) Cog. Engr. Date	(6) Cog. Mgr. Date
	(7)		
0	**EDT: 607699**		
1	**ECN: 637174** *Revision 1 adds a comparison of radiological and toxicological exposures showing that radiological consequences are always worse. Revision also adds air transport factors for stack emissions. The maximum onsite exposure time was changed from 8 hours to 12 hours, to be consistent with the current Hanford practice.*		
RS 2	**ECN: 647503** *Revision 2 shows joint frequency tables and wind roses for the 100 and 200 Areas of the Hanford Site using the average of nine years of data (1983 to 1991). Revision includes the overall site 95% values for air transport factors. Distances have been revised in each direction to follow the method given in NRC Regulatory Guide 1.145.*	P. D. Rittmann *Paul Rittmann* 5/10/99	L. J. Garvin *[signature]* 5/10/99

A DISCUSSION ON THE METHODOLOGY FOR CALCULATING RADIOLOGICAL AND TOXICOLOGICAL CONSEQUENCES FOR THE SPENT NUCLEAR FUEL PROJECT AT THE HANFORD SITE

HNF-SD-SNF-TI-059
Revision 2

Paul D. Rittmann

May 1999

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CONTENTS

CONTENTS (Continued)

APPENDIXES

LIST OF TABLES

LIST OF TERMS

CSB   Canister Storage Building
CVDF   Cold Vacuum Drying Facility
CWRG   composition-weighted risk guideline
DBA   design basis accident
DOE   U.S. Department of Energy
DOE-RL   U.S. Department of Energy, Richland Operations Office
EDE   effective dose equivalent
ERPG   emergency response planning guideline
HEPA   high-efficiency particulate air (filter)
HVAC   heating, ventilation, and air conditioning
NRC   U.S. Nuclear Regulatory Commission
PEL   permissible exposure limit
SNF   spent nuclear fuel
TWA   time-weighted average

A DISCUSSION ON THE METHODOLOGY FOR CALCULATING RADIOLOGICAL AND TOXICOLOGICAL CONSEQUENCES FOR THE SPENT NUCLEAR FUEL PROJECT AT THE HANFORD SITE

by Paul D. Rittmann, PhD CHP

1.0 PURPOSE

This report contains technical support information used to determine accident consequences for the Spent Nuclear Fuel (SNF) Project safety documents. It does not determine accident consequences or describe specific accident scenarios, but instead provides generic information used to calculate radiological doses and air concentrations of toxic chemicals for postulated accident releases from SNF facilities.

Both radionuclides and toxic chemicals may be released into the air through postulated accidents and then travel downwind to other onsite workers and offsite to members of the public. Section 2.0 provides the methodology for modeling the air transport of airborne materials. It contains air transport factors that were generated for the locations of the SNF Project facilities in the 200 East Area and in the 100 K Area. Guidance is provided on the appropriate selection and use of these air transport factors for calculating accident consequences.

Specific modeling assumptions and methods for radiological emissions are presented in Section 3.0. This section lists radionuclide inventories for high-burnup Mark IV fuel. This inventory is developed into a unit dose for calculating accident consequences (i.e., dose equivalent) from radionuclides released into the air. Calculated radiological doses are evaluated by comparison with guidance from U.S. Department of Energy, Richland Operations Office (DOE-RL). Postulated accidents that lead to doses exceeding the guidelines require mitigation.

The method for calculating air concentrations of toxic chemicals is presented in Section 4.0. This section lists chemical inventories for high-burnup Mark IV fuel and a discussion of other potential chemical emission hazards. This inventory is developed into a unit sum-of-fractions for evaluating toxicological hazards presented by specific mixtures of the chemicals found in spent fuel. Calculated air concentrations are evaluated by comparison with guidance from DOE-RL. Postulated accidents that lead to air concentrations exceeding the guidelines require mitigation.

Section 5.0 compares the radiological and the toxicological consequences of postulated accidents using a ratioing approach in which doses and air concentrations are compared with the corresponding DOE-RL guidance. It is shown that the radiological guidelines are always more limiting than the toxicological guidelines. For this reason, the accident analyses need only examine the radiological effects.

The U.S. Department of Energy (DOE)-recommended risk evaluation guidelines (Sellers 1997) for radiological consequences and for toxicological exposures are shown in Tables 1-1 and 1-2 below.

Table 1-1. Radiological Dose Limits/Guidelines for
the Spent Nuclear Fuel Project.

Frequency	Onsite, Sv (rem)	Offsite, Sv (rem)
Anticipated 10^{+0} to 10^{-2}/yr	0.01 Sv (1.0 rem)	0.005 Sv (0.5 rem)
Unlikely 10^{-2} to 10^{-4}/yr	0.1 Sv (10 rem)	0.05 Sv (5.0 rem)
Extremely unlikely 10^{-4} to 10^{-6}/yr	0.25 Sv (25 rem)	0.05 Sv (5.0 rem)

1 Sv = 100 rem.
The doses are 50 year committed effective dose equivalents.
Onsite values are "risk evaluation guidelines," while offsite values are "accident release limits" (Sellers 1997).

Table 1-2. Toxicological Air Concentration Guidelines
for the Spent Nuclear Fuel Project.

Frequency	Onsite	Offsite
Anticipated 10^{+0} to 10^{-2}/yr	≤ERPG-1	≤PEL-TWA
Unlikely 10^{-2} to 10^{-4}/yr	≤ERPG-2	≤ERPG-1
Extremely unlikely 10^{-4} to 10^{-6}/yr	≤ERPG-3	≤ERPG-2

ERPG = emergency response planning guideline.
PEL = permissible exposure limit.
TWA = time-weighted average.

The following are definitions for emergency response planning guidelines (ERPGs) and the permissible exposure limit (PEL)-time-weighted average (TWA) (AIHA 1991).

- The ERPG-1 value is the maximum airborne concentration to which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor.

- The ERPG-2 value is the maximum airborne concentration to which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.

- The ERPG-3 value is the maximum airborne concentration to which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.

- The PEL-TWA value is the employees' average airborne exposure in any 8-hour work shift of a 40-hour work week that shall not be exceeded.

PEL-TWA use for emergency response is not strictly appropriate because the PEL-TWA is designed to control relatively long-term worker exposure rather than the short term exposure to the public that would be expected for accident response. The lower of the ERPG-1 and the PEL-TWA should be used for the offsite exposure for high frequency events. Use of the limits that are at or below the ERPG-1 accident category provides an additional level of conservatism. However, it is shown in Section 5.0 that radiological effects are greater than toxicological effects, so this refinement is not needed.

No published ERPG values exist for a number of chemicals found in SNF. Therefore ERPG values developed by Craig to fill these gaps were employed (Craig 1997). These interim ERPG values are known as temporary emergency exposure limits or TEELs.

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2.0 AIR TRANSPORT FACTORS

2.1 GENERATION OF AIR TRANSPORT FACTORS

In this report, the air transport factors (χ/Q' and χ/Q) represent the dilution of a contaminant by atmospheric turbulence and diffusion as the contaminant travels downwind. Two types of air transport factors are needed to represent both dose and air concentration.

The symbol χ/Q' is the time-integrated normalized air concentration at a downwind receptor location. It can also be regarded as the ratio of the average air concentration measured at the downwind receptor to the average release rate measured at the release point. It is used to determine radionuclide doses and noncorrosive chemical concentrations at downwind locations. The primary indicator of harm to the receptor is the amount that accumulates in the body via inhalation or skin absorption rather than the actual air concentration during the passage of the plume. The methods described in NRC Regulatory Guide 1.145, *Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants* are followed for ground level emissions. However, for stack emissions affected by nearby buildings (i.e., the Cold Vacuum Drying Facility [CVDF] and Canister Storage Building [CSB] heating, ventilation, and air conditioning [HVAC] stacks), this regulatory guide provides no specific direction, so a simple model was developed to extend the U.S. Nuclear Regulatory Commission (NRC) model to represent expected phenomena.

The symbol χ/Q is the normalized peak air concentration, that is, the peak air concentration at the center of a puff divided by the quantity released. It is used to determine the consequences to a receptor for toxic chemicals that are corrosive. The actual concentration is the primary indicator of harm to the receptor rather than the amount that accumulates in the body during plume passage. NRC Regulatory Guide 1.145 does not address air concentrations, so a simple puff model was developed to represent expected effects. Some aspects of the NRC regulatory model are preserved.

For both types of air transport factors, a realistic worst case model is developed for the accident analyses. The worst observed wind conditions are not selected. Instead, the hourly wind data collected at a given location are used to construct a distribution of potential values for a given wind direction, and also for the entire boundary. As recommended by the NRC Regulatory Guide 1.145, values which are exceeded only 0.5% of the time for each wind direction, or 5.0% of the time for the entire boundary, are selected. For SNF facilities the sector maximum (0.5%) is always greater than the overall site value (5.0%) for ground-level emissions. Tables of sector and site air transport factors are provided in Appendix A for ground-level emissions and in Appendix C for elevated emissions.

The computer program GXQ (WHC-SD-GN-SWD-30002 and WHC-SD-GN-SWD-30003) was used to generate χ/Q' and χ/Q values. Input files for the GXQ program are provided in Appendix B for ground-level releases and in Appendix D for elevated releases. The joint frequency data used are 9-year averaged data from the years 1983 through 1991. The data used to represent 100 K Area winds were collected at the meteorology tower

located between the 100 N and 100 K Areas (100N). The data used to represent 200 East Area winds were obtained east of the 200 West Area (Hanford Meteorological Station). These values are listed in Appendix E for reference.

Unlike many air transport computer programs, GXQ has the ability to represent both the height of the release and the height of the receptor. Traditional ground-level release models assume the release height is zero meters, and the receptor is also breathing air from a height of zero meters. This unrealistic model is adequate at large distances, where elevations of a few meters for the release or the receptor location do not affect the result. However, at the onsite location (100 m) for stability class G, this unrealistic assumption has the effect of doubling the result. The doubling comes about by including the ground reflection factor. For class G conditions, the vertical spread of the plume is small enough that reflection is insignificant at 100 m downwind for release and receptor heights of 2 m. To be consistent with the formulas given in NRC Regulatory Guide 1.145, as well as previous Hanford Site practice, this feature was not used.

GXQ, Version 4.0 (WHC-SD-GN-SWD-30002), is a FORTRAN program for calculating atmospheric dispersion using site specific wind data. It uses the Gaussian straight line model for both instantaneous and continuous releases. Several models are available that modify parameters within the Gaussian plume model to account for phenomena such as plume depletion, building wake, plume meander, gravitational settling, and plume rise. The treatment of site wind data is also subject to user controls to allow various frequencies of exceedence to be computed. GXQ is an expert program. This means that it is intended to be used by individuals who are knowledgeable of the limits and applicability of the models implemented. The program has been reviewed and tested to verify that it implements its calculational models correctly (WHC-SD-GN-SWD-30003). In addition, since GXQ can duplicate GENII (PNL-6584) air transport results, it has been checked against the GENII software.

Air transport factors have been computed for three release durations: very short, 2 hours, and annual average. These are derived from NRC Regulatory Guide 1.145. Annual average is the largest time interval. The 2-hour case is needed to calculate air transport factors for release durations between 2 hours and 1 year using the method given in NRC Regulatory Guide 1.145. The very short duration case looks at a time scale short enough that the corrections and averaging used in the 2-hour case cannot be assumed. In the discussion below, the very short duration case is considered bounding. For ground level releases, "very short" means less than one hour. For stack releases, "very short" means less than 30 minutes. For toxicological calculations, the "puff" model would normally used for very short duration emissions. In the puff model, the meaning of "very short" depends on the transport distance. Further discussion is provided below.

2.2 DISCUSSION OF TERMS AND RESULTS

2.2.1 Receptor Locations

Each of the principal receptors locations (onsite or offsite) has a unique value for air transport factor. Several locations have been selected in order to identify the locations with the largest air transport factors. Because both the radiological dose and the toxicological concentration are directly proportional to the air transport factor, the consequences of a release are greatest at the location with the greatest air transport factor.

Onsite workers are assumed to be located no closer than 100 m from the release point. These individuals are part of the Hanford Site workforce not directly involved with SNF activities. Onsite members of the public are assumed to be located on the Columbia River or Highway 240, which represent the nearest public access locations for SNF facilities. Receptor locations in all 16 wind directions must be evaluated to identify the location with the greatest air transport factor. An additional onsite receptor location for 100 K Area releases is the 100 Area Fire Station (3,750 m ESE). Other onsite locations (e.g., the 100-N reactor) are not evaluated because the nearest onsite worker location (at 100 m) will receive substantially higher consequences from any release.

Offsite receptors are located on the Hanford Site boundary. To the north this boundary is the Wahluke slope, consistent with guidance from DOE-RL (Sellers 1996). Receptor locations in all 16 wind directions must be evaluated to identify the location with the greatest air transport factor.

Distances from the three SNF Project facilities (CSB, CVDF, and 100-KW reactor building) to public access locations (onsite and offsite) in all 16 wind transport directions are shown in Tables 2-1, 2-2, and 2-3. In each table, the distances to the nearest public access locations onsite, as well as to the Hanford Site boundary, are shown for two methods. The first method is that specified in NRC Regulatory Guide 1.145, which uses the shortest distance in a 45-degree sector centered on the direction of interest. These values are incorporated into air transport calculations. The second method is provided to show changes from Revision 1 of this document. This method finds the shortest distance in the sector of interest (i.e., 22.5 degrees centered on the direction of interest). The NRC method can lead to considerably smaller values if the distance to the boundary is changing rapidly with wind transport direction.

2.2.2 Bounding Values

Table 2-4 shows the bounding χ/Q' values for onsite and offsite receptors for continuous ground-level releases under the column heading "<1 hr". These χ/Q' values should be used for ground-level releases less than 1 hour in duration. The 1-hour cutoff comes from NRC Regulatory Guide 1.145. Releases lasting less than 1 hour are modeled as point sources.

Table 2-1. Distances (meters) in Each Wind Transport Direction
for the Canister Storage Building.

Transport direction	45° Sector method		22.5° Sector method	
	Public access	Site boundary	Public access	Site boundary
S	7,830	16,260	8,490	18,830
SSW	7,830	16,260	7,830	16,260
SW	7,830	16,260	7,830	17,910
WSW	7,830	17,910	9,280	18,800
W	9,280	18,400	10,510	18,400
WNW	10,510	18,400	13,860	18,870
NW	11,250	18,870	11,530	19,670
NNW	11,250	19,450	11,250	19,450
N	11,250	19,450	12,750	22,880
NNE	12,750	20,390	14,470	25,860
NE	12,670	17,540	12,840	20,390
ENE	12,670	17,390	12,670	17,540
E	12,670	17,390	14,230	17,390
ESE	14,230	17,390	14,500	22,390
SE	11,070	20,630	14,560	26,200
SSE	8,490	18,830	11,070	20,630

"Transport Direction" is from the Canister Storage Building toward the location of interest.

"45° Sector Method" uses the shortest distance inside a 45° sector centered on the direction of interest. This approach is found in NRC Regulatory Guide 1.145, 1982, *Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants*, U.S. Nuclear Regulatory Commission, Washington, D.C., and is used in further calculations.

"22.5° Sector Method" uses the shortest distance inside a 22.5° sector centered on the direction of interest. This approach was used in HNF-SD-SNF-TI-059 Rev. 1, and is provided for comparison.

Table 2-2. Distances (meters) in Each Wind Transport Direction
for the Cold Vacuum Drying Facility.

Transport direction	45° Sector method		22.5° Sector method	
	Public access	Site boundary	Public access	Site boundary
S	12,650	24,960	15,600	24,960
SSW	11,340	17,130	12,650	25,360
SW	1,690	15,510	11,340	17,130
WSW	700	11,990	1,690	15,510
W	650	10,090	700	11,990
WNW	580	8,740	650	10,090
NW	580	8,740	580	8,740
NNW	580	8,740	580	8,930
N	580	8,930	640	10,750
NNE	640	10,750	860	15,390
NE	860	15,390	2,540	20,080
ENE	2,540	20,080	11,470	20,510
E	11,470	20,510	12,060	20,670
ESE	12,060	20,670	15,150	21,790
SE	15,150	21,790	24,290	32,320
SSE	15,600	24,960	19,660	30,830

"Transport Direction" is from the Cold Vacuum Drying Facility toward the location of interest.

"45° Sector Method" uses the shortest distance inside a 45° sector centered on the direction of interest. This approach is found in NRC Regulatory Guide 1.145, 1982, *Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants*, U.S. Nuclear Regulatory Commission, Washington, D.C., and is used in further calculations.

"22.5° Sector Method" uses the shortest distance inside a 22.5° sector centered on the direction of interest. This approach was used in HNF-SD-SNF-TI-059 Rev. 1, and is provided for comparison.

Table 2-3. Distances (meters) in Each Wind Transport Direction
for the 100 KW Reactor Building.

Transport direction	45° Sector method		22.5° Sector method	
	Public access	Site boundary	Public access	Site boundary
S	12,850	25,150	15,800	25,150
SSW	11,400	17,310	12,850	25,540
SW	1,060	15,660	11,400	17,310
WSW	710	12,040	1,060	15,660
W	520	10,070	710	12,040
WNW	480	8,650	520	10,070
NW	480	8,650	480	8,650
NNW	480	8,650	480	8,810
N	480	8,810	530	10,910
NNE	530	10,910	730	15,190
NE	730	15,190	2,250	19,880
ENE	2,250	19,880	11,330	20,380
E	11,330	20,380	11,780	20,570
ESE	11,780	20,570	15,050	21,700
SE	15,050	21,700	24,370	32,080
SSE	15,800	25,150	19,980	30,990

"Transport Direction" is from 100-KW Reactor toward the location of interest.

"45° Sector Method" uses the shortest distance inside a 45° sector centered on the direction of interest. This approach is found in NRC Regulatory Guide 1.145, 1982, *Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants*, U.S. Nuclear Regulatory Commission, Washington, D.C., and is used in further calculations.

"22.5° Sector Method" uses the shortest distance inside a 22.5° sector centered on the direction of interest. This approach was used in HNF-SD-SNF-TI-059 Rev. 1, and is provided for comparison.

Table 2-4. Maximum Individual Locations and Air Transport Factors
for Ground-Level Releases.

Receptor type	Air transport factors, s/m³				
	<1 hr	1 hr to 2 hr	12 hr[a]	24 hr[a]	Annual
K West Reactor and adjacent buildings					
Onsite worker 100 m E	7.32 E-02	1.24 E-02	6.28 E-03	NA	5.12 E-04
Columbia River 520 m W	3.55 E-03	6.17 E-04	2.90 E-04	NA	1.79 E-05
100 Area Fire Station 3,750 m ESE	1.60 E-04	7.82 E-05	2.73 E-05	NA	5.70 E-07
Hanford Site boundary 10,070 m W	4.49 E-05	3.12 E-05	1.01 E-05	6.51 E-06	1.58 E-07
Cold Vacuum Drying Facility					
Onsite worker 100 m E	7.32 E-02	1.24 E-02	6.28 E-03	NA	5.12 E-04
Columbia River 650 m W	2.44 E-03	4.25 E-04	1.99 E-04	NA	1.21 E-05
100 Area Fire Station 3,750 m ESE	1.60 E-04	7.82 E-05	2.73 E-05	NA	5.70 E-07
Hanford Site boundary 10,090 m W	4.48 E-05	3.11 E-05	1.01 E-05	6.50 E-06	1.58 E-07
Canister Storage Building					
Onsite worker 100 m E	3.41 E-02	1.13 E-02[b]	5.54 E-03	NA	4.03 E-04[b]
Highway 240 9,280 m W	2.36 E-05	1.81 E-05	6.23 E-06	NA	1.23 E-07[c]
Hanford Site boundary 17,390 m E	1.30 E-05	1.09 E-05	3.84 E-06	2.57 E-06	8.31 E-08[d]

[a]The 12- and 24-hour values are computed by interpolation. The rest are computed by GXQ (WHC-SD-GN-SWD-30002, 1993, *GXQ Program Users' Guide*, Rev. 0, Westinghouse Hanford Company, Richland, Washington). All GXQ runs use a release height and receptor height of zero meters.
[b]For the Canister Storage Building, this receptor is located 100 m ESE.
[c]For the Canister Storage Building, this receptor is located 12,670 m E.
[d]For the Canister Storage Building, this receptor is located 17,390 m ESE.

NA = not applicable.

Releases lasting 1 hour or more are modeled using plume meander and building wake corrections. No guidance is offered for when these corrections begin to take full effect, so the maximum allowable time (1 hour) has been chosen.

Table 2-5 shows the bounding χ/Q' values for onsite and offsite receptors for continuous stack releases under the column heading "<0.5 hr". These χ/Q' values should be used for stack releases less than 0.5 hour in duration. The 0.5-hour limit comes from NRC Regulatory Guide 1.145 as a general characteristic of fumigation conditions at inland sites. The GXQ software does not model fumigation conditions directly (WHC-SD-GN-SWD-30002). However, the condition can be closely approximated using the MACCS building wake model (NUREG/CR-4691). The input values for building width and height are just the stack diameter and height. The release height should be zero meters (ground level). Finally, the mixing depth should be set equal to the height of the stack.

For the CVDF HVAC stack, the GXQ inputs for building width and height are 0.762 m (30 in.) and 31 m (102 ft). The actual stack height is considerably smaller (14.63 m [48 ft]), but because of the large exhaust flow rate (8.33 m^3/s [17,650 ft^3/min]), there is considerable plume rise. Appendix C describes the calculation of plume rise. At low wind speeds (0.89 m/s [2 mi/hr]), the average final plume height for stable conditions is about 31 m (102 ft). This value is used for the mixing depth in the GXQ input.

For the CSB HVAC stack, the GXQ inputs for building width and height are 0.71 m (28 in.) and 30 m (98 ft). The actual stack height is somewhat smaller (22.86 m [75 ft]), but because of the exhaust flow rate (2.12 m^3/s [4,500 ft^3/min]), there is significant plume rise. At low wind speed (0.89 m/s [2 mi/hr]), average plume height for stable conditions is 30 m (98 ft) (Appendix C).

For the CSB's natural circulation stack, the GXQ inputs for building width and height are 2.13 m and 48 m (7 ft and 157 ft). The actual stack height is essentially the same (47.55 m [156 ft]). As shown in Appendix C, the expected low exhaust flow rates for this stack result in minimal plume rise.

For receptors located farther than 2 km away, the fumigation model does not apply. The reduced vertical spread of the plume represented by the fumigation model does not hold indefinitely. The long transport time exceeds the duration of the fumigation condition, so other processes affect the dilution and dispersion of the emissions. To model very short release durations at great distances, the "0.5 to 2 hr" model (discussed below) was simplified by eliminating all adjustments (i.e., building wake, plume meander, and wind speed changes with elevation) and reducing the stack height to half the mixing depth used in the fumigation model. These changes serve to increase the air transport factor to represent very short duration releases while to some degree including the presence of the stack and nearby buildings.

Table 2-5. Maximum Individual Locations and Air Transport Factors for Stack Releases.

Receptor type	Air transport factors, s/m³				
	<0.5 hr	0.5 to 2 hr	12 hr[a]	24 hr[a]	Annual
Cold Vacuum Drying Facility HVAC stack (48 ft)					
Onsite worker	6.88E-03 100 m E	6.98E-04[b] 100 m	3.40E-04	NA	2.76E-05 150 m E
Columbia River	9.93E-04 650 m W	2.01E-04 580 m WNW	9.86E-05	NA	7.16E-06 650 m W
100 Area Fire Station	1.22E-04 3,750 ESE	6.61E-05 3,750 ESE	2.34E-05	NA	5.15E-07 3,750 ESE
Hanford Site boundary	3.95E-05 10,090 m W	2.82E-05 10,090 m W	9.18E-06	5.95E-06	1.48E-07 10,090 m W
Canister Storage Building HVAC stack (75 ft)					
Onsite worker	4.85E-03 100 m E	2.66E-04 150 m W	1.19E-04	NA	6.08E-06 100 m S
Highway 240	2.02E-05 9,280 m W	1.17E-05 9,280 m W	4.09E-06	NA	8.60E-08 12,670 E
Hanford Site boundary	1.25E-05 17,390 m E	7.42E-06 17,390 m E	2.65E-06	1.78E-06	5.99E-08 17,390 m ESE
Canister Storage Building natural circulation stack (156 ft)					
Onsite worker	3.04E-03 100 m E	4.84E-05 300 m W	2.01E-05	NA	7.89E-07 250 m S
Highway 240	1.08E-05[b]	6.66E-06 7,830 m S	2.27E-06	NA	4.30E-08 7,830 m S
Hanford Site boundary	7.23E-06 17,390 m E	3.75E-06 17,390 m E	1.36E-06	9.23E-07	3.31E-08 17,390 m ESE

[a]The 12- and 24-hour values are computed by interpolation. The rest are computed by GXQ (WHC-SD-GN-SWD-30002, 1993, *GXQ Program Users' Guide*, Rev. 0, Westinghouse Hanford Company, Richland, Washington). All GXQ runs use a receptor height of 2 m.

[b]These values are the overall site 95% result. For the Cold Vacuum Drying Facility onsite worker, the sector maximum was 6.73E-04 s/m³ at 100 m east. For the Canister Storage Building highway receptor, the sector maximum was 1.07E-05 s/m³ at 7,830 m south.

HVAC = heating, ventilation, and air conditioning.
NA = not applicable.

Note that the shortest distance to a boundary did not always lead to the largest air transport. In some cases the wind speed and stability class distributions lead to larger transport factors in other directions than the one with the smallest distance. Values shown in Tables 2-4 and 2-5 are worst-case numbers. The actual values in each wind transport direction (99.5%) as well as the overall site value (95%) are listed in Appendices A and C.

Tables 2-4 and 2-5 provide the air transport factors for the various facilities associated with the SNF Project (K Basins, CVDF, and CSB). Air transport factors are given for continuous releases only. The χ/Q' values are given for receptors at onsite work locations, the nearest onsite public access, the 100 Area Fire Station, and the current boundary of the Hanford Site (including the north Wahluke slope). For the 100 K Area facilities, the nearest onsite public location is the near bank of the Columbia River. For the CSB, the nearest onsite public location is Highway 240.

2.2.3 Two-Hour Values

As with the bounding χ/Q' values, the 2-hour values are computed using the 99.5% criterion for each sector, and the 95% criterion for the entire boundary. For each wind transport direction, the χ/Q' values at particular wind speeds and stability classes are computed, sorted, and plotted against the fraction of the hours in a year that they occur. The 99.5% χ/Q' values are read from this graph. For the entire boundary, the χ/Q' values at particular wind speeds and stability classes for all 16 directions are computed, sorted, and plotted against the fraction of the hours in a year that they occur. The 95% χ/Q' value is read from this graph. The wind transport direction with the largest value is reported on Tables 2-4 and 2-5.

For ground-level releases with durations from 1 to 2 hours, the point-source (i.e., bounding) χ/Q' values are adjusted downward by including the effects of plume meander. NRC Regulatory Guide 1.145 states that 1-hour average χ/Q' values are lower than the bounding model predicts because of plume meander. Thus the plume meander adjustment should be taken if the duration of the release is 1 hour or greater. In reality, some meander effects will be seen at much shorter release durations. Using the unadjusted χ/Q' values for durations up to 1 hour is certainly conservative. Plume meander is accounted for in the GXQ program (WHC-SD-GN-SWD-30002 and WHC-SD-GN-SWD-30003) using the empirical model given in the in NRC Regulatory Guide 1.145. Table 2-4 contains χ/Q' values with plume meander for ground-level releases under the column heading "1 hr to 2 hr". These χ/Q' values with plume meander should be used for ground-level releases with durations from 1 to 2 hours.

For stack releases with durations from 0.5 to 2 hours, a typical stack release calculation normally would be done. For the 47.55-m (156-ft) natural circulation stacks at the CSB, this is appropriate because the stack is more than 2.5 times the height of the nearby building. However, for the HVAC stacks at the CSB and CVDF, this is not appropriate because each HVAC stack is just a few feet taller than the roof of the main building nearby. Thus the stack emissions are often captured and diluted in the turbulent eddies near the building. The method used to represent the rooftop emissions from the CVDF and CSB HVAC stacks is the NRC plume meander and building wake model (NRC Regulatory Guide 1.145) with a release height corresponding to the height of the facility. The CVDF is modeled as being 10.67 m (35 ft) tall and 24.38 m (80 ft)

wide. The CSB is modeled as being 18.29 m (60 ft) tall and 42.37 m (139 ft) wide. Note that the minimum width of the main structure is used to represent the building.

Using the NRC model (NRC Regulatory Guide 1.145) with an elevated release height results in air transport factors somewhat smaller than those for ground-level emissions. Note that this method approximates the air concentration near stacks that are just above the level of the roof. Normally one would use a split-H model that divides the emission into two parts, one for the stack and one for the building area. Since neither GXQ nor GENII has implemented the split-H model (WHC-SD-GN-SWD-30002, PNL-6584), this approximation scheme is used in its place. Plume rise from momentum effects, stack tip downwash, and wind speed adjustment for elevation are also used in the GXQ input. Table 2-5 contains χ/Q' values for stack releases under the column heading "0.5 to 2 hr." These χ/Q' values should be used for elevated releases with durations from 0.5 to 2 hours.

2.2.4 Annual Average Values

Accident analyses normally do not consider annual release durations. However, the NRC Regulatory Guide 1.145 method for calculating air transport factors for release durations longer than 2 hours requires the use of the annual average χ/Q'. Therefore, annual average χ/Q' values are provided for chronic (i.e., routine or long-term) releases.

Annual average χ/Q' values are calculated for each sector, and the sector with the highest annual average χ/Q' value is reported. This is a "sector-averaged" value, which assumes there is no cross-wind variation in concentration within the sector. Annual average χ/Q' values are appropriate for long-term or routine releases not normally associated with accident conditions. The average is computed by weighting the χ/Q' values at individual wind speeds and stability classes by the fraction of the year that those combinations occur in each wind direction. The weighted values are summed to give the annual average. The annual average χ/Q' values included in this report provide a method for calculating χ/Q' values for release durations between 2 hours and 1 year using an interpolation method mentioned in NRC Regulatory Guide 1.145.

Table 2-4 contains annual average χ/Q' values for ground-level releases from the various SNF Project facilities under the column heading "Annual." The sources are modeled with no adjustments other than the sector-averaging normally used with annual averages. These annual average χ/Q' values should be used for ground-level release durations of 1 year.

Table 2-5 contains annual average χ/Q' values for stack releases from the various SNF Project facilities under the column heading "Annual." The HVAC stacks at the CVDF and CSB are modeled using the roof height as the release height, while the natural circulation stack at the CSB is modeled using the actual stack height. In addition to the sector-averaging normally used with annual averages, plume rise due to momentum effects, stack tip downwash, and the wind speed adjustment for elevated emissions are included in the GXQ input. These annual average χ/Q' values should be used for stack release durations of 1 year.

2.2.5 Interpolated Values

For accident scenarios with release durations from 2 to 8,760 hours (1 year), NRC Regulatory Guide 1.145 recommends a logarithmic interpolation method to calculate χ/Q'. The interpolation is between the 2-hour χ/Q' value and the annual average χ/Q' value. Doing the interpolation graphically requires plotting χ/Q' versus release duration on log-log graph paper and drawing a line between the two points. Analytically, the χ/Q' for release durations between 2 and 8,760 hours is computed using the formula below. The release duration is represented by the symbol "T_{rel}."

$$\frac{\log(\chi/Q')_{Trel} - \log(\chi/Q')_{2hr}}{\log(\chi/Q')_{chronic} - \log(\chi/Q')_{2hr}} = \frac{\log(T_{rel}) - \log(2\,hr)}{\log(8,760\,hr) - \log(2\,hr)}$$

which can be written more directly as

$$(\chi/Q')_{Trel} = (\chi/Q')_{2hr} \left(\frac{T_{rel}}{2\,hr}\right)^{slope}$$

$$slope = \frac{\ln\left(\dfrac{(\chi/Q')_{chronic}}{(\chi/Q')_{2hr}}\right)}{\ln(8,760\,hr / 2\,hr)} .$$

This method is illustrated by the following example. Assume an accident at the CVDF is postulated to last 12 hours and produce a ground-level release of some quantity of spent fuel. To calculate the χ/Q' (12 hours), one first finds the 1-hour to 2-hour and annual average χ/Q' values from Table 2-4. For the onsite worker at the K Basins or CVDF during a ground-level release, the 1-hour to 2-hour χ/Q' is 1.24×10^{-2} s/m^3, and the annual average χ/Q' is 5.12×10^{-4} s/m^3. From the equations above, one finds the result shown below.

$$slope = \frac{\ln\left(\dfrac{5.12 \times 10^{-4}\ s/m^3}{1.24 \times 10^{-2}\ s/m^3}\right)}{\ln(8,760\,hr / 2\,hr)} = -0.38011 .$$

$$(\chi/Q')_{Trel} = (1.24 \times 10^{-2}\ s/m^3)\left(\frac{12\,hr}{2\,hr}\right)^{-0.38011} = 6.28 \times 10^{-3}\ s/m^3 .$$

Interpolated χ/Q' values are given in Tables 2-4 and 2-5 for release durations of 12 hours and 24 hours. Note that the onsite receptors can be exposed for at most 12 hours. This is the longest time a worker is likely to spend in a work location at the Hanford Site. Thus the 24-hour values for onsite receptors are not needed and are not shown on the tables.

2.2.6 Puff Release Values for Toxicological Releases

Air concentrations must be computed to evaluate toxicological releases. Long duration emissions are computed using the mass released divided by the release duration and multiplied by the plume air transport factor, χ/Q'. Short duration emissions are computed using the mass released multiplied by the puff air transport factor, χ/Q. Plume air transport factors were discussed in previous sections. Puff air transport factors are discussed in this section.

The idealized puff model represents a hemispherical cloud of contamination that is increasing in size as it travels downwind. The air concentration in the center of the puff decreases according to the cube of the distance traveled. The idealized finite plume model represents an oblong shape whose initial length depends on the release duration and wind speed. The finite plume becomes wider and longer as it travels downwind. The air concentration in the center of the finite plume decreases according to the square of the distance traveled. The reason for the difference can be seen by imagining the finite plume as a series of puffs. Adjacent puffs grow as the cube of the distance, but overlap the puffs next to them. In effect, the finite plume is spreading in only two dimensions.

At some point downwind, the finite plume is large enough that it looks and acts like a puff. The concentration in the center begins to fall according to the cube of the distance. The transition from plume to puff depends on the release duration and the stability class. Unstable conditions make the plume spread more quickly with distance, so the transition occurs earlier. When using NRC Regulatory Guide 1.145 methods, there is no defined stability class. Therefore, the next best approach to estimate the transition time is to simply divide the plume air transport factor by the puff air transport factor.

Using the GXQ software, ground-level, point-source χ/Q values have been computed for each wind speed and stability class and the results sorted and plotted against the fraction of hours in a year that the combination occurs. To be consistent with NRC Regulatory Guide 1.145, the χ/Q values that are exceeded only 0.5% of the hours in a year (about 44 hours for all sectors) are shown on Table 2-6 for the worst-case onsite and offsite receptors. Note that puff release values are only given for ground-level emissions. Very short duration (puff) releases from stacks are assumed to be unimportant for SNF Project facilities at the present time. In addition, very short duration releases are hardly affected by building turbulence and elevated release heights. The puff simply follows the building eddies or atmospheric circulation under unstable (i.e., looping) conditions. Buildings and stacks only lower the air concentration when averaged over a period of time. Thus the ground-level puff values can be used to represent stack emissions.

Table 2-6. Air Transport Factors for Puffs and
Puff-to-Plume Transition Times.

Receptor type	Air transport factor (1/m³)	Transition time (seconds)
K West Reactor and adjacent buildings		
Onsite worker 100 m E	9.85 E-03	7.4
Columbia River 520 m W	1.23 E-04	29
100 Area Fire Station 3,750 m ESE	8.88 E-07	180
Hanford Site boundary 10,070 m W	1.07 E-07	420
Cold Vacuum Drying Facility		
Onsite worker 100 m E	9.85 E-03	7.4
Columbia River 650 m W	6.90 E-05	35
100 Area Fire Station 3,750 m ESE	8.88 E-07	180
Hanford Site boundary 10,090 m W	1.07 E-07	420
Canister Storage Building		
Onsite worker 100 m ESE	9.85 E-03	3.5
Highway 240 11,070 m SE	8.04 E-08	260
Hanford Site boundary 17,390 m E	3.58 E-08	360

Note that the larger of the release duration or the exposure averaging time should be compared with the above transition times. Releases lasting less than the transition time should be treated as puffs, longer durations as plumes.

Time limits on release durations are given in Table 2-6. The time values are computed by dividing the puff χ/Q into the bounding (point source) plume χ/Q' from Table 2-4. Note that the greater the receptor distance, the longer the release can last and still be treated as a puff at the receptor location. These maximum release durations are called transition times. For a given accident scenario, the estimated release duration must be compared with the transition time to decide whether to use a puff or plume air transport factor. Release durations less than the transition time should be modeled as puffs. Release durations greater than the transition time should be modeled as plumes. It is overly conservative to use the puff model for longer times or the continuous release model for shorter times.

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3.0 RADIOLOGICAL CONSEQUENCE METHODOLOGY

3.1 SOURCE COMPOSITION AND UNIT DOSE

The radionuclide composition of SNF for safety analysis modeling was obtained from information contained in HNF-SD-SNF-TI-015, *Spent Nuclear Fuel Project Technical Databook*. The safety-basis values were selected based on potential inhalation dose from the mixture. The worst-case radioisotope mixture is Mark IV fuel irradiated to 16.72% ^{240}Pu content and discharged on February 20, 1979. These radioisotopes are then decayed to May 31, 1998. The long decay half-lives of the main contributors (plutonium and americium) means the decay time has little effect on the resulting doses. Table 3-1 shows this radionuclide composition in both Ci/MTU and Bq/g U.

Assuming that this mixture becomes airborne as respirable-sized particles, a unit dose factor that gives the dose per gram inhaled can be computed. It is assumed that the relative amounts of each radionuclide do not change. The usefulness of this dose factor is that one number replaces many numbers (i.e., the individual dose factors for each nuclide). The drawback to this number is that it only applies to one specific nuclide composition.

The unit dose factor is the sum of the products of the activity per gram of uranium and the effective dose equivalent (EDE) per unit activity inhaled as shown in the equation below. These dose factors are compiled in various references and can be computed by the GENII software (PNL-6584). For this report, values for "Inhalation dose factor" were taken from Federal Guidance Report Number 11, *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation*, and are listed on Table 3-1. The computed unit dose factors are listed in the column labeled "Unit dose." To indicate the relative importance of the various radionuclides to the total dose, the last column shows the fraction contributed by each nuclide to the total dose per gram inhaled.

$$UD = \sum\nolimits_{K} (UQ_K)(DF_K)$$

where

$\quad$ UD $\quad$ = $\quad$ 50-year committed EDE from inhalation of a unit mass of SNF as respirable particles, Sv/g

$\quad$ UQ_K $\quad$ = $\quad$ activity of the Kth nuclide per unit mass of SNF, Bq/g

$\quad$ DF_K $\quad$ = $\quad$ 50-year committed EDE per unit activity inhaled of the Kth nuclide, Sv/Bq.

Table 3-1. Radionuclide Composition of Fuel and the Unit Dose Factor. (3 sheets)

Nuclide	Activity[a] (Ci/MTU)	Activity (Bq/g U)	Inhalation dose factor[b]		Unit dose[c] (Sv/g U)	Percent of total
			(Sv/Bq)	Class		
Fission and activation products						
H-3	2.61 E+01	9.66 E+05	2.60 E-11	Vapor	2.51 E-05	0.00%
C-14	5.53 E-01	2.05 E+04	5.64 E-10	Organic	1.15 E-05	0.00%
Fe-55	5.41 E-01	2.00 E+04	7.26 E-10	D	1.45 E-05	0.00%
Co-60	2.09 E+00	7.73 E+04	5.91 E-08	Y	4.57 E-03	0.00%
Ni-59	3.18 E-02	1.18 E+03	7.31 E-10	Vapor	8.60 E-07	0.00%
Ni-63	3.47 E+00	1.28 E+05	1.70 E-09	Vapor	2.18 E-04	0.00%
Se-79	6.54 E-02	2.42 E+03	2.66 E-09	W	6.44 E-06	0.00%
Kr-85	3.70 E+02	1.37 E+07	3.57 E-13	Gas[d]	4.89 E-06	0.00%
Sr-90	6.93 E+03	2.56 E+08	6.47 E-08	D	1.66 E+01	0.38%
Y-90	6.93 E+03	2.56 E+08	2.28 E-09	Y	5.85 E-01	0.01%
Zr-93	2.95 E-01	1.09 E+04	8.67 E-08	D	9.46 E-04	0.00%
Nb-93m	1.93 E-01	7.14 E+03	7.90 E-09	Y	5.64 E-05	0.00%
Tc-99	2.19 E+00	8.10 E+04	2.25 E-09	W	1.82 E-04	0.00%
Ru-106	2.56 E-02	9.47 E+02	1.29 E-07	Y	1.22 E-04	0.00%
Rh-106	2.56 E-02	9.47 E+02	DP[e]	NA	NA	NA
Pd-107	1.56 E-02	5.77 E+02	3.45 E-09	Y	1.99 E-06	0.00%
Ag-110	7.17 E-10	2.65 E-05	DP[e]	NA	NA	NA
Ag-110m	5.39 E-08	1.99 E-03	2.17 E-08	Y	4.33 E-11	0.00%
Cd-113m	2.78 E+00	1.03 E+05	4.13 E-07	D	4.25 E-02	0.00%
In-113m	1.36 E-19	5.03 E-15	1.11 E-11	D	5.59 E-26	0.00%
Sn-113	1.36 E-19	5.03 E-15	2.88 E-09	W	1.45 E-23	0.00%
Sn-119m	6.14 E-08	2.27 E-03	1.69 E-09	W	3.84 E-12	0.00%
Sn-121m	6.27 E-02	2.32 E+03	3.22 E-09	W	7.46 E-06	0.00%
Sn-123	1.72 E-16	6.36 E-12	8.79 E-09	W	5.59 E-20	0.00%
Sn-126	1.29 E-01	4.77 E+03	2.69 E-08	W	1.28 E-04	0.00%
Sb-125	0.00 E+00	0.00 E+00	3.30 E-09	W	0.00 E+00	0.00%

Table 3-1. Radionuclide Composition of Fuel and the Unit Dose Factor. (3 sheets)

Nuclide	Activity[a] (Ci/MTU)	Activity (Bq/g U)	Inhalation dose factor[b]		Unit dose[c] (Sv/g U)	Percent of total
			(Sv/Bq)	Class		
Sb-126	1.81 E-02	6.70 E+02	3.17 E-09	W	2.12 E-06	0.00%
Sb-126m	1.29 E-01	4.77 E+03	9.17 E-12	D	4.38 E-08	0.00%
Te-123m	1.50 E-21	5.55 E-17	2.86 E-09	D	1.59 E-25	0.00%
Te-125m	0.00 E+00	0.00 E+00	1.97 E-09	W	0.00 E+00	0.00%
Te-127	2.12 E-19	7.84 E-15	8.60 E-11	W	6.75 E-25	0.00%
Te-127m	2.16 E-19	7.99 E-15	5.81 E-09	W	4.64 E-23	0.00%
I-129	5.16 E-03	1.91 E+02	4.69 E-08	D	8.95 E-06	0.00%
Cs-134	6.47 E+00	2.39 E+05	1.25 E-08	D	2.99 E-03	0.00%
Cs-135	6.04 E-02	2.23 E+03	1.23 E-09	D	2.75 E-06	0.00%
Cs-137	9.66 E+03	3.57 E+08	8.63 E-09	D	3.08 E+00	0.07%
Ba-137m	9.14 E+03	3.38 E+08	DP[e]	NA	NA	NA
Ce-144	7.91 E-04	2.93 E+01	1.01 E-07	Y	2.96 E-06	0.00%
Pr-144	7.82 E-04	2.89 E+01	1.17 E-11	Y	3.39 E-10	0.00%
Pr-144m	9.48 E-06	3.51 E-01	DP[e]	NA	NA	NA
Pm-147	1.09 E+02	4.03 E+06	1.06 E-08	Y	4.28 E-02	0.00%
Sm-151	1.02 E+02	3.77 E+06	8.10 E-09	W	3.06 E-02	0.00%
Eu-152	8.45 E-01	3.13 E+04	5.97 E-08	W	1.87 E-03	0.00%
Eu-154	1.13 E+02	4.18 E+06	7.73 E-08	W	3.23 E-01	0.01%
Eu-155	1.06 E+01	3.92 E+05	1.12 E-08	W	4.39 E-03	0.00%
Gd-153	5.19 E-19	1.92 E-14	6.43 E-09	D	1.23 E-22	0.00%
Subtotal:	3.34 E+04	1.24 E+09	1.20 E-06		2.07 E+01	0.47%
Actinides						
U-234	3.84 E-01	1.42 E+04	3.58 E-05	Y	5.09 E-01	0.01%
U-235	1.27 E-02	4.70 E+02	3.32 E-05	Y	1.56 E-02	0.00%
U-236	7.16 E-02	2.65 E+03	3.39 E-05	Y	8.98 E-02	0.00%
U-238	3.31 E-01	1.22 E+04	3.20 E-05	Y	3.92 E-01	0.01%
Np-237	4.66 E-02	1.72 E+03	1.46 E-04	W	2.52 E-01	0.01%

Table 3-1. Radionuclide Composition of Fuel and the Unit Dose Factor. (3 sheets)

Nuclide	Activity[a] (Ci/MTU)	Activity (Bq/g U)	Inhalation dose factor[b]		Unit dose[c] (Sv/g U)	Percent of total
			(Sv/Bq)	Class		
Pu-238	1.33 E+02	4.92 E+06	1.06 E-04	W	5.22 E+02	11.91%
Pu-239	1.73 E+02	6.40 E+06	1.16 E-04	W	7.43 E+02	16.96%
Pu-240	1.37 E+02	5.07 E+06	1.16 E-04	W	5.88 E+02	13.43%
Pu-241	6.82 E+03	2.52 E+08	2.23 E-06	W	5.63 E+02	12.85%
Pu-242	8.71 E-02	3.22 E+03	1.11 E-04	W	3.58 E-01	0.01%
Am-241	4.34 E+02	1.61 E+07	1.20 E-04	W	1.93 E+03	44.01%
Am-242	3.71 E-01	1.37 E+04	1.58 E-08	W	2.17 E-04	0.00%
Am-242m	3.72 E-01	1.38 E+04	1.15 E-04	W	1.58 E+00	0.04%
Am-243	2.78 E-01	1.03 E+04	1.19 E-04	W	1.22 E+00	0.03%
Cm-242	3.08 E-01	1.14 E+04	4.67 E-06	W	5.32 E-02	0.00%
Cm-244	4.47 E+00	1.65 E+05	6.70 E-05	W	1.11 E+01	0.25%
Subtotal:	7.70 E+03	2.85 E+08	1.16 E-03		4.36 E+03	99.53%
					Total: 4.38 E+03	Sv/g U

[a]Results are decayed to May 31, 1998. Fuel activities are from HNF-SD-SNF-TI-015, 1998, *Spent Nuclear Fuel Project Technical Databook*, Rev. 6, Fluor Daniel Hanford, Incorporated, Richland, Washington.

[b]Inhalation dose factors are bounding values from Federal Guidance Report Number 11, 1988, *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion*, U.S. Environmental Protection Agency, Washington, D.C. The internal dose factor for tritium was increased by 50% to include absorption through the skin.

[c]The unit dose is the product of the normalized activity and the inhalation dose factor. To convert Sv/g to rem/g multiply by 100.

[d]Krypton-85 is a noble gas. It does not accumulate in the body; therefore its internal dose factor is zero. The value shown is the external dose rate factor for submersion in an infinite cloud divided by the light activity breathing rate.

[e]Daughter products are included with parents and not tracked individually. Short half life progeny nuclides not shown are assumed to be in equilibrium with their parent nuclide.

D = very soluble compounds with lung residence times of days
DP = daughter product.
MTU = metric ton of uranium.
NA = not applicable.
W = moderately soluble compounds with lung residence times of weeks
Y = insoluble compounds with lung residence times of years

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For nuclides with more than one biological lung clearance class, the class that gives the largest dose factor is used unless clear justification for non-conservative values can be provided. These represent bounding values. More realistic lung clearance classes based on insoluble chemical forms have been selected to evaluate the degree of conservatism built into the unit dose. These are shown in Appendix F together with a summary table with all unit dose factors. The more realistic value for unit dose is 17% lower than the value recommended above for use in the SNF accident calculations.

The unit dose in consequence analysis for accident scenarios for the SNF Project is 4.38×10^3 Sv/g (4.38×10^5 rem/g). As can be seen from the table, the radionuclides that account for 99.5% of the unit dose are ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{241}Am, and ^{244}Cm. Fuel that has been processed to remove transuranic isotopes would have a substantially lower unit dose. Note that the unit dose value presented here assumes the full mixture of spent fuel is present in the airborne material. In other words, all nuclides have the same release fraction. Accident scenarios that preferentially release certain nuclides may require calculation of a new unit dose.

Inhalation of SNF particles also produces doses to individual organs. The NRC has established dose equivalent limits (10 CFR 72.106) for organs as well as the risk-based EDE. The NRC recently revised the dose equivalent limits for individuals at the nearest boundary from design basis accidents (DBA) to be consistent with ICRP Publication 26, *Recommendations of the International Commission on Radiological Protection*. The new EDE limit is 5 rem, and the corresponding organ dose limit is 50 rem.

For comparison with the NRC DBA limits, organ doses from inhalation of SNF were computed using the same methods as for the EDE. Since the various nuclides in SNF have different target organs, several organs were used in the calculation and the organ with the greatest dose was selected. The inhalation dose factors for five organs are shown in Table 3-2, along with the external dose rate factors for submersion in a semi-infinite cloud for a person standing on the ground. Both of these dose factors are from recent U.S. Environmental Protection Agency compilations (Federal Guidance Report No. 11, Federal Guidance Report No. 12). Table 3-3 shows the resulting unit dose factors. Organs not listed in the table were found to have smaller unit dose factors. The organ unit dose factors were computed as the product of the organ dose factor from Table 3-2 and the activity concentration in the fuel from Table 3-1. The external unit dose factors were computed as the external dose rate factor from Table 3-2 divided by the light activity breathing rate (3.33E-04 m³/s) and multiplied by the SNF activity concentration from Table 3-1.

The organ with the largest unit dose is the bone surface. Note that the organ unit dose is a factor of 18 larger than the EDE unit dose shown on Table 3-1. For anticipated events, the offsite dose guideline is 0.5 rem (Table 1-1). An accident with an offsite dose of 0.5 rem also produces an organ dose of 9 rem (to the bone surface). These doses are less than the NRC limits. Therefore, accidents with offsite doses below the DOE-RL guidance for anticipated events will necessarily be in compliance with the NRC limits.

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Table 3-2. Organ Dose Factors from Inhalation and Air Submersion Dose Factors. (3 sheets)

Nuclide	Inhalation dose factors, Sv/Bq[a]					Air submersion (Sv/s per Bq/m^3)
	Bone surface	Red marrow	Lungs	Gonads	Remainder	
Fission and activation products						
H-3	2.60 E-11	2.60 E-11	2.60 E-11	2.60 E-11	2.60 E-11	3.31 E-19
C-14	5.64 E-10	5.64 E-10	5.64 E-10	5.64 E-10	5.64 E-10	2.24 E-19
Fe-55	5.14 E-10	5.17 E-10	5.19 E-10	5.23 E-10	1.21 E-09	0.0
Co-60	1.35 E-08	1.72 E-08	3.45 E-07	4.76 E-09	3.60 E-08	1.26 E-13
Ni-59	7.25 E-10	7.31 E-10	7.14 E-10	7.43 E-10	7.33 E-10	0.0
Ni-63	1.70 E-09	1.70 E-09	1.73 E-09	1.70 E-09	1.70 E-09	0.0
Se-79	5.98 E-10	5.98 E-10	9.81 E-09	5.98 E-10	3.77 E-09	3.03 E-19
Kr-85	0.0	0.0	0.0	0.0	0.0	1.19 E-16
Sr-90	7.27 E-07	3.36 E-07	3.73 E-09	2.64 E-09	3.36 E-09	7.53 E-18
Y-90	1.51 E-11	1.52 E-11	9.31 E-09	5.17 E-13	3.87 E-09	1.90 E-16
Zr-93	2.18 E-06	1.77 E-07	8.68 E-11	2.18 E-11	8.48 E-11	0.0
Nb-93m	2.84 E-10	1.14 E-10	6.45 E-08	1.55 E-10	3.04 E-10	4.44 E-18
Tc-99	3.99 E-11	3.99 E-11	1.67 E-08	3.99 E-11	6.26 E-10	1.62 E-18
Ru-106	1.61 E-09	1.76 E-09	1.04 E-06	1.30 E-09	1.20 E-08	0.0
Rh-106	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	1.04 E-14
Pd-107	1.51 E-12	5.68 E-13	2.85 E-08	1.05 E-13	9.71 E-11	0.0
Ag-110	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	1.78 E-15
Ag-110m	5.19 E-09	6.74 E-09	1.20 E-07	2.43 E-09	1.51 E-08	1.36 E-13
Cd-113m	3.32 E-08	3.32 E-08	3.38 E-08	3.32 E-08	1.30 E-06	6.94 E-18
In-113m	2.30 E-12	3.63 E-12	4.98 E-11	2.32 E-12	1.26 E-11	1.21 E-14
Sn-113	1.32 E-09	7.71 E-10	1.84 E-08	3.16 E-10	1.38 E-09	3.82 E-16
Sn-119m	1.10 E-09	4.62 E-10	1.15 E-08	7.14 E-11	6.28 E-10	1.01 E-16
Sn-121m	4.06 E-09	1.50 E-09	2.08 E-08	1.97 E-10	1.10 E-09	6.20 E-17
Sn-123	3.75 E-09	1.36 E-09	6.11 E-08	1.81 E-10	3.70 E-09	4.03 E-16
Sn-126	3.33 E-08	1.69 E-08	1.51 E-07	4.95 E-09	1.20 E-08	2.11 E-15

Table 3-2. Organ Dose Factors from Inhalation and Air Submersion Dose Factors. (3 sheets)

Nuclide	Inhalation dose factors, Sv/Bq[a]					Air submersion (Sv/s per Bq/m^3)
	Bone surface	Red marrow	Lungs	Gonads	Remainder	
Sb-125	9.78 E-10	5.35 E-10	2.17 E-08	3.60 E-10	1.45 E-09	2.02 E-14
Sb-126	6.75 E-10	7.97 E-10	1.38 E-08	1.32 E-09	3.19 E-09	1.37 E-13
Sb-126m	1.32 E-12	1.46 E-12	5.04 E-11	1.19 E-12	7.92 E-12	7.50 E-14
Te-123m	6.09 E-08	5.79 E-09	6.05 E-10	2.77 E-10	4.75 E-10	6.51 E-15
Te-125m	1.18 E-08	1.15 E-09	1.04 E-08	7.93 E-11	6.75 E-10	4.53 E-16
Te-127	4.09 E-12	4.09 E-12	4.27 E-10	2.02 E-12	1.11 E-10	2.42 E-16
Te-127m	2.04 E-08	5.36 E-09	3.34 E-08	1.10 E-10	1.66 E-09	1.47 E-16
I-129	1.38 E-10	1.40 E-10	3.14 E-10	8.69 E-11	1.18 E-10	3.80 E-16
Cs-134	1.10 E-08	1.18 E-08	1.18 E-08	1.30 E-08	1.39 E-08	7.57 E-14
Cs-135	1.20 E-09	1.20 E-09	1.41 E-09	1.20 E-09	1.20 E-09	5.65 E-19
Cs-137	7.94 E-09	8.30 E-09	8.82 E-09	8.76 E-09	9.12 E-09	7.74 E-18
Ba-137m	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	2.88 E-14
Ce-144	4.72 E-09	2.88 E-09	7.91 E-07	2.39 E-10	1.91 E-08	8.53 E-16
Pr-144	1.47 E-14	1.38 E-14	9.40 E-11	2.41 E-15	1.40 E-12	1.95 E-15
Pr-144m	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	2.79 E-16
Pm-147	2.01 E-08	1.61 E-09	7.74 E-08	8.25 E-15	1.56 E-09	6.93 E-19
Sm-151	1.38 E-07	1.10 E-08	3.26 E-09	4.03 E-14	7.51 E-09	3.61 E-20
Eu-152	2.40 E-07	7.91 E-08	5.76 E-08	1.31 E-08	9.99 E-08	5.65 E-14
Eu-154	5.23 E-07	1.06 E-07	7.92 E-08	1.17 E-08	1.13 E-07	6.14 E-14
Eu-155	1.52 E-07	1.43 E-08	1.19 E-08	3.56 E-10	1.11 E-08	2.49 E-15
Gd-153	9.23 E-08	1.09 E-08	1.40 E-09	4.35 E-10	6.56 E-09	3.71 E-15
Actinides						
U-234	1.13 E-06	7.22 E-08	2.98 E-04	2.65 E-09	1.06 E-07	7.63 E-18
U-235	1.05 E-06	7.15 E-08	2.76 E-04	2.85 E-09	1.02 E-07	7.72 E-15
U-236	1.07 E-06	6.83 E-08	2.82 E-04	2.51 E-09	1.00 E-07	5.01 E-18
U-238	1.01 E-06	6.91 E-08	2.66 E-04	2.44 E-09	1.02 E-07	1.21 E-15

Table 3-2. Organ Dose Factors from Inhalation and Air Submersion Dose Factors. (3 sheets)

Nuclide	Inhalation dose factors, Sv/Bq[a]					Air submersion (Sv/s per Bq/m³)
	Bone surface	Red marrow	Lungs	Gonads	Remainder	
Np-237	3.27 E-03	2.62 E-04	1.61 E-05	2.96 E-05	2.34 E-05	1.04 E-14
Pu-238	1.90 E-03	1.52 E-04	1.84 E-05	2.80 E-05	7.02 E-05	4.88 E-18
Pu-239	2.11 E-03	1.69 E-04	1.73 E-05	3.18 E-05	7.56 E-05	4.24 E-18
Pu-240	2.11 E-03	1.69 E-04	1.73 E-05	3.18 E-05	7.56 E-05	4.75 E-18
Pu-241	4.20 E-05	3.36 E-06	7.42 E-09	6.82 E-07	1.31 E-06	2.19 E-19
Pu-242	2.01 E-03	1.61 E-04	1.64 E-05	3.02 E-05	7.18 E-05	4.01 E-18
Am-241	2.17 E-03	1.74 E-04	1.84 E-05	3.25 E-05	7.82 E-05	8.18 E-16
Am-242	1.65 E-07	1.32 E-08	5.20 E-08	1.94 E-09	8.54 E-09	6.15 E-16
Am-242m	2.12 E-03	1.69 E-04	4.20 E-06	3.21 E-05	7.48 E-05	1.61 E-16
Am-243	2.17 E-03	1.73 E-04	1.78 E-05	3.26 E-05	7.74 E-05	9.87 E-15
Cm-242	4.87 E-05	3.90 E-06	1.55 E-05	5.70 E-07	2.45 E-06	5.69 E-18
Cm-244	1.17 E-03	9.38 E-05	1.93 E-05	1.59 E-05	4.78 E-05	4.91 E-18

[a]Inhalation dose factors are bounding values from Federal Guidance Report Number 11, 1988, *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion,* U.S. Environmental Protection Agency, Washington, D.C. The internal dose factor for tritium was increased by 50% to include skin absorption. External dose rate factors are from Federal Guidance Report Number 12, 1993, *External Exposure to Radionuclides in Air, Water, and Soil,* U.S. Environmental Protection Agency, Washington, D.C. To convert Sv/Bq to mrem/pCi multiply by 3,700.

[b]Daughter products are included with parents and not tracked individually. Short half life progeny nuclides not shown are assumed to be in equilibrium with their parent nuclide.

Table 3-3. Unit Dose Factors for Organs and for Air Submersion. (3 sheets)

Nuclide	Organ and air submersion unit dose factors, Sv/g[a]					
	Bone surface	Red marrow	Lungs	Gonads	Remainder	Air submersion
Fission and activation products						
H-3	2.51 E-05	2.51 E-05	2.51 E-05	2.51 E-05	2.51 E-05	9.59 E-10
C-14	1.15 E-05	1.15 E-05	1.15 E-05	1.15 E-05	1.15 E-05	1.37 E-11
Fe-55	1.03 E-05	1.03 E-05	1.04 E-05	1.05 E-05	2.42 E-05	0.0
Co-60	1.04 E-03	1.33 E-03	2.67 E-02	3.68 E-04	2.78 E-03	2.92 E-05
Ni-59	8.53 E-07	8.60 E-07	8.40 E-07	8.74 E-07	8.62 E-07	0.0
Ni-63	2.18 E-04	2.18 E-04	2.22 E-04	2.18 E-04	2.18 E-04	0.0
Se-79	1.45 E-06	1.45 E-06	2.37 E-05	1.45 E-06	9.12 E-06	2.20 E-12
Kr-85	0.0	0.0	0.0	0.0	0.0	4.89 E-06
Sr-90	1.86 E+02	8.62 E+01	9.56 E-01	6.77 E-01	8.62 E-01	5.79 E-06
Y-90	3.87 E-03	3.90 E-03	2.39 E+00	1.33 E-04	9.92 E-01	1.46 E-04
Zr-93	2.38 E-02	1.93 E-03	9.47 E-07	2.38 E-07	9.26 E-07	0.0
Nb-93m	2.03 E-06	8.14 E-07	4.61 E-04	1.11 E-06	2.17 E-06	9.51 E-11
Tc-99	3.23 E-06	3.23 E-06	1.35 E-03	3.23 E-06	5.07 E-05	3.94 E-10
Ru-106	1.52 E-06	1.67 E-06	9.85 E-04	1.23 E-06	1.14 E-05	0.0
Rh-106	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	2.96 E-08
Pd-107	8.72 E-10	3.28 E-10	1.65 E-05	6.06 E-11	5.60 E-08	0.0
Ag-110	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	1.42 E-16
Ag-110m	1.04 E-11	1.34 E-11	2.39 E-10	4.85 E-12	3.01 E-11	8.14 E-13
Cd-113m	3.41 E-03	3.41 E-03	3.48 E-03	3.41 E-03	1.34 E-01	2.14 E-09
In-113m	1.16 E-26	1.83 E-26	2.51 E-25	1.17 E-26	6.34 E-26	1.83 E-25
Sn-113	6.64 E-24	3.88 E-24	9.26 E-23	1.59 E-24	6.94 E-24	5.77 E-27
Sn-119m	2.50 E-12	1.05 E-12	2.61 E-11	1.62 E-13	1.43 E-12	6.88 E-16
Sn-121m	9.42 E-06	3.47 E-06	4.83 E-05	4.56 E-07	2.55 E-06	4.32 E-10
Sn-123	2.39 E-20	8.66 E-21	3.89 E-19	1.15 E-21	2.35 E-20	7.69 E-24
Sn-126	1.59 E-04	8.07 E-05	7.21 E-04	2.36 E-05	5.73 E-05	3.02 E-08
Sb-125	0.0	0.0	0.0	0.0	0.0	0.0

Table 3-3. Unit Dose Factors for Organs and for Air Submersion. (3 sheets)

Nuclide	Organ and air submersion unit dose factors, Sv/g[a]					
	Bone surface	Red marrow	Lungs	Gonads	Remainder	Air submersion
Sb-126	4.52 E-07	5.34 E-07	9.24 E-06	8.84 E-07	2.14 E-06	2.75 E-07
Sb-126m	6.30 E-09	6.97 E-09	2.41 E-07	5.68 E-09	3.78 E-08	1.07 E-06
Te-123m	3.38 E-24	3.21 E-25	3.36 E-26	1.54 E-26	2.64 E-26	1.08 E-27
Te-125m	0.0	0.0	0.0	0.0	0.0	0.0
Te-127	3.21 E-26	3.21 E-26	3.35 E-24	1.58 E-26	8.71 E-25	5.69 E-27
Te-127m	1.63 E-22	4.28 E-23	2.67 E-22	8.79 E-25	1.33 E-23	3.52 E-27
I-129	2.63 E-08	2.67 E-08	5.99 E-08	1.66 E-08	2.25 E-08	2.18 E-10
Cs-134	2.63 E-03	2.82 E-03	2.82 E-03	3.11 E-03	3.33 E-03	5.44 E-05
Cs-135	2.68 E-06	2.68 E-06	3.15 E-06	2.68 E-06	2.68 E-06	3.79 E-12
Cs-137	2.84 E+00	2.97 E+00	3.15 E+00	3.13 E+00	3.26 E+00	8.30 E-06
Ba-137m	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	2.92 E-02
Ce-144	1.38 E-07	8.43 E-08	2.32 E-05	6.99 E-09	5.59 E-07	7.49 E-11
Pr-144	4.25 E-13	3.99 E-13	2.72 E-09	6.97 E-14	4.05 E-11	1.69 E-10
Pr-144m	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	2.94 E-13
Pm-147	8.11 E-02	6.49 E-03	3.12 E-01	3.33 E-08	6.29 E-03	8.38 E-09
Sm-151	5.21 E-01	4.15 E-02	1.23 E-02	1.52 E-07	2.83 E-02	4.09 E-10
Eu-152	7.50 E-03	2.47 E-03	1.80 E-03	4.10 E-04	3.12 E-03	5.30 E-06
Eu-154	2.19 E+00	4.43 E-01	3.31 E-01	4.89 E-02	4.72 E-01	7.70 E-04
Eu-155	5.96 E-02	5.61 E-03	4.67 E-03	1.40 E-04	4.35 E-03	2.93 E-06
Gd-153	1.77 E-21	2.09 E-22	2.69 E-23	8.35 E-24	1.26 E-22	2.14 E-25
Subtotal:	1.92 E+02	8.96 E+01	7.19 E+00	3.86 E+00	5.77 E+00	3.02 E-02
Actinides						
U-234	1.61 E-02	1.03 E-03	4.23 E+00	3.77 E-05	1.51 E-03	3.25 E-10
U-235	4.93 E-04	3.36 E-05	1.30 E-01	1.34 E-06	4.81 E-05	1.09 E-08
U-236	2.83 E-03	1.81 E-04	7.47 E-01	6.65 E-06	2.65 E-04	3.98 E-11
U-238	1.24 E-02	8.46 E-04	3.26 E+00	2.99 E-05	1.25 E-03	4.45 E-08
Np-237	5.64 E+00	4.52 E-01	2.78 E-02	5.10 E-02	4.03 E-02	5.37 E-08

Table 3-3. Unit Dose Factors for Organs and for Air Submersion. (3 sheets)

Nuclide	Organ and air submersion unit dose factors, Sv/g[a]					
	Bone surface	Red marrow	Lungs	Gonads	Remainder	Air submersion
Pu-238	9.35 E+03	7.48 E+02	9.05 E+01	1.38 E+02	3.45 E+02	7.20 E-08
Pu-239	1.35 E+04	1.08 E+03	1.11 E+02	2.04 E+02	4.84 E+02	8.14 E-08
Pu-240	1.07 E+04	8.57 E+02	8.77 E+01	1.61 E+02	3.83 E+02	7.22 E-08
Pu-241	1.06 E+04	8.48 E+02	1.87 E+00	1.72 E+02	3.31 E+02	1.66 E-07
Pu-242	6.48 E+00	5.19 E-01	5.29 E-02	9.73 E-02	2.31 E-01	3.88 E-11
Am-241	3.48 E+04	2.79 E+03	2.95 E+02	5.22 E+02	1.26 E+03	3.94 E-05
Am-242	2.26 E-03	1.81 E-04	7.14 E-04	2.66 E-05	1.17 E-04	2.53 E-08
Am-242m	2.92 E+01	2.33 E+00	5.78 E-02	4.42 E-01	1.03 E+00	6.66 E-09
Am-243	2.23 E+01	1.78 E+00	1.83 E-01	3.35 E-01	7.96 E-01	3.05 E-07
Cm-242	5.55 E-01	4.44 E-02	1.77 E-01	6.50 E-03	2.79 E-02	1.95 E-10
Cm-244	1.94 E+02	1.55 E+01	3.19 E+00	2.63 E+00	7.91 E+00	2.44 E-09
Subtotal:	7.93 E+04	6.35 E+03	5.98 E+02	1.20 E+03	2.81 E+03	4.02 E-05
SNF Total:	7.94 E+04	6.44 E+03	6.06 E+02	1.20 E+03	2.81 E+03	3.03 E-02

[a]The unit dose is the product of the normalized activity (Table 3-1) and the inhalation dose factor (Table 3-2). To convert Sv/g to rem/g multiply by 100. The values shown for air submersion are the external dose rate factor for submersion in an infinite cloud (Table 3-2) divided by the light activity breathing rate and multiplied by the normalized activity (Table 3-1).

[b]Daughter products are included with parents and not tracked individually. Short half life progeny nuclides not shown are assumed to be in equilibrium with their parent nuclide.

Separate occupational exposure limits were provided in ICRP Publication 26 for the EDE and the organs to limit both stochastic and non-stochastic effects. Stochastic effects are biological effects whose probability depends on the dose, but whose severity does not. An example of a stochastic effect is the development of a fatal cancer. The EDE is a measure of the probability of a fatal cancer developing due to exposure to ionizing radiation. Non-stochastic effects are the result of too much dose to specific organs, leading to some symptoms of tissue damage. For non-stochastic effects the severity depends on the dose, and there normally is a threshold below which there is no effect. Examples of non-stochastic effects in persons exposed to large radiation doses from World War II atomic bombs and therapeutic radiation exposures was published in ICRP Publication 41, *Non-Stochastic Effects of Ionizing Radiation*. From a health standpoint, the exposure threshold values reported in ICRP Publication 41 are high enough that radiation dose can be effectively controlled using only the EDE. The 50 rem organ limit is unnecessary.

The guidance from DOE-RL presented (Table 1-1) only limits EDE. Organ dose limits are not given. NRC compliance then requires that the postulated DBAs have site boundary EDE values less than 2.8 rem. This value is lower than the guidelines given in Table 1-1 for "unlikely" and "extremely unlikely" events. Events considered "anticipated" have DOE limits that are lower than the NRC equivalent.

3.2 RADIOLOGICAL EXPOSURE PATHWAYS

Two general exposure pathways associated with accidental releases of radioactive materials are internal and external. Internal exposure occurs when radioactive materials get inside the body. External exposure is received from radioactive materials outside the body. The total radiation dose received by a receptor downwind is equal to the sum of the dose contributions from the internal and external exposure pathways. In this section, the internal is divided into inhalation and ingestion contributions. The pathway of concern for SNF is the inhalation pathway. The external pathway is divided into contributions from air submersion and ground deposition. Neither external pathway is a significant contributor to total dose. Another route of entry is injection through cuts in the skin. This last one will not be considered, because it assumes additional accidents take place at the receptor location at the time of the postulated SNF accident. This represents a low probability due to the small time window.

3.2.1 Inhalation Pathway

The major internal exposure pathway for accidents occurring at the SNF Project facilities is the inhalation pathway. Exposure through the inhalation pathway occurs when an accident results in a release of airborne radioactive materials that are transported downwind and inhaled, or when radioactive materials that have been deposited on the ground during plume passage become resuspended and subsequently inhaled.

Inhalation Dose During Plume Passage. The calculation of inhalation dose from a mixture of radionuclides transported downwind is computed as the sum of the products of the

quantity released, the air transport factor, the inhalation rate, and the unit dose factor for the radionuclide released. This is summarized in the following equation.

$$DE_{INHALE} = \sum_K (Q_K)(\chi/Q')(BR)(DF_K)$$

where

DE_{INHALE} = 50-year committed EDE from inhalation of a mixture of nuclides, Sv

Q_K = activity of the Kth nuclide released into the air as respirable particles, Bq

χ/Q' = air transport factor, s/m³

BR = average inhalation rate during the release, m³/s

DF_K = 50-year committed EDE per unit activity inhaled of the Kth nuclide, Sv/Bq.

Inhalation dose factors (DF_K) are taken from Federal Guidance Report No. 11. For nuclides with more than one biological lung clearance class, the class that gives the largest dose factor is used unless clear justification for non-conservative values can be provided. For example, Sr-90 has both class D and class Y dose factors and the class Y is larger. However, the class Y material is only for a compound, $SrTiO_3$, that is not found in SNF. Therefore, class D is used for Sr-90.

Inhalation rates (BR) for the reference man (ICRP Publication 23) are used. The light activity breathing rate (1.2 m³/hr or 3.33 x 10⁻⁴ m³/s) normally applies during the first 16 hours of the day when the man is assumed to be awake. The resting breathing rate (0.45 m³/hr or 1.25 x 10⁻⁴ m³/s) applies during the last 8 hours of the day when the man is assumed to be asleep. The 24-hour average breathing rate is 2.64 x 10⁻⁴ m³/s. Note that the adult male breathing rate is used rather than the adult female breathing rate to maximize the intake and also the dose from SNF.

The air transport factor (χ/Q') depends on which receptor is being considered, the release height, and the duration of the release. Values are given in Tables 2-4 and 2-5.

The quantity released is based on the accident scenario. Since only the respirable portion contributes to inhalation dose, the value for Q_K is limited to the respirable portion. If this is not known, then the entire release should be assumed to be respirable. Note that if the various activities released are those found in a certain number of grams of SNF (M), then the equation can be written as

$$DE_{INHALE} = \sum_K (M)(UQ_K)(\chi/Q')(BR)(DF_K)$$

$$DE_{INHALE} = (M)(\chi/Q')(BR)(UD)$$

where

DE_{INHALE} = 50-year committed EDE from inhalation of a mixture of nuclides, Sv

M = mass of SNF released into the air as respirable particles, g

UQ_K = activity of the Kth nuclide per unit mass of SNF, Bq/g

χ/Q' = air transport factor, s/m^3 (Tables 2-4 and 2-5)

BR = average inhalation rate during the release, m^3/s

DF_K = 50-year committed EDE per unit activity inhaled of the Kth nuclide, Sv/Bq (Table 3-1)

UD = 50-year committed EDE from inhalation of a unit mass of SNF as respirable particles, 4380 Sv/g (Table 3-1)

An additional consideration for certain downwind receptors is occupancy time, the period out of the total release duration that they are actually exposed. Onsite workers and onsite members of the public can be exposed for as many as 12 hours if they are not evacuated. For release durations longer than 1 day, the typical 8-hour per day exposure schedule should be used. For example, if a continuous release lasts 24 hours then the dose to onsite individuals should be modeled using the 12-hour χ/Q' along with the activity released during the first 12 hours. Dose to the offsite individual should be modeled using the 24-hour χ/Q' along with the total activity released during the 24 hours.

The selection of 12 hours as the bounding case exposure duration for the onsite worker finds a compromise between the single shift of the majority of the Hanford workforce and a double shift occasionally worked by a few. The air transport factors for 16-hour releases are just 24% lower than the air transport factors for 8-hour releases. A constant release rate leads to onsite worker doses for 16-hour releases that are 53% higher than the 8-hour doses. Selecting 12 hours as the onsite maximum presents a realistic worst-case exposure time that does consider the effect of additional dose during extra work hours.

Inhalation Dose from Resuspension of Deposited Material. The airborne emission not only leads to an inhalation dose at the receptor location while the plume passes, but also some long-term inhalation due to resuspended activity. Since inhalation dose from resuspended particulate is accumulated over an extended period of time following the accident, it can be estimated using a resuspension model. The dose from inhalation of resuspended activity is a small addition to the dose from inhalation of the passing plume. This is demonstrated in the discussion below by constructing a ratio of inhalation doses.

To estimate dose from resuspended material, one first needs an estimate of how much can be resuspended. It will be assumed that the average air concentration of resuspended material is proportional to the concentration deposited on the ground surface. The constant of proportionality is called a resuspension factor. A bounding value is 1×10^{-5} per meter (DOE-HDBK-3010-94, Figure 4-22). Doses are computed using the formula below.

$$DE_{INH,RES} = \sum_K (S_K)(R)(BR)(T_B)(DF_K)$$

where

$DE_{INH,RES}$ = 50-year committed EDE from inhalation of resuspended activity, Sv

S_K = surface concentration of the Kth nuclide, Bq/m^2

R = resuspension factor, 1×10^{-5} per meter

BR = average inhalation rate during the exposure period, m^3/s

T_B = period during which the resuspended activity is inhaled, s

DF_K = 50-year committed EDE per unit activity inhaled of the Kth nuclide, Sv/Bq.

Note that the breathing rates in the two inhalation dose equations could be different. For a short-duration release followed by a week of resuspension, the light activity breathing rate applies to the inhalation dose from plume passage, while the daily average breathing rate applies to the inhalation dose from resuspension.

Surface contamination from the passing plume is the result of deposition on the ground surface. Ground deposition a the low rates typical of respirable particles is modeled using the formula below.

$$S_K = (Q_K)(\chi/Q')(V_K)$$

where

S_K = surface concentration of the Kth nuclide, Bq/m^2

Q_K = activity of the Kth nuclide released into the air as respirable particles, Bq

χ/Q' = air transport factor, s/m^3

V_K = ground surface deposition speed for the Kth nuclide, m/s.

For the nuclides of interest in SNF, the ground deposition speed is 0.001 m/s. Inserting the surface activity equation into the resuspended dose equation and dividing this by the plume inhalation dose equation leads to the result shown below.

$$(DE_{INH,RES})/(DE_{INHALE}) = (V)(R)(T_B)(BR_{RESUS})/(BR_{PLUME})$$

$$= (0.001 \text{ m/s})(1 \times 10^{-5} \text{ m}^{-1})(3.15 \times 10^7 \text{ s})(2.64 \times 10^{-4} \text{ m}^3/\text{s})/(3.33 \times 10^{-4} \text{ m}^3/\text{s})$$

$$= 0.25$$

If the exposure period is 1 year following the postulated accident, the ratio of resuspension dose to plume dose is 0.25, which is not negligible. Two additional considerations allow it to be discarded. The first is weathering effects on the surface contamination. The second is the assumed exposure time of the individual spending time in the contamination.

Weathering of the surface contamination refers to migration by wind and precipitation stresses into locations that are not exposed to the surface air. Weathering causes the surface activity to become unavailable for resuspension. In effect, the surface activity decreases with time, which lowers the inhalation dose from resuspended activity. The GENII software was also used to provide a more sophisticated estimate of resuspension dose. The time-dependent resuspension model in GENII (known as the Anspaugh resuspension model) includes the effects of weathering, but also starts at a higher initial resuspension factor. From GENII (see next section), the ratio of inhalation dose from resuspended activity to inhalation dose from the plume is 0.14.

The assumed exposure period of 1 year is unlikely. Any measurable contamination on the ground following an accidental release would be removed before the general workforce could have access to the area. In addition, the Hanford Site dosimetry program is set up to detect elevated external dose rates and elevated bioassay results (i.e., internal contamination of workers from radioactivity in their work environment). Offsite individuals would be warned to evacuate areas with measurable surface contamination, according to current emergency plans for the Hanford Site (DOE-0223, WSDOA 1994, WSDOH 1993, EPA 1992). Thus the dose from resuspended activity is a small addition to the total inhalation dose, and will not be considered.

3.2.2 Ingestion Pathway

The other internal exposure pathway is the ingestion pathway. Exposure through the ingestion pathway occurs when radioactive materials that have been deposited offsite are ingested. An example is activity deposited on vegetable produce that is collected and eaten the day of the accident. Another example is activity deposited on grass that is consumed by a cow, transferred to the cow's milk, and consumed the day of the accident. Intake of contaminated food is assumed to end after the first day as a result of state and federal programs in place to prevent ingestion of contaminated food and water in the event of an accident (DOE-0223, WSDOA 1994, WSDOH 1993, EPA 1992). The primary determinant of exposure from the ingestion pathway is the effectiveness of public health measures (i.e., interdiction) rather than the severity of the accident itself.

The ingestion pathway, if it occurs, is a slow-to-develop pathway and is not considered an immediate threat to an exposed population in the same sense as airborne plume exposures. The first day's ingestion dose is estimated below using the GENII software (PNL-6584). The ingestion dose turns out to be less than 1% of the dose from inhalation. Therefore, the ingestion pathway is not included in calculations of the radiological dose for comparison against the risk evaluation criteria.

The approach used to estimate bounding ingestion doses for the first day after an accident is similar to that used in tank waste calculations (WHC-SD-WM-SAR-016). The GENII software (PNL-6584) is used to estimate this dose contribution. The GENII internal dose factors differ slightly from those developed by the U.S. Environmental Protection Agency (Federal Guidance Report No. 11). This difference does not affect the conclusion that 24 hour ingestion dose is small compared to the inhalation dose from the passing plume.

The title lines from the data libraries used by the GENII code in these calculations are listed below.

- GENII Default Parameter Values (28-Mar-90 RAP)

- Radionuclide Library - Times<100 years (23-July-93 PDR)

- Pacific Northwest National Laboratory Food Transfer Factor Library (by Z, with Fr&Os 7/19/93 PDR)

- External Dose Factors for GENII in person Sv/yr per Bq/x (8-May-90 RAP)

- Worst-Case Solubilities, Yearly Dose Increments (23-Jul-93 PDR).

There are two known errors in these files. First, the dose factors for ^{110m}Ag are a factor of three too large because an incorrect branching ratio was used. Second, the food transfer factors are of uncertain origin due to inadequate documentation. Nevertheless, this code and libraries are currently preferred for Hanford Site modeling.

Specific modeling inputs for 24 hour ingestion dose calculations using GENII are listed below:

- Direct dose equivalent from the plume (i.e., inhalation and external dose from submersion) is not considered. Both doses were computed separately using dose factors from the U.S. Environmental Protection Agency listed in Tables 3-1 and 3-2. The external dose from air submersion dose is orders of magnitude smaller than the inhalation dose (Table 3-3).

- Resuspension of contamination deposited on the ground is estimated using the Anspaugh model found in GENII. Since GENII spreads the deposited activity to a depth of 15 cm, this was also used as the depth of material resuspended so that all the deposited material participates. The first day's dose is approximated as the total in 1 year divided by 365 days.

- External exposure from material deposited on the ground is for 1 day. The exposure time input to GENII is 8766 hours, and the annual dose is divided by 365 days.

- The four vegetable pathways in GENII are (1) leafy vegetables, (2) other vegetables, (3) fruit, and (4) grain. Leafy vegetables are consumed directly from the garden, with

little or no washing. Other vegetables (e.g., beans, peas, corn) and fruit are assumed to be harvested and a portion consumed the day of the accident. Since these crops are normally not ready for harvest on the same day, the resulting 24-hour dose is overestimated. In addition, since the produce is grown and consumed for only a portion of the year, the annual dose was divided by 180 days rather than 365 days to arrive at the 24-hour dose. Dose from grains is not included because the delay between harvest and consumption normally exceeds 1 day. It is assumed that people are successfully warned not to consume grain after the first day.

- The only animal pathway of concern is milk. The poultry and egg pathways rely on contamination of the grain the poultry eats. These products will not be contaminated the first day. The beef cow may graze on contaminated pasture prior to slaughter, but it will be assumed that the owners are warned and do not consume the meat. The milk cow grazes and is milked before the owners are warned not to drink the milk. Since equilibrium assumptions are made to estimate the milk concentration, the dose from contaminated milk is overestimated. Since milk is consumed daily throughout the year, the first day's dose is the total annual dose divided by 365 days.

The activity input to the GENII software is activity in 1 g of uranium with the spent fuel composition. This is the same source listed in Table 3-1. Two input files were used, one for animal products (milk) and one for vegetable produce. The GENII input files are listed in Appendix G, for reference. Table 3-4 shows the dose results by pathway. The dose factors shown on Table 3-4 are multiplied by the mass airborne and the air transport factor to arrive at the dose equivalent to a particular receptor from a given accident. This only differs from the inhalation dose formula by the omission of a breathing rate.

From Table 3-4 the direct dose from the plume is more than 99% of the total dose. Thus the other pathways can be ignored as negligible. (For information, the GENII value for the plume dose factor turns out to be 1.2 Sv/s per g U/m^3, which agrees well with the calculated value.)

3.2.3 External Pathway

The external exposure pathways are the result of exposure to gamma and X-ray radiation. Downwind receptors receive external radiation exposure by submersion, groundshine, and direct exposure to exposed SNF. Submersion refers to the external dose received by a person located in the airborne radioactive plume during plume passage. Groundshine refers to the external dose received by a person standing on ground contaminated by radioactive materials deposited during passage of the airborne radioactive plume. As shown in Table 3-4, groundshine and submersion doses are much smaller than inhalation doses for the nuclides present in SNF. Therefore, the groundshine and submersion doses are not included in calculations of the unit dose.

Table 3-4. Unit Dose Factor for 24-Hour Exposure to the
Offsite Maximum Exposed Individual.

Direct dose from plume (inhalation and submersion)	(4,380 Sv/g U)(2.64 E-4 m³/s) = 1.16 Sv/s per g U/m³
Inhalation dose from resuspended material	5.7 E-4 Sv/s per g U/m³
External dose from surface contamination	3.8 E-6 Sv/s per g U/m³
Ingestion dose from milk	5.6 E-4 Sv/s per g U/m³
Ingestion dose from vegetable products	6.9 E-3 Sv/s per g U/m³
Total dose factor	1.17 Sv/s per g U/m³

The direct dose factor was computed using U.S. Environmental Protection Agency inhalation dose factors and the daily average breathing rate. The other dose factors were computed using GENII Version 1.485 (PNL-6584). To compute the dose to the Site boundary farmer, multiply the total dose factor by the air transport factor and the mass released into the air as respirable particles.

The only other exposure pathway is direct exposure from the SNF itself. Because the nearest downwind receptor is 100 m from the scene of the accident, direct exposure to penetrating radiation emitted by the SNF is negligible due to the inverse square law reducing the dose rate. Note that 100 m of air does not present enough mass ($0.12\ g/cm^2$) to have a shielding effect. Dose rates near any exposed SNF would be very high and create a worker safety issue.

3.3 DOSE CALCULATION METHODS

The process of estimating consequences from postulated emissions due to an accident at SNF Project facilities requires calculation of inhalation dose to worst-case receptors downwind and comparison of that dose with the risk evaluation guides (Sellers 1997). Calculating the dose begins with an estimation of the quantity of SNF that is released to the environment as respirable particles. This quantity is then multiplied by the appropriate air transport factor and unit dose to arrive at the receptor dose. The formula below summarizes the method for calculating this.

$$M = (MAR)(ARF)(RF)(LPF)$$

where

M = mass released into the air as respirable particles, g

MAR = material at risk: quantity of SNF that is involved in the postulated accident, g

ARF = airborne release fraction: fraction of the MAR that becomes airborne when some kind of stress (e.g., thermal, explosive) is applied to the MAR during a postulated accident

RF = respirable fraction: fraction of the airborne materials that can be transported through air and inhaled into the human respiratory system, normally unit density spheres 10 μm or less in diameter (or their aerodynamic equivalent)

LPF = leak path factor: fraction of the airborne material that is transported through some confinement deposition or filtration processes.

For many accident scenarios (particularly those involving releases through high-efficiency particulate air [HEPA] filters), the respirable fraction is 1, which means the total airborne release quantity is assumed to be equal to the respirable airborne release quantity. Once again, this depends on the type of stress applied to the material at risk during the accident scenario. The development of airborne release fractions and subsequent doses to downwind receptors should strive for realistic levels of conservatism. Bounding calculations usually assume the respirable fraction is 1, unless credible experimental data is available.

Leak path factors are normally 1 for unmitigated dose calculations. The typical mitigating feature that affects leak path factor is HEPA filtration prior to release into the environment. Individual HEPA filter efficiency is greater than 99.97% for particles the filter is least efficient at removing. For accident mitigation calculations, reducing the environmental release by a factor of 1,000 (i.e., assume 99.90% efficiency) is adequate, unless the accident may damage the HEPA filter.

It is important to recognize that while the inhalation dose is a function of the quantity of respirable radioactive contaminants present at the receptor, the dose from other pathways (e.g., submersion, ingestion) is a function of the total quantity of radioactive contaminants present at the receptor. Because the inhalation dose is orders of magnitude greater than the dose from other pathways, this distinction normally is not considered. Only the respirable portion of the release is used in the dose calculations.

Because gases (e.g., tritium, krypton) and volatile solids (e.g., iodine) are in the fuel matrix, some accidents could liberate these materials more readily than others. If the release is filtered, the particulate material is reduced while these gases and volatile elements pass through unimpaired. The end result could be that the downwind consequences must be determined using a nuclide mixture that differs significantly from the original spent fuel. In such a case, a new value for unit dose is warranted.

In summary, the radiological dose calculations addressed in this report include only the inhalation pathway for all accident scenarios. These doses should be computed using the steps shown below.

1. Determine the accident frequency range for the event.

2. Determine the quantity of radioactive material released into the air as respirable particles. It is also important to estimate the time required to release this material. The shorter the release duration, the larger the dose results to the downwind receptors.

3. Multiply the mass released by the air transport factor, the breathing rate, and the unit dose for each receptor of interest.

4. Compare the receptor doses with the risk evaluation guidelines. Doses which exceed the guidelines require controls of some type.

To illustrate the method, the doses from a 1-gram release of SNF as respirable particles is shown in Table 3-5. The table shows that the release duration has a significant effect on the estimated dose. Values in Table 3-5 were computed from the unit dose (Table 3-1), the appropriate breathing rate, and the ground-level air transport factors (Table 2-4).

The significance of the doses in Table 3-5 is found by comparison with the risk evaluation guidelines (Sellers 1997). Since the shortest release duration gives the largest doses, it will be closest to the risk guidelines. One way to make the comparison is to compute ratios of the above doses to the risk guidelines. For general evaluation purposes, it is useful to know the smallest release needed to produce downwind doses that exceed the risk evaluation guidelines. From such a table one can quickly determine which receptors are closest to their limits. In addition, one can avoid unnecessary detail in the accident analysis by knowing the bounding release amounts. Table 3-6 shows the number of grams that would have to be released to reach the risk guidelines. At all SNF facilities, the onsite receptor is closest to the risk guideline or first to exceed it.

Table 3-5. Effective Dose Equivalent in Sieverts from One-Gram Uranium Fuel Releases.

Receptor type	Release duration category			
	< 1 hr	1 hr to 2 hr	12 hr	24 hr
K West Reactor and adjacent buildings				
Onsite worker	1.07 E-01	1.81 E-02	9.16 E-03	4.58 E-03
Columbia River	5.18 E-03	9.00 E-04	4.23 E-04	2.11 E-04
100 Area Fire Station	2.33 E-04	1.14 E-04	3.99 E-05	1.99 E-05
Hanford Site boundary	6.55 E-05	4.55 E-05	1.27 E-05	7.52 E-06
Cold Vacuum Drying Facility				
Onsite worker	1.07 E-01	1.81 E-02	9.16 E-03	4.58 E-03
Columbia River	3.56 E-03	6.20 E-04	2.90 E-04	1.45 E-04
100 Area Fire Station	2.33 E-04	1.14 E-04	3.99 E-05	1.99 E-05
Hanford Site boundary	6.54 E-05	4.54 E-05	1.47 E-05	7.51 E-06
Canister Storage Building				
Onsite worker	4.98 E-02	1.65 E-02	8.09 E-03	4.04 E-03
Highway 240	3.44 E-05	2.64 E-05	9.09 E-06	4.54 E-06
Hanford Site boundary	1.90 E-05	1.59 E-05	5.61 E-06	2.97 E-06

Notes: Release quantity is 1 g of SNF at ground level. Air transport factors are from Table 2-4. The light activity breathing rate (3.33×10^{-4} m³/s) is used everywhere except for 24-hour releases where the average breathing rate for the Hanford Site boundary receptor is 2.64×10^{-4} m³/s corresponding to 16 hours awake and 8 hours asleep. The unit dose is from Table 3-1.

Table 3-6. Minimum Releases to Reach the Radiological Risk Guidelines.

Receptor type	Receptor location	Grams of fuel to be released to reach risk guidelines		
		Anticipated	Unlikely	Extremely unlikely
K West Reactor and Adjacent Buildings				
Onsite worker	100 m E	9.36 E-02	9.36 E-01	2.34 E+00
Columbia River	520 m W	9.65 E-01	9.65 E+00	9.65 E+00
100 Area Fire Station	3,750 m ESE	4.28 E+01	4.28 E+02	1.07 E+03
Hanford Site boundary	10,070 m W	7.63 E+01	7.63 E+02	7.63 E+02
Cold Vacuum Drying Facility				
Onsite worker	100 m E	9.36 E-02	9.36 E-01	2.34 E+00
Columbia River	650 m W	1.40 E+00	1.40 E+01	1.40 E+01
100 Area Fire Station	3,750 m ESE	4.28 E+01	4.28 E+02	1.07 E+03
Hanford Site boundary	10,090 m W	7.65 E+01	7.65 E+02	7.65 E+02
Canister Storage Building				
Onsite worker	100 m E	2.01 E-01	2.01 E+00	5.02 E+00
Highway 240	9,280 m W	1.45 E+02	1.45 E+03	1.45 E+03
Hanford Site boundary	17,390 m E	2.64 E+02	2.64 E+03	2.64 E+03

The assumed release is from ground level and has a duration less than 1 hour.

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.4.0 TOXICOLOGICAL CONSEQUENCE METHODOLOGY

4.1 SOURCE COMPOSITION

Table 4-1 shows the fuel composition and the air concentration limits for each analyte. The fuel composition is taken from HNF-SD-SNF-TI-015. The value for cesium has been increased by a factor of 100 to correct an obvious error in the databook. The air concentration limits are from PEC-CAT-97-0044A, *ERPGs and TEELs for Chemicals of Concern at SRS* (Craig 1997). Conservative limits were chosen by assuming the compounds that could be formed during an explosion are present. The column labeled "Normalized" shows the grams of each element per gram of SNF. It was computed by dividing the values in the first column by the value for the total mass.

Other chemicals which are likely to be part of any release from the MCO are helium and hydrogen. The primary hazard from hydrogen is the explosive reaction with air. Both gases will displace air, and may present a suffocation hazard to personnel in the facility. However, at the downwind locations under consideration, these gases will have been diluted with air to the point that neither hazard is realistic. The hydrogen will be below the lower flammable limit, and enough oxygen is present in the mixture to sustain life.

Table 4-2 shows the ratios between mass per gram of fuel and the limiting air concentration for each element. The units for this table are m³/g SNF. Elements with no concentration limit have been omitted from the table. Only three elements cause 99.9% of the result. These are uranium, zirconium, and beryllium. Of these three, uranium contributes more than 97% of the total result. As long as the composition of the material released into the air does not differ significantly from the fuel itself, the toxicological effects are determined by one element, uranium. Uranium acts like many heavy metals to damage one or more internal organs of individuals exposed to high air concentrations. The toxicity depends on the solubility of the uranium, with more soluble compounds being a greater hazard because they are transferred from the respiratory tract into the blood more quickly.

Note that using the PEL-TWA for accidental releases is not strictly appropriate because the PEL-TWA is designed to control relatively long-term worker exposure rather than the short-term exposure to the public that would be expected for accident response. The lower of the ERPG-1 and the PEL-TWA should be used for the offsite exposure for high frequency events. Use of the limits that are at or below the ERPG-1 accident category provides an additional level of conservatism. However, only iodine falls into this category, so this refinement has no effect on the resulting composition-weighted risk guideline (CWRG).

Note that there are no concentration limits for long-lived alpha-emitting radionuclides (Am, Cm, Np, and Pu). If it is assumed that these elements have biological effects similar to uranium, then the limits for uranium could be used as a first approximation. With this assumption, it can be seen that these heavy metals would add about 0.20% to the total. In other words, the omitted heavy metals are a negligible addition to the toxicological effects.

Table 4-1. Composition of Spent Fuel and Air Concentration Limits. (2 sheets)

Analyte	Mass in fuel, kg	Normalized	Air concentration limits, mg/m³			
			PEL-TWA	ERPG-1	ERPG-2	ERPG-3
Al	1.70 E+03	8.10 E-04	10	15	15	25
Am	1.09 E+02	5.19 E-05	NA	NA	NA	NA
B	6.05 E-01	2.88 E-07	10	30	50	250
Be	1.63 E+02	7.76 E-05	0.002	0.01	0.025	0.1
C	1.20 E+03	5.71 E-04	39.9	228	399	570
Cd	6.05 E-01	2.88 E-07	0.005	0.03	4	9
Cm	1.78 E-02	8.48 E-09	NA	NA	NA	NA
Co	1.54 E+00	7.33 E-07	NA	NA	NA	NA
Cr	2.88 E+02	1.37 E-04	0.5	1.5	2.5	25
Cs	4.65 E+02	2.21 E-04	NA	NA	NA	NA
Cu	1.66 E+02	7.90 E-05	1	3	5	100
Fe	9.41 E+02	4.48 E-04	10	15	25	2,500
H	8.06 E+00	3.84 E-06	NA	NA	NA	NA
Hf	3.02 E+01	1.44 E-05	NA	NA	NA	NA
I	4.61 E+01	2.20 E-05	3.1	1.0	5.2	52
Kr	7.71 E+01	3.67 E-05	NA	NA	NA	NA
Mg	5.58 E+01	2.66 E-05	10	30	50	250
Mn	6.03 E+01	2.87 E-05	0.2	3	5	500
Mo	7.54 E+00	3.59 E-06	NA	NA	NA	NA
N	1.70 E+02	8.10 E-05	NA	NA	NA	NA
Na	3.02 E+00	1.44 E-06	2	2	40	100
Ni	2.94 E+02	1.40 E-04	1	3	10	10
Np	8.11 E+01	3.86 E-05	NA	NA	NA	NA
O	6.53 E+00	3.11 E-06	NA	NA	NA	NA
Pb	1.52 E+01	7.24 E-06	0.05	0.15	0.25	100
Pd	1.33 E+02	6.33 E-05	10	30	50	250

Table 4-1. Composition of Spent Fuel and Air Concentration Limits. (2 sheets)

Analyte	Mass in fuel, kg	Normalized	Air concentration limits, mg/m³			
			PEL-TWA	ERPG-1	ERPG-2	ERPG-3
Pm	5.00 E-01	2.38 E-05	NA	NA	NA	NA
Pu	4.12 E+03	1.96 E-03	NA	NA	NA	NA
Se	1.20 E+01	5.71 E-06	0.2	0.6	1	1
Si	2.77 E+02	1.32 E-04	0.1	0.3	0.5	25
Sm	6.54 E+00	3.11 E-06	NA	NA	NA	NA
Sn	2.19 E+03	1.04 E-03	2	6	10	100
Sr	1.52 E+02	3.52 E-05	10	30	50	500
Tc	1.70 E+02	8.10 E-05	NA	NA	NA	NA
Ti	7.54 E+00	3.59 E-06	10	30	50	250
U	2.10 E+06	1.00 E+00	0.05	0.6	0.6	10
V	7.54 E+00	3.59 E-06	0.05	0.15	7	35
W	7.68 E+00	3.66 E-06	NA	NA	NA	NA
Xe	1.04 E+03	4.95 E-04	NA	NA	NA	NA
Zr	1.48 E+05	7.05 E-02	5	10	25	50

Notes: Limits for aluminum (Al) are for aluminum oxide. Limits for carbon (C) are for carbon monoxide. Limits for chromium (Cr) are for chromium oxide. Limits for sodium (Na) are for sodium hydroxide. Fuel masses are from HNF-SD-SNF-TI-015, 1998, *Spent Nuclear Fuel Project Technical Databook*, Rev. 6, Fluor Daniel Hanford, Incorporated, Richland, Washington.

ERPG = emergency response planning guidelines.
NA = not applicable.
PEL = permissible exposure limit.
TWA = time-weighted average.

Table 4-2. Ratios of Normalized Fuel Composition to Risk Guidelines.

Analyte	PEL-TWA	ERPG-1	ERPG-2	ERPG-3
Al	8.10 E-02	5.40 E-02	5.40 E-02	3.24 E-02
B	2.88 E-05	9.60 E-06	5.76 E-06	1.15 E-06
Be	3.88 E+01	7.76 E+00	3.10 E+00	7.76 E-01
C	1.43 E-02	2.51 E-03	1.43 E-03	1.00 E-03
Cd	5.76 E-02	9.60 E-03	7.20 E-05	3.20 E-05
Cr	2.74 E-01	9.14 E-02	5.49 E-02	5.49 E-03
Cu	7.90 E-02	2.63 E-02	1.58 E-02	7.90 E-04
Fe	4.48 E-02	2.99 E-02	1.79 E-02	1.79 E-04
I	7.06 E-03	2.12 E-02	4.23 E-03	4.23 E-04
Mg	2.66 E-03	8.86 E-04	5.31 E-04	1.06 E-04
Mn	1.44 E-01	9.57 E-03	5.74 E-03	5.74 E-05
Na	7.19 E-04	7.19 E-04	3.60 E-05	1.44 E-05
Ni	1.40 E-01	4.67 E-02	1.40 E-02	1.40 E-02
Pb	1.45 E-01	4.83 E-02	2.90 E-02	7.24 E-05
Pd	6.33 E-03	2.11 E-03	1.27 E-03	2.53 E-04
Se	2.86 E-02	9.52 E-03	5.71 E-03	5.71 E-03
Si	1.32 E+00	4.40 E-01	2.64 E-01	5.28 E-03
Sn	5.21 E-01	1.74 E-01	1.04 E-01	1.04 E-02
Sr	7.24 E-03	2.41 E-03	1.45 E-03	1.45 E-04
Ti	3.59 E-04	1.20 E-04	7.18 E-05	1.44 E-05
U	2.00 E+04	1.67 E+03	1.67 E+03	1.00 E+02
V	7.18 E-02	2.39 E-02	5.13 E-04	1.03 E-04
Zr	1.41 E+01	7.05 E+00	2.82 E+00	1.41 E+00
Total:	2.01 E+04	1.68 E+03	1.67 E+03	1.02 E+02
Notes: Units are m^3/g SNF, resulting from dividing the grams of each element per gram of uranium by the concentration limit in mg/m^3. Elements without limits have been omitted from the table. The fractions of the total for the three main contributors are shown below.				
Be	0.19%	0.46%	0.19%	0.76%
U	99.72%	99.06%	99.61%	97.79%
Zr	0.07%	0.42%	0.17%	1.38%

ERPG = emergency response planning guidelines.
PEL = permissible exposure limit.
TWA = time-weighted average.

The totals for each concentration limit category can be used in the air transport calculations of air concentration directly. They are given the name "Composition-weighted Risk Guides", or CWRG for spent fuel. The inverse of these values is the weighted concentration guide for SNF. The totals are listed in Table 4-3 according to the risk category and receptor. The formula below summarizes the calculation of a value for CWRG.

$$CWRG = \sum_K (M_K)/(CG_K)$$

where

$CWRG$ = composition-weighted risk guide, m³/g of spent fuel

M_K = mass of the Kth chemical per gram of SNF, g of chemical/g of spent fuel (U)

CG_K = concentration guide for the Kth chemical, g of chemical/m³ of air.

Table 4-3. Composition-Weighted Risk Guidelines for Spent Fuel.

Receptor type	Accident frequency		
	Anticipated >0.01/yr	Unlikely 0.01 to 1 E-04/yr	Extremely unlikely
Onsite	1,680 m³/g	1,670 m³/g	102 m³/g
Offsite	20,100 m³/g	1,680 m³/g	1,670 m³/g

Values are computed as the sum of the ratios of normalized chemical masses per gram of fuel divided by the concentration guidelines.

The composition-weighted concentration guide for SNF is the inverse of the CWRG computed in Table 4-3. These concentration guides are shown in Table 4-4. The units were changed from g/m³ to mg/m³. The values shown are essentially the concentration guidelines for uranium.

Table 4-4. Composition-Weighted Air Concentration Guidelines for Spent Fuel.

Receptor type	Accident frequency		
	Anticipated >0.01/yr	Unlikely 0.01 to 1 E-04/yr	Extremely unlikely
Onsite	0.60 mg/m³	0.60 mg/m³	9.8 mg/m³
Offsite	0.05 mg/m³	0.60 mg/m³	0.60 mg/m³

Values are computed as 1,000 mg/g divided by the composition-weighted risk guideline values in Table 4-3.

4.2 TOXICOLOGICAL EXPOSURE PATHWAYS

Toxicants enter the bodies of people downwind by being inhaled, ingested or absorbed through the skin. Another route of entry is injection through cuts in the skin. This last one will not be considered, because it involves additional accidents downwind besides the SNF Project accident. After the toxicant enters the body it moves into the bloodstream and may cause some damage to a target organ. Eventually it is eliminated from the body. For a class of chemicals known as corrosives, the biological damage can occur without entering the bloodstream. Corrosive chemicals damage whatever tissue they are in contact with. They cause damage to organs such as the eyes, skin, or lungs, and usually exhibit a rapid effect.

The major toxicological exposure pathway for SNF accidents is inhalation of airborne particulate matter. Although a few compounds may be released as gases during accidents, the important chemicals are not gases. Helium and hydrogen are not toxic at the concentrations that would reach the downwind receptors. Particulate matter transported to the maximum onsite and/or offsite individual is assumed to be respirable. Larger particles would be removed by surface deposition mechanisms.

Other potential internal exposure pathways are absorption through the skin and ingestion of contaminated material. Absorption through the skin occurs primarily through physical contact between skin and the chemical, such as handling objects that have been contaminated by the passing plume. This pathway leads to smaller exposures than inhalation during plume passage. Ingestion of chemicals could occur from consuming crops or animals that have been exposed to the chemicals, consuming contaminated water, or ingestion of trace amounts of contaminated soil. Potential chemical exposures from the ingestion pathway are not included because federal and state programs are in place to prevent ingestion of contaminated food and water (DOE-0223, WSDOH 1993, WSDOA 1994, EPA 1992).

In evaluating the toxicological effects of accidental releases of particulate matter from SNF Project facilities the major contributors are three metals (uranium, beryllium, and zirconium). Conditions that result in concentrations of particulate matter high enough to interfere with breathing must be considered separately. Given the nature of the spent fuel particulate matter (uranium, zirconium, and oxides of both), there are no corrosive chemicals.

4.3 TOXICOLOGICAL DOSE CALCULATION METHODS

For toxic chemicals the accumulated dose is not computed. Rather, the air concentration is determined and compared with guidelines. Health effects from exposure to contaminated air depend on the chemical, the air concentration, and the exposure time. For corrosive chemicals the air concentration alone determines the amount of damage. Noncorrosive chemicals are carcinogens or have toxic effects based on the amount accumulated in the body. For noncorrosive chemicals the health effects depend on exposure time.

For accidents with release durations less than the transition times shown on Table 2-6, the puff model is appropriate for calculating air concentrations. The peak air concentration is calculated using the following equation:

$$C_{puff} = (M)(\chi/Q)$$

where

C_{puff} = peak concentration at a downwind receptor location, g/m^3

M = mass of the toxic chemical released, g

χ/Q = puff release air transport factor, per m^3 (Table 2-6).

For accidents with release durations greater than the transition times shown on Table 2-6, the plume model is appropriate for calculating air concentrations. The average air concentration during plume passage is calculated using the following equation:

$$C_{plume} = (M)(\chi/Q')/T_{rel}$$

where

C_{plume} = average plume concentration at a downwind receptor location, g/m^3

M = mass of the toxic chemical released, g

χ/Q' = continuous release air transport factor, s/m^3 (Tables 2-4 and 2-5)

T_{rel} = release duration, s.

For short release durations, the air concentrations can become quite large for brief periods. Because chemical injury takes a finite amount of time to occur in biological materials, a very high exposure for only a few seconds has a lower injury potential than a much lower exposure over a longer period of time. To accommodate this effect in a conservative way, the concept of an averaging period has been developed. One calculates the average concentration during some minimum period and compares this concentration with the concentration guideline. The averaging time used in the present calculations is 15 minutes, based on the following guidance from WSRC-MS-92-206, *Toxic Chemical Hazard Classification and Risk Acceptance Guidelines for Use in DOE Facilities* (Craig 1995):

4.2 Exposure time: Concentrations for comparison with the guidelines must be calculated as the peak 15-minute average concentrations, which are then compared with the guideline concentration limits. This is applicable for all chemicals for which the toxic effect is immediate (i.e., concentration-dependent). If it is known that the toxic effects of a chemical are not concentration-dependent, but depend on the total quantity of chemical taken up by the body (i.e., dose-dependent), then the peak 1-hour concentration may be used. Concentration dependent chemicals are defined as fast-acting chemicals whose toxic effects are immediate, and correlate more closely to concentration than dose. Included in this category are sensory irritants and chemicals which are corrosive or vesicant in their action. Any chemical which has

been assigned an OSHA [Occupational Safety and Health Administration] PEL-STEL or PEL-C, or an ACGIH [American Conference of Governmental Industrial Hygienists] TLV-STEL or TLV-C value must be considered concentration-dependent. In contrast, the effects of dose-dependent chemicals are a function of both concentration and duration of exposure. However, a chemical may elicit concentration-dependent effects at high levels and dose-dependent effects at lower concentrations.

Since the exposure averaging time (15 minutes or 900 seconds) is greater than all the transition times shown on Table 2-6, puff releases are eliminated from further consideration. Air concentrations from accidents with release durations less than 15 minutes are calculated using the plume equation with the release time set to 900 seconds. This is summarized in the modified equation below.

$$C_{ave} = (M)(\chi/Q')/\max(T_{rel}, T_{ave})$$

where

C_{ave} = average concentration of a chemical at a downwind receptor location, g/m^3

M = mass of the toxic chemical released, g

χ/Q' = continuous release air transport factor, s/m^3 (Tables 2-4 and 2-5)

T_{rel} = release duration, s

T_{ave} = exposure averaging period, 900 s.

When more than one chemical is released, a sum-of-fractions method is used to evaluate concentrations against the risk guidelines. The sum-of-fractions method was adapted from American Conference of Governmental Industrial Hygienists and Occupational Safety and Health Administration methods for adding combined exposures to compounds with similar health effects:

$$SOF = \sum_{K} (C_K)/(CG_K)$$

where

SOF = sum-of-fractions for a mixture of chemicals in air

C_K = calculated average air concentration for the Kth chemical, g/m^3

CG_K = concentration guide for the Kth chemical, g of chemical/m^3 of air.

When the formula for average air concentration at the downwind receptor location is substituted into the sum-of-fractions formula, the result is shown below. The sum over ratios of mass fraction divided by concentration guideline has been written as CWRG. Equivalently, the CWRG could be replaced with the inverse of the composition-weighted air concentration guideline (Table 4-4).

$$SOF = \sum\nolimits_{K} (M)(M_K)(\chi/Q')/\max(T_{rel}, T_{ave})/(CG_K)$$

$$SOF = (M)(CWRG)(\chi/Q')/\max(T_{rel}, T_{ave})$$

where

SOF = sum-of-fractions for a mixture of chemicals (e.g., SNF) suspended in air

M = total mass of SNF (a mixture of chemicals) released into the air as respirable particles, g

M_K = mass of the Kth chemical per gram of SNF, g of chemical/g of spent fuel (U). This can be estimated for a given accident using the method described in Section 3.3.

χ/Q' = continuous release air transport factor, s/m^3

T_{rel} = release duration, s

T_{ave} = exposure averaging period, 900 s.

CWRG = composition-weighted risk guide, m^3/g of spent fuel (U)

CG_K = concentration guide for the Kth chemical, g of chemical/m^3 of air.

Note that one more refinement should be considered for long duration releases. In the event that the release duration is greater than the time characteristic of the risk evaluation guideline (1 hour or 8 hours), then the concentration guideline should be reduced. This approach is based on the observation that the total amount inhaled is related to the health effects on individuals downwind. Mathematically, one changes the definition of the concentration guideline to that shown below.

$$\text{If } T_{rel} < T_{guide}, \text{ then } CG_K' = CG_K$$
$$\text{If } T_{rel} > T_{guide}, \text{ then } CG_K' = (CG_K)(T_{guide})/(T_{rel})$$

$$\text{or, } CG_K' = (CG_K)\cdot\min[1,(T_{guide})/(T_{rel})]$$

With this revised definition of CWRG for long duration releases, it is necessary to revise the formula for sum-of-fractions. The formula below shows the results of the revision. Note that the main effect of the revision is to limit the release duration (T_{rel}) to the time inherent in the risk evaluation guideline (T_{guide}). For release durations less than T_{ave}, the formula uses the minimum averaging time. For release durations longer than T_{ave} but shorter than T_{guide}, the formula uses the release duration. For release durations longer than T_{guide}, the formula uses the guideline time.

$$SOF = (M)(CWRG)(\chi/Q')/\min[T_{guide}, \max(T_{rel}, T_{ave})]$$

This equation should be used when it is necessary to determine the toxicological consequences of accidental releases from SNF Project facilities. Sum-of-fractions that are less than one indicate that risk evaluation guidelines are met. Sum-of-fractions that are greater than one indicate that risk evaluation guidelines are exceeded and some type of control must be added.

Note that the released material is assumed to have the same composition as spent fuel. If an accident results in additional chemicals besides the materials in SNF, then a new CWRG must be generated.

The toxicological calculations addressed in this report use the above equation. The calculations for toxic chemical releases should be carried out using the steps shown below.

1. Determine the accident frequency range for the event.

2. Determine the quantity of material released into the air as respirable particles. It is also important to estimate the time required to release this material. If the duration exceeds 15 minutes, then the 15-minute period during the release that contains the greatest amount released must be used in the calculation of the sum-of-fractions.

3. Determine the sum-of-fractions by multiplying the mass released by the air transport factor and the CWRG, and dividing by the larger of the release duration or 900 seconds.

To illustrate the method, the sum-of-fractions following a 1-gram release of SNF as respirable particles is shown in Table 4-5. Values in Table 4-5 were computed from the CWRG (Table 4-3), the ground-level air transport factors (Table 2-4), and an assumed release duration of 15 minutes.

For general purpose evaluation of accidents, it is useful to know the smallest release needed to exceed the risk evaluation guidelines. From such a table one can quickly determine which receptors are closest to their limits. In addition, one can avoid unnecessary detail in the accident analysis by knowing the bounding release amounts. Table 4-6 shows the number of grams that would have to be released to reach the risk guidelines. At all SNF Project facilities, the onsite receptor is closest to the risk guideline or first to exceed it.

Table 4-5. Maximum Sum-of-Fractions for a One-Gram Uranium
Fuel Release at Ground Level.

Receptor type	Receptor location	Accident frequency		
		Anticipated	Unlikely	Extremely unlikely
K West Reactor and adjacent buildings				
Onsite worker	100 m E	1.37 E-01	1.36 E-01	8.32 E-03
Columbia River	520 m W	7.91 E-02	6.64 E-03	6.60 E-03
100 Area Fire Station	3,750 m ESE	2.99 E-04	2.97 E-04	1.82 E-05
Hanford Site boundary	10,070 m W	1.00 E-03	8.39 E-05	8.35 E-05
Cold Vacuum Drying Facility				
Onsite worker	100 m E	1.37 E-01	1.36 E-01	8.32 E-03
Columbia River	650 m W	5.44 E-02	4.56 E-03	4.54 E-03
100 Area Fire Station	3,750 m ESE	2.99 E-04	2.97 E-04	1.82 E-05
Hanford Site boundary	10,090 m W	9.98 E-04	8.37 E-05	8.33 E-05
Canister Storage Building				
Onsite worker	100 m E	6.37 E-02	6.34 E-02	3.87 E-03
Highway 240	9,280 m W	5.26 E-04	4.41 E-05	4.39 E-05
Hanford Site boundary	17,390 m E	2.90 E-04	2.43 E-05	2.42 E-05

Since the exposure averaging time is 15 minutes, the release duration is chosen to be 15 minutes to maximize the Sum-of-fractions.

Table 4-6. Minimum Releases to Reach the Toxicological Risk Guidelines.

Receptor type	Receptor location	Accident frequency		
		Anticipated	Unlikely	Extremely unlikely
K West Reactor and adjacent buildings				
Onsite worker	100 m E	7.31 E+00	7.35 E+00	1.20 E+02
Columbia River	520 m W	1.26 E+01	1.51 E+02	1.52 E+02
100 Area Fire Station	3,750 m ESE	3.34 E+03	3.36 E+03	5.50 E+04
Hanford Site boundary	10,070 m W	9.99 E+02	1.19 E+04	1.20 E+04
Cold Vacuum Drying Facility				
Onsite worker	100 m E	7.31 E+00	7.35 E+00	1.20 E+02
Columbia River	650 m W	1.84 E+01	2.19 E+02	2.20 E+02
100 Area Fire Station	3,750 m ESE	3.34 E+03	3.36 E+03	5.50 E+04
Hanford Site boundary	10,090 m W	1.00 E+03	1.19 E+04	1.20 E+04
Canister Storage Building				
Onsite worker	100 m E	1.57 E+01	1.58 E+01	2.58 E+02
Highway 240	9,280 m W	1.90 E+03	2.27 E+04	2.28 E+04
Hanford Site boundary	17,390 m E	3.45 E+03	4.11 E+04	4.14 E+04

The assumed release is at ground level and has a duration of 15 minutes.

5.0 COMPARISON OF TOXICOLOGICAL AND RADIOLOGICAL IMPORTANCE

Because any environmental release of SNF could have toxicological and radiological effects, both should be computed for comparison with consequence guidelines. The methods for evaluating the importance of radiological and toxicological emissions from SNF Project facilities have been presented in previous sections. Comparison of Tables 3-6 and 4-6 reveals that more grams of SNF must be released to reach the toxicological risk evaluation guideline than the radiological for each accident frequency range and receptor location. A more rigorous comparison will be presented in this section by using a ratio of radiological and toxicological ratios. The radiological (or toxicological) ratio shows the importance of a given release by comparing the resulting dose (or air concentration) with the risk evaluation guidelines. The ratio of these radiological and toxicological ratios simplifies the comparison so that a broader variety of accident conditions can be evaluated.

The formulas used to calculate the radiological and toxicological significance of airborne releases from SNF facilities are shown below. For the purposes of comparison, the radiological consequence formula has been written as the dose equivalent divided by the radiological risk evaluation guideline. Both radiological and toxicological consequences are thereby reduced to unitless, risk-based ratios. The utility of risk-based ratios is that accidents having a ratio greater than 1.0 requires additional controls to lessen either the severity or probability of the accident.

$$\text{Radiological ratio} = (M)(\chi/Q')(BR)(UD)/(RRG)$$

$$\text{Toxicological ratio} = (M)(\chi/Q')(CWRG)/\min[T_{guide}, \max(T_{rel}, T_{ave})]$$

where

M = mass of SNF released into the air as respirable particles, g fuel

χ/Q' = air transport factor, s/m^3 (Tables 2-4 and 2-5)

BR = average inhalation rate during the release, m^3/s

UD = committed EDE per gram inhaled, 4380 Sv/g (Table 3-1)

RRG = radiological risk evaluation guideline, Sv (Table 1-1)

$CWRG$ = spent fuel composition-weighted risk guideline, m^3/g of fuel (Table 4-3)

T_{guide} = time period characteristic of the toxicological risk guideline, s

T_{rel} = release duration, s

T_{ave} = exposure averaging period, 900 seconds.

The air transport factors for toxic chemicals never use the puff values because the puff-to-plume transition times are all less than the exposure averaging time of 900 seconds. Thus the same air transport factors are always used in both the radiological and toxicological calculations. When the ratio of radiological to toxicological is computed, the quantity released (M) and the air transport factors (χ/Q') cancel out. The resulting simplified ratio is shown below.

$$\frac{\text{Radiological ratio}}{\text{Toxicological ratio}} = \frac{(BR)\ (UD)\ \min(T_{guide}, \max(T_{rel}, T_{ave}))}{(RRG)\ (CWRG)}$$

To minimize this ratio, the shortest time possible should be selected for the release duration. This shortest time is the exposure averaging time, 15 minutes (900 seconds). The numerator is then 1,310 (Sv m^3)/g U. The denominator comes from Tables 1-1 and 4-3, and depends on the location of the receptor (onsite or offsite) and the accident probability. Values for the above ratios of radiological to toxicological consequences were computed for each case. Results are shown in Table 5-1. The radiological ratios are greater than the toxicological ratios for any mass released and any release duration.

Table 5-1. Radiological Ratios Divided by Toxicological Ratios.

Receptor type	Accident frequency		
	Anticipated < 0.01/y	Unlikely 0.01 to 1 E-04/y	Extremely unlikely
Onsite	78	7.8	51
Offsite	13	16	16

The assumed release duration is at most 15 minutes. Larger release durations increase the ratios shown above due to smaller toxicological consequences.

The preferential release of specific constituents in the spent fuel rather than the complete composition could affect the above ratios. If the radiological ratio decreases more than the toxicological ratio, then the toxicological consequences could dominate. In order for the toxicological risk to dominate, the plutonium and americium (which constitute most of the radiological risk) would have to be left behind. However, the plutonium and americium are an inescapable part of the uranium fuel. If they are not released, then the majority of the mass is also not released. This means that the toxicological constituents will only be present in trace amounts. Minuscule emissions cannot present a toxicological hazard downwind. Thus it can be stated that for all accidents involving SNF, the radiological risk guidelines are more limiting than the toxicological guidelines. In other words, if the radiological risk is brought within radiological guidelines, the toxicological risk is below toxicological guidelines with margin.

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APPENDIX A

GROUND-LEVEL AIR TRANSPORT FACTORS
FOR EACH WIND DIRECTION

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Table A-1. Air Transport Factors for Releases from 105-KW to
Hanford Site Boundary Locations.

Transport direction	Distance (m)	Air transport factors			
		Bounding	Meander	Chronic	Puff
S	25,150	9.38E-06	8.16E-06	2.69E-08	9.69E-09
SSW	17,310	1.12E-05	9.57E-06	2.91E-08	1.37E-08
SW	15,660	1.38E-05	1.15E-05	3.60E-08	1.69E-08
WSW	12,040	2.02E-05	1.61E-05	6.46E-08	5.42E-08
W	10,070	4.49E-05	3.12E-05	1.58E-07	1.07E-07
WNW	8,650	3.05E-05	2.27E-05	1.22E-07	9.95E-08
NW	8,650	2.88E-05	2.15E-05	9.93E-08	7.02E-08
NNW	8,650	1.42E-05	1.28E-05	6.93E-08	3.87E-08
N	8,810	2.65E-05	2.01E-05	8.58E-08	4.02E-08
NNE	10,910	1.10E-05	1.05E-05	5.16E-08	2.43E-08
NE	15,190	1.47E-05	1.22E-05	4.77E-08	2.76E-08
ENE	19,880	1.67E-05	1.37E-05	5.30E-08	2.44E-08
E	20,380	2.31E-05	1.84E-05	8.41E-08	2.55E-08
ESE	20,570	1.79E-05	1.46E-05	5.04E-08	2.13E-08
SE	21,700	1.36E-05	1.14E-05	3.48E-08	1.52E-08
SSE	25,150	9.57E-06	8.31E-06	2.43E-08	8.89E-09
Sector Maximum:		4.49E-05	3.12E-05	1.58E-07	1.07E-07
Overall Site (95%):		2.65E-05	2.00E-05	6.48E-08	4.19E-08

Units for distances are meters. Units for bounding, meander, and chronic coefficients are s/m³. Units for puff coefficients are 1/m³. Directions are for travel from the 105-KW facility to the Hanford Site boundary (wind toward).

Table A-2. Air Transport Factors for Releases from 105-KW to
Columbia River Locations.

Transport direction	Distance (m)	Air transport factors			
		Bounding	Meander	Chronic	Puff
S	12,850	2.15E-05	1.69E-05	6.79E-08	4.08E-08
SSW	11,400	1.90E-05	1.51E-05	5.21E-08	3.37E-08
SW	1,060	5.81E-04	1.78E-04	2.15E-06	8.08E-06
WSW	710	1.20E-03	3.03E-04	5.38E-06	4.11E-05
W	520	3.55E-03	6.17E-04	1.79E-05	1.23E-04
WNW	480	2.28E-03	5.81E-04	1.31E-05	1.01E-04
NW	480	2.15E-03	5.55E-04	1.07E-05	7.13E-05
NNW	480	1.08E-03	4.44E-04	7.52E-06	3.96E-05
N	480	2.02E-03	5.32E-04	9.54E-06	4.27E-05
NNE	530	9.36E-04	4.15E-04	6.47E-06	3.19E-05
NE	730	1.11E-03	2.84E-04	5.34E-06	3.22E-05
ENE	2,250	2.94E-04	1.15E-04	1.25E-06	3.08E-06
E	11,330	4.80E-05	3.35E-05	1.89E-07	9.02E-08
ESE	11,780	3.58E-05	2.60E-05	1.09E-07	7.06E-08
SE	15,050	2.14E-05	1.69E-05	5.75E-08	3.32E-08
SSE	15,800	1.70E-05	1.38E-05	4.58E-08	2.40E-08
Sector Maximum:		3.55E-03	6.17E-04	1.79E-05	1.23E-04
Overall Site (95%):		1.58E-03	4.25E-04	5.00E-06	4.02E-05

Units for distances are meters. Units for bounding, meander, and chronic coefficients are s/m³. Units for puff coefficients are 1/m³. Directions are for travel from the 105-KW facility to the Columbia River and the Hanford Site boundary (wind toward).

Table A-3. Air Transport Factors at 100 Meters for Releases from
105-KW or the Cold Vacuum Drying Facility.

Direction	Air transport factors			
	Bounding	Meander	Chronic	Puff
S	3.88E-02	9.03E-03	2.29E-04	5.73E-03
SSW	2.91E-02	7.71E-03	1.48E-04	3.17E-03
SW	3.17E-02	8.12E-03	1.56E-04	3.72E-03
WSW	3.36E-02	8.48E-03	1.89E-04	6.75E-03
W	5.91E-02	1.03E-02	3.63E-04	9.04E-03
WNW	3.33E-02	8.46E-03	2.33E-04	6.05E-03
NW	3.13E-02	8.08E-03	1.91E-04	4.28E-03
NNW	1.58E-02	6.51E-03	1.34E-04	2.38E-03
N	2.94E-02	7.75E-03	1.70E-04	2.56E-03
NNE	1.61E-02	7.15E-03	1.37E-04	2.47E-03
NE	3.27E-02	8.33E-03	2.00E-04	5.70E-03
ENE	5.16E-02	1.01E-02	3.13E-04	8.94E-03
E	7.32E-02	1.24E-02	5.12E-04	9.85E-03
ESE	5.76E-02	1.03E-02	3.15E-04	8.39E-03
SE	4.69E-02	9.53E-03	2.36E-04	6.71E-03
SSE	3.95E-02	9.03E-03	2.01E-04	5.38E-03
Sector Maximum:	7.32E-02	1.24E-02	5.12E-04	9.85E-03
Overall Site (95%):	6.10E-02	1.03E-02	2.33E-04	8.83E-03

Units for bounding, meander, and chronic coefficients are s/m³. Units for puff coefficients
are 1/m³. Directions are for travel from the release point to a distance of 100 m (wind toward).

Table A-4. Air Transport Factors for Releases from the Cold Vacuum
Drying Facility to Columbia River Locations.

Transport direction	Distance (m)	Air transport factors			
		Bounding	Meander	Chronic	Puff
S	12,650	2.20E-05	1.72E-05	6.94E-08	4.22E-08
SSW	11,340	1.91E-05	1.52E-05	5.25E-08	3.41E-08
SW	1,690	2.76E-04	1.11E-04	9.74E-07	2.52E-06
WSW	700	1.23E-03	3.10E-04	5.52E-06	4.26E-05
W	650	2.44E-03	4.25E-04	1.21E-05	6.90E-05
WNW	580	1.66E-03	4.23E-04	9.38E-06	6.19E-05
NW	580	1.56E-03	4.04E-04	7.66E-06	4.38E-05
NNW	580	7.89E-04	3.24E-04	5.37E-06	2.43E-05
N	580	1.47E-03	3.88E-04	6.81E-06	2.62E-05
NNE	640	6.84E-04	3.03E-04	4.62E-06	1.96E-05
NE	860	8.48E-04	2.27E-04	4.00E-06	2.12E-05
ENE	2,540	2.47E-04	1.03E-04	1.04E-06	2.32E-06
E	11,470	4.73E-05	3.31E-05	1.86E-07	8.79E-08
ESE	12,060	3.48E-05	2.54E-05	1.05E-07	6.71E-08
SE	15,150	2.13E-05	1.67E-05	5.70E-08	3.28E-08
SSE	15,600	1.72E-05	1.40E-05	4.66E-08	2.46E-08
Sector Maximum:		2.44E-03	4.25E-04	1.21E-05	6.90E-05
Overall Site (95%):		1.22E-03	3.14E-04	3.62E-06	2.30E-05

Units for distances are meters. Units for bounding, meander, and chronic coefficients are s/m^3. Units for puff coefficients are $1/m^3$. Directions are for travel from the Cold Vacuum Drying Facility to the Columbia River and the Hanford Site boundary (wind toward).

Table A-5. Air Transport Factors for Releases from the Cold Vacuum
Drying Facility to Hanford Site Boundary Locations.

Transport direction	Distance (m)	Air transport factors			
		Bounding	Meander	Chronic	Puff
S	24,960	9.47E-06	8.23E-06	2.72E-08	9.85E-09
SSW	17,130	1.14E-05	9.68E-06	2.95E-08	1.40E-08
SW	15,510	1.40E-05	1.16E-05	3.65E-08	1.72E-08
WSW	11,990	2.03E-05	1.62E-05	6.50E-08	5.46E-08
W	10,090	4.48E-05	3.11E-05	1.58E-07	1.07E-07
WNW	8,740	3.01E-05	2.25E-05	1.20E-07	9.73E-08
NW	8,740	2.84E-05	2.13E-05	9.79E-08	6.86E-08
NNW	8,740	1.41E-05	1.27E-05	6.83E-08	3.78E-08
N	8,930	2.61E-05	1.98E-05	8.41E-08	3.90E-08
NNE	10,750	1.12E-05	1.07E-05	5.27E-08	2.51E-08
NE	15,390	1.45E-05	1.21E-05	4.68E-08	2.69E-08
ENE	20,080	1.65E-05	1.35E-05	5.22E-08	2.39E-08
E	20,510	2.29E-05	1.83E-05	8.34E-08	2.52E-08
ESE	20,670	1.78E-05	1.45E-05	5.01E-08	2.11E-08
SE	21,790	1.36E-05	1.13E-05	3.46E-08	1.51E-08
SSE	24,960	9.65E-06	8.38E-06	2.45E-08	9.03E-09
Sector Maximum:		4.48E-05	3.11E-05	1.58E-07	1.07E-07
Overall Site (95%):		2.62E-05	2.03E-05	6.44E-08	4.07E-08

Units for distances are meters. Units for bounding, meander, and chronic coefficients are s/m^3. Units for puff coefficients are $1/m^3$. Directions are for travel from the Cold Vacuum Drying Facility to the Hanford Site boundary (wind toward).

Table A-6. Air Transport Factors at 100 Meters from the
Canister Storage Building.

Direction	Air transport factors			
	Bounding	Meander	Chronic	Puff
S	1.56E-02	5.96E-03	1.68E-04	2.25E-03
SSW	1.13E-02	4.54E-03	1.04E-04	1.36E-03
SW	1.21E-02	4.80E-03	9.93E-05	8.69E-04
WSW	1.22E-02	4.80E-03	9.97E-05	8.43E-04
W	2.80E-02	7.43E-03	1.73E-04	2.53E-03
WNW	1.60E-02	6.67E-03	1.39E-04	2.55E-03
NW	2.89E-02	7.65E-03	1.57E-04	5.36E-03
NNW	2.90E-02	8.06E-03	1.54E-04	7.02E-03
N	3.12E-02	8.29E-03	1.61E-04	6.99E-03
NNE	1.54E-02	5.36E-03	9.04E-05	2.38E-03
NE	1.57E-02	6.02E-03	1.07E-04	2.74E-03
ENE	2.52E-02	7.79E-03	1.42E-04	6.49E-03
E	3.41E-02	1.09E-02	3.78E-04	9.85E-03
ESE	3.25E-02	1.13E-02	4.03E-04	9.85E-03
SE	3.07E-02	8.37E-03	2.52E-04	8.35E-03
SSE	1.58E-02	6.20E-03	1.47E-04	2.52E-03
Sector Maximum:	3.41E-02	1.13E-02	4.03E-04	9.85E-03
Overall Site (95%):	3.28E-02	9.40E-03	1.74E-04	7.27E-03

Units for bounding, meander, and chronic coefficients are s/m³. Units for puff coefficients
are 1/m³. Directions are for travel from the release point to a distance of 100 m (wind toward).

Table A-7. Air Transport Factors for Releases from the Canister Storage Building
to Nearest Public Access Locations.

Transport direction	Distance (m)	Air transport factors			
		Bounding	Meander	Chronic	Puff
S	7,830	1.57E-05	1.35E-05	9.22E-08	4.83E-08
SSW	7,830	9.66E-06	8.29E-06	5.56E-08	3.65E-08
SW	7,830	1.25E-05	1.01E-05	5.48E-08	1.66E-08
WSW	7,830	1.25E-05	1.01E-05	5.47E-08	1.61E-08
W	9,280	2.36E-05	1.81E-05	7.67E-08	3.54E-08
WNW	10,510	1.14E-05	1.06E-05	5.31E-08	2.72E-08
NW	11,250	1.91E-05	1.52E-05	5.62E-08	4.98E-08
NNW	11,250	1.92E-05	1.53E-05	5.73E-08	6.52E-08
N	11,250	2.06E-05	1.62E-05	6.09E-08	6.49E-08
NNE	12,750	7.96E-06	6.96E-06	2.85E-08	1.66E-08
NE	12,670	8.50E-06	7.75E-06	3.38E-08	1.95E-08
ENE	12,670	1.44E-05	1.21E-05	4.50E-08	4.66E-08
E	12,670	1.92E-05	1.54E-05	1.23E-07	7.08E-08
ESE	14,230	1.59E-05	1.30E-05	1.10E-07	5.51E-08
SE	11,070	2.07E-05	1.63E-05	9.26E-08	8.04E-08
SSE	8,490	1.44E-05	1.28E-05	7.48E-08	4.28E-08
Sector Maximum:		2.36E-05	1.81E-05	1.23E-07	8.04E-08
Overall Site (95%):		2.02E-05	1.59E-05	6.68E-08	7.00E-08

Units for distances are meters. Units for bounding, meander, and chronic coefficients are s/m^3. Units for puff coefficients are $1/m^3$. Directions are for travel from the Canister Storage Building to the Hanford Site boundary (wind toward).

Table A-8. Air Transport Factors for Releases from the Canister Storage Building
to Hanford Site Boundary Locations.

Transport direction	Distance (m)	Air transport factors			
		Bounding	Meander	Chronic	Puff
S	16,260	6.05E-06	5.56E-06	3.23E-08	9.88E-09
SSW	16,260	3.83E-06	3.53E-06	1.94E-08	7.42E-09
SW	16,260	4.91E-06	4.38E-06	1.91E-08	3.26E-09
WSW	17,910	4.36E-06	3.92E-06	1.67E-08	2.54E-09
W	18,400	9.97E-06	8.57E-06	2.92E-08	8.07E-09
WNW	18,400	5.59E-06	5.36E-06	2.42E-08	8.14E-09
NW	18,870	1.00E-05	8.64E-06	2.73E-08	1.63E-08
NNW	19,450	9.70E-06	8.38E-06	2.68E-08	2.01E-08
N	19,450	1.04E-05	8.93E-06	2.86E-08	2.00E-08
NNE	20,390	4.31E-06	3.94E-06	1.49E-08	6.05E-09
NE	17,540	5.60E-06	5.23E-06	2.15E-08	9.69E-09
ENE	17,390	9.69E-06	8.46E-06	2.90E-08	2.36E-08
E	17,390	1.30E-05	1.09E-05	7.98E-08	3.58E-08
ESE	17,390	1.24E-05	1.05E-05	8.31E-08	3.58E-08
SE	20,630	9.51E-06	8.25E-06	3.88E-08	2.11E-08
SSE	18,830	5.16E-06	4.85E-06	2.42E-08	7.64E-09
Sector Maximum:		1.30E-05	1.09E-05	8.31E-08	3.58E-08
Overall Site (95%):		1.16E-05	9.95E-06	3.22E-08	3.02E-08

Units for distances are meters. Units for bounding, meander, and chronic coefficients are s/m³. Units for puff coefficients are 1/m³. Directions are for travel from the Canister Storage Building to the Hanford Site boundary (wind toward).

APPENDIX B

GXQ INPUT FILES FOR GROUND-LEVEL RELEASES

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GXQ Output for Release Durations < 1 Hour

CVDF & 100-KW -- 99.5%

```
                        GXQ Version 4.0
                        December 19, 1994

General Purpose Atmospheric Dispersion Code
Produced by Westinghouse Hanford Company

Users Guide documented in WHC-SD-GN-SWD-30002 Rev. 1.
Validation documented in WHC-SD-GN-SWD-30003 Rev. 1.
Code Custodian is: Brit E. Hey
                    Westinghouse Hanford Company
                    P.O. Box 1970
                    Richland, WA 99352
                    (509) 376-2921


Run Date = 04/09/99
Run Time = 14:43:25.68


INPUT ECHO:
Acute -- Ground Level Release Height
c GXQ Version 4.0 Input File
    1
c MODE SELECTION:
c   1 - X/Q based on Hanford site specific meteorology
c   2 - X/Q based on atmospheric stability class and wind speed
c   3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
c   ifox  inorm icdf  ichk  isite ipop
    T     F     F     F     F     F
c   ifox  = t then joint frequency used to compute frequency-to-exceed X/Q
c         = f then joint frequency used to compute annual average X/Q
c   inorm = t then joint frequency data is normalized (as in GENII)
c         = f then joint frequency data is un-normalized
c   icdf  = t then cumulative distribution file created (CDF.OUT)
c         = f then no cumulative distribution file created
c   ichk  = t then X/Q parameter print option turned on
c         = f then no parameter print
c   isite = t then X/Q based on joint frequency data for all 16 sectors
c         = f then X/Q based on joint frequency data of individual sectors
c   ipop  = t then X/Q is population weighted
c         = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c   ipuff idep  isrc  iwind
    0     0     0     0
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c   iwake ipm   iflow ientr
    0     0     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c   (irise igrnd)iwash igrav
    0     0     0     0
c   ipuff = 1 then X/Q calculated using puff model
c         = 0 then X/Q calculated using default continuous plume model
c   idep  = 1 then plume depletion model turned on (Chamberlain model)
c   isrc  = 1 then X/Q multiplied by scalar
c         = 2 then X/Q adjusted by wind speed function
c   iwind = 1 then wind speed corrected for plume height
c   iwake = 1 then NRC RG 1.145 building wake model turned on
c         = 2 then MACCS virtual distance building wake model turned on
c   ipm   = 1 then NRC RG 1.145 plume meander model turned on
c         = 2 then 5th Power Law plume meander model turned on
c         = 3 then sector average model turned on
c   iflow = 1 then sigmas adjusted for volume flow rate
c   ientr = 1 then method of Pasquill used to account for entrainment
c   irise = 1 then MACCS buoyant plume rise model turned on
c         = 2 then ISC2 momentum/buoyancy plume rise model turned on
```

```
c    igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c    iwash = 1 then stack downwash model turned on
c    igrav = 1 then gravitational settling model turned on
c          = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c    release        anemometer     mixing         frequency
c    height         height         height         to
c    (m)            (m)            (m)            exceed
     0.00000E+00    1.00000E+01    1.00000E+03    5.00000E-01
c
c    initial        initial                                      gravitational
c    plume          plume          release        deposition     settling
c    width          height         duration       velocity       velocity
c    Wb(m)          Hb(m)          (hour)         (m/s)          (m/s)
     0.00000E+00    0.00000E+00    0.00000E+00    1.00000E-03    1.00000E-03
c
c                   initial        initial                       convective
c    ambient        plume          plume          release        heat release
c    temperature    temperature    flow rate      diameter       rate*
c    (°C)           (°C)           (m3/s)         (m)            (watts)
     2.00000E+01    2.20000E+01    1.00000E+00    1.00000E+00    0.00000E+00
c    *If zero then buoyant flux based on plume/ambient temperature difference.
c
c    X/Q            Wind
c    scaling        Speed
c    factor         Exponent
     1.00000E+00    7.80000E-01
c
c RECEPTOR LOCATIONS (no line limit)
c    MODE                 RECEPTOR DEPENDENT DATA
c    1 (site winds)       sector, distance, receptor height
c    2 (special case)     class, windspeed, distance, offset, receptor height
c    3 (plot file)        class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
c    sector = 0, 1, 2... (all, S, SSW, etc.)
c    distance = receptor distance (m)
c    receptor height = height of receptor (m)
c    class = 1,2,3,4,5,6,7 (Pasquill stability A,B,C,D,E,F,G)
c    windspeed = anemometer wind speed (m/s)
c    offset = offset from plume centerline (m)
c    xmax  = maximum distance to plot or calculate to (m)
c    imax  = distance intervals
c    ymax  = maximum offset to plot (m)
c    jmax  = offset intervals
c    xqmin = minimum scaled X/Q to calculate
c    power = exponent in power function step size
c
c  CVDF (& KW Reactor) Receptor Locations
c  **** sector maximum values -- ground level
c
```

MODE:
Site specific X/Q calculated.

LOGICAL CHOICES:
Joint frequency used to calculate X/Q based on frequency of exceedance.
No normalization of joint frequency.
X/Q calculated for single sector.

MODELS SELECTED:
Default Gaussian plume model selected.

WARNING/ERROR MESSAGES:

JOINT FREQUENCY DATA:
100 N AREA - 10 M - Pasquill A - G (1983 - 1991 Average)
Created 8/26/92 KR

Acute -- Ground Level Release Height

SECTOR	DISTANCE (m)	RECEPT HEIGHT (m)	SECT. FREQ. (%)	POPULATION	TOTAL POPULATION SCALED X/Q (s/m3)	AVERAGE INDIVIDUAL SCALED X/Q (s/m3)	ATM. STAB. CLASS	WIND SPEED (m/s)
S	100	0	6.18	1	3.88E-02	3.88E-02	F	0.89
SSW	100	0	5.01	1	2.91E-02	2.91E-02	G	2.65
SW	100	0	3.91	1	3.17E-02	3.17E-02	F	0.89
WSW	100	0	3.88	1	3.36E-02	3.36E-02	F	0.89
W	100	0	7.54	1	5.91E-02	5.91E-02	F	0.89
WNW	100	0	5.46	1	3.33E-02	3.33E-02	F	0.89
NW	100	0	4.92	1	3.13E-02	3.13E-02	G	2.65
NNW	100	0	3.41	1	1.58E-02	1.58E-02	G	4.70
N	100	0	3.89	1	2.94E-02	2.94E-02	G	2.65
NNE	100	0	3.54	1	1.61E-02	1.61E-02	G	4.70
NE	100	0	5.96	1	3.27E-02	3.27E-02	F	0.89
ENE	100	0	9.19	1	5.16E-02	5.16E-02	F	0.89
E	100	0	16.14	1	7.32E-02	7.32E-02	G	0.89
ESE	100	0	10.16	1	5.76E-02	5.76E-02	F	0.89
SE	100	0	6.17	1	4.69E-02	4.69E-02	F	0.89
SSE	100	0	4.44	1	3.95E-02	3.95E-02	F	0.89
ESE	3750	0	10.16	1	1.60E-04	1.60E-04	F	0.89
S	12650	0	6.18	1	2.20E-05	2.20E-05	F	0.89
SSW	11340	0	5.01	1	1.91E-05	1.91E-05	G	2.65
SW	1690	0	3.91	1	2.76E-04	2.76E-04	F	0.89
WSW	700	0	3.88	1	1.23E-03	1.23E-03	F	0.89
W	650	0	7.54	1	2.44E-03	2.44E-03	F	0.89
WNW	580	0	5.46	1	1.66E-03	1.66E-03	F	0.89
NW	580	0	4.92	1	1.56E-03	1.56E-03	G	2.65
NNW	580	0	3.41	1	7.89E-04	7.89E-04	G	4.70
N	580	0	3.89	1	1.47E-03	1.47E-03	G	2.65
NNE	640	0	3.54	1	6.84E-04	6.84E-04	G	4.70
NE	860	0	5.96	1	8.48E-04	8.48E-04	F	0.89
ENE	2540	0	9.19	1	2.47E-04	2.47E-04	F	0.89
E	11470	0	16.14	1	4.73E-05	4.73E-05	G	0.89
ESE	12060	0	10.16	1	3.48E-05	3.48E-05	F	0.89
SE	15150	0	6.17	1	2.13E-05	2.13E-05	F	0.89
SSE	15600	0	4.44	1	1.72E-05	1.72E-05	F	0.89
S	24960	0	6.18	1	9.47E-06	9.47E-06	F	0.89
SSW	17130	0	5.01	1	1.14E-05	1.14E-05	G	2.65
SW	15510	0	3.91	1	1.40E-05	1.40E-05	F	0.89
WSW	11990	0	3.88	1	2.03E-05	2.03E-05	F	0.89
W	10090	0	7.54	1	4.48E-05	4.48E-05	F	0.89
WNW	8740	0	5.46	1	3.01E-05	3.01E-05	F	0.89
NW	8740	0	4.92	1	2.84E-05	2.84E-05	G	2.65
NNW	8740	0	3.41	1	1.41E-05	1.41E-05	G	4.70
N	8930	0	3.89	1	2.61E-05	2.61E-05	G	2.65
NNE	10750	0	3.54	1	1.12E-05	1.12E-05	G	4.70
NE	15390	0	5.96	1	1.45E-05	1.45E-05	F	0.89
ENE	20080	0	9.19	1	1.65E-05	1.65E-05	F	0.89
E	20510	0	16.14	1	2.29E-05	2.29E-05	G	0.89
ESE	20670	0	10.16	1	1.78E-05	1.78E-05	F	0.89
SE	21790	0	6.17	1	1.36E-05	1.36E-05	F	0.89
SSE	24960	0	4.44	1	9.65E-06	9.65E-06	F	0.89
S	12850	0	6.18	1	2.15E-05	2.15E-05	F	0.89
SSW	11400	0	5.01	1	1.90E-05	1.90E-05	G	2.65
SW	1060	0	3.91	1	5.81E-04	5.81E-04	F	0.89
WSW	710	0	3.88	1	1.20E-03	1.20E-03	F	0.89
W	520	0	7.54	1	3.55E-03	3.55E-03	F	0.89
WNW	480	0	5.46	1	2.28E-03	2.28E-03	F	0.89
NW	480	0	4.92	1	2.15E-03	2.15E-03	G	2.65
NNW	480	0	3.41	1	1.08E-03	1.08E-03	G	4.70
N	480	0	3.89	1	2.02E-03	2.02E-03	G	2.65
NNE	530	0	3.54	1	9.36E-04	9.36E-04	G	4.70
NE	730	0	5.96	1	1.11E-03	1.11E-03	F	0.89
ENE	2250	0	9.19	1	2.94E-04	2.94E-04	F	0.89
E	11330	0	16.14	1	4.80E-05	4.80E-05	G	0.89
ESE	11780	0	10.16	1	3.58E-05	3.58E-05	F	0.89
SE	15050	0	6.17	1	2.14E-05	2.14E-05	F	0.89
SSE	15800	0	4.44	1	1.70E-05	1.70E-05	F	0.89
S	25150	0	6.18	1	9.38E-06	9.38E-06	F	0.89
SSW	17310	0	5.01	1	1.12E-05	1.12E-05	G	2.65
SW	15660	0	3.91	1	1.38E-05	1.38E-05	F	0.89
WSW	12040	0	3.88	1	2.02E-05	2.02E-05	F	0.89
W	10070	0	7.54	1	4.49E-05	4.49E-05	F	0.89

WNW	8650	0	5.46	1	3.05E-05	3.05E-05	F	0.89
NW	8650	0	4.92	1	2.88E-05	2.88E-05	G	2.65
NNW	8650	0	3.41	1	1.42E-05	1.42E-05	G	4.70
N	8810	0	3.89	1	2.65E-05	2.65E-05	G	2.65
NNE	10910	0	3.54	1	1.10E-05	1.10E-05	G	4.70
NE	15190	0	5.96	1	1.47E-05	1.47E-05	F	0.89
ENE	19880	0	9.19	1	1.67E-05	1.67E-05	F	0.89
E	20380	0	16.14	1	2.31E-05	2.31E-05	G	0.89
ESE	20570	0	10.16	1	1.79E-05	1.79E-05	F	0.89
SE	21700	0	6.17	1	1.36E-05	1.36E-05	F	0.89
SSE	25150	0	4.44	1	9.57E-06	9.57E-06	F	0.89

GXQ Output for Release Durations < 1 Hour

CSB -- 99.5%

GXQ Version 4.0
December 19, 1994

General Purpose Atmospheric Dispersion Code
Produced by Westinghouse Hanford Company

Users Guide documented in WHC-SD-GN-SWD-30002 Rev. 1.
Validation documented in WHC-SD-GN-SWD-30003 Rev. 1.
Code Custodian is: Brit E. Hey
                   Westinghouse Hanford Company
                   P.O. Box 1970
                   Richland, WA 99352
                   (509) 376-2921

Run Date = 04/09/99
Run Time = 14:43:34.14


```
INPUT ECHO:
Acute -- Ground Level Release Height
c GXQ Version 4.0 Input File
    1
c MODE SELECTION:
c    1 - X/Q based on Hanford site specific meteorology
c    2 - X/Q based on atmospheric stability class and wind speed
c    3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
c    ifox  inorm  icdf  ichk  isite ipop
     T     F      F     F     F     F
c    ifox  = t then joint frequency used to compute frequency-to-exceed X/Q
c          = f then joint frequency used to compute annual average X/Q
c    inorm = t then joint frequency data is normalized (as in GENII)
c          = f then joint frequency data is un-normalized
c    icdf  = t then cumulative distribution file created (CDF.OUT)
c          = f then no cumulative distribution file created
c    ichk  = t then X/Q parameter print option turned on
c          = f then no parameter print
c    isite = t then X/Q based on joint frequency data for all 16 sectors
c          = f then X/Q based on joint frequency data of individual sectors
c    ipop  = t then X/Q is population weighted
c          = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c    ipuff idep   isrc  iwind
     0     0      0     0
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c    iwake ipm    iflow ientr
     0     0      0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c    (irise igrnd)iwash igrav
     0     0      0     0
c    ipuff = 1 then X/Q calculated using puff model
c          = 0 then X/Q calculated using default continuous plume model
c    idep  = 1 then plume depletion model turned on (Chamberlain model)
c    isrc  = 1 then X/Q multiplied by scalar
c          = 2 then X/Q adjusted by wind speed function
c    iwind = 1 then wind speed corrected for plume height
c    iwake = 1 then NRC RG 1.145 building wake model turned on
c          = 2 then MACCS virtual distance building wake model turned on
c    ipm   = 1 then NRC RG 1.145 plume meander model turned on
c          = 2 then 5th Power Law plume meander model turned on
c          = 3 then sector average model turned on
c    iflow = 1 then sigmas adjusted for volume flow rate
c    ientr = 1 then method of Pasquill used to account for entrainment
c    irise = 1 then MACCS buoyant plume rise model turned on
c          = 2 then ISC2 momentum/buoyancy plume rise model turned on
```

```
c   igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c   iwash = 1 then stack downwash model turned on
c   igrav = 1 then gravitational settling model turned on
c         = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c   release      anemometer    mixing        frequency
c   height       height        height        to
c   (m)          (m)           (m)           exceed
    0.00000E+00  1.00000E+01   1.00000E+03   5.00000E-01
c
c   initial      initial                                   gravitational
c   plume        plume         release       deposition    settling
c   width        height        duration      velocity      velocity
c   Wb(m)        Hb(m)         (hour)        (m/s)         (m/s)
    0.00000E+00  0.00000E+00   0.00000E+00   1.00000E-03   1.00000E-03
c
c                initial       initial                     convective
c   ambient      plume         plume         release       heat release
c   temperature  temperature   flow rate     diameter      rate*
c   (°C)         (°C)          (m3/s)        (m)           (watts)
    2.00000E+01  2.20000E+01   1.00000E+00   1.00000E+00   0.00000E+00
c   *If zero then buoyant flux based on plume/ambient temperature difference.
c
c   X/Q          Wind
c   scaling      Speed
c   factor       Exponent
    1.00000E+00  7.80000E-01
c
c RECEPTOR LOCATIONS (no line limit)
c   MODE              RECEPTOR DEPENDENT DATA
c   1 (site winds)    sector, distance, receptor height
c   2 (special case)  class, windspeed, distance, offset, receptor height
c   3 (plot file)     class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
c   sector = 0, 1, 2... (all, S, SSW, etc.)
c   distance = receptor distance (m)
c   receptor height = height of receptor (m)
c   class = 1,2,3,4,5,6,7 (Pasquill stability A,B,C,D,E,F,G)
c   windspeed = anemometer wind speed (m/s)
c   offset = offset from plume centerline (m)
c   xmax   = maximum distance to plot or calculate to (m)
c   imax   = distance intervals
c   ymax   = maximum offset to plot (m)
c   jmax   = offset intervals
c   xqmin  = minimum scaled X/Q to calculate
c   power  = exponent in power function step size
c
c   CSB Receptor Locations
c   **** sector maximum values -- ground level
c
```

MODE:
Site specific X/Q calculated.

LOGICAL CHOICES:
Joint frequency used to calculate X/Q based on frequency of exceedance.
No normalization of joint frequency.
X/Q calculated for single sector.

MODELS SELECTED:
Default Gaussian plume model selected.

WARNING/ERROR MESSAGES:

JOINT FREQUENCY DATA:
200 AREA (HMS) - 10 M - Pasquill A - G (1983 - 1991 Average)
Created 8/26/92 KR

Acute -- Ground Level Release Height

SECTOR	DISTANCE (m)	RECEPT HEIGHT (m)	SECT. FREQ. (%)	POPULATION	TOTAL POPULATION SCALED X/Q (s/m3)	AVERAGE INDIVIDUAL SCALED X/Q (s/m3)	ATM. STAB. CLASS	WIND SPEED (m/s)
S	100	0	6.30	1	1.56E-02	1.56E-02	E	0.89
SSW	100	0	4.53	1	1.13E-02	1.13E-02	F	2.65
SW	100	0	2.93	1	1.21E-02	1.21E-02	F	2.65
WSW	100	0	2.72	1	1.22E-02	1.22E-02	F	2.65
W	100	0	4.80	1	2.80E-02	2.80E-02	G	2.65
WNW	100	0	3.98	1	1.60E-02	1.60E-02	G	4.70
NW	100	0	4.72	1	2.89E-02	2.89E-02	G	2.65
NNW	100	0	4.58	1	2.90E-02	2.90E-02	G	2.65
N	100	0	4.36	1	3.12E-02	3.12E-02	G	2.65
NNE	100	0	2.49	1	1.54E-02	1.54E-02	E	0.89
NE	100	0	3.90	1	1.57E-02	1.57E-02	E	0.89
ENE	100	0	6.17	1	2.52E-02	2.52E-02	G	2.65
E	100	0	14.05	1	3.41E-02	3.41E-02	F	0.89
ESE	100	0	18.80	1	3.25E-02	3.25E-02	F	0.89
SE	100	0	10.83	1	3.07E-02	3.07E-02	G	2.65
SSE	100	0	4.78	1	1.58E-02	1.58E-02	G	4.70
S	7830	0	6.30	1	1.57E-05	1.57E-05	E	0.89
SSW	7830	0	4.53	1	9.66E-06	9.66E-06	F	2.65
SW	7830	0	2.93	1	1.25E-05	1.25E-05	F	2.65
WSW	7830	0	2.72	1	1.25E-05	1.25E-05	F	2.65
W	9280	0	4.80	1	2.36E-05	2.36E-05	G	2.65
WNW	10510	0	3.98	1	1.14E-05	1.14E-05	G	4.70
NW	11250	0	4.72	1	1.91E-05	1.91E-05	G	2.65
NNW	11250	0	4.58	1	1.92E-05	1.92E-05	G	2.65
N	11250	0	4.36	1	2.06E-05	2.06E-05	G	2.65
NNE	12750	0	2.49	1	7.96E-06	7.96E-06	E	0.89
NE	12670	0	3.90	1	8.50E-06	8.50E-06	E	0.89
ENE	12670	0	6.17	1	1.44E-05	1.44E-05	G	2.65
E	12670	0	14.05	1	1.92E-05	1.92E-05	F	0.89
ESE	14230	0	18.80	1	1.59E-05	1.59E-05	F	0.89
SE	11070	0	10.83	1	2.07E-05	2.07E-05	G	2.65
SSE	8490	0	4.78	1	1.44E-05	1.44E-05	G	4.70
S	16260	0	6.30	1	6.05E-06	6.05E-06	E	0.89
SSW	16260	0	4.53	1	3.83E-06	3.83E-06	F	2.65
SW	16260	0	2.93	1	4.91E-06	4.91E-06	F	2.65
WSW	17910	0	2.72	1	4.36E-06	4.36E-06	F	2.65
W	18400	0	4.80	1	9.97E-06	9.97E-06	G	2.65
WNW	18400	0	3.98	1	5.59E-06	5.59E-06	G	4.70
NW	18870	0	4.72	1	1.00E-05	1.00E-05	G	2.65
NNW	19450	0	4.58	1	9.70E-06	9.70E-06	G	2.65
N	19450	0	4.36	1	1.04E-05	1.04E-05	G	2.65
NNE	20390	0	2.49	1	4.31E-06	4.31E-06	E	0.89
NE	17540	0	3.90	1	5.60E-06	5.60E-06	E	0.89
ENE	17390	0	6.17	1	9.69E-06	9.69E-06	G	2.65
E	17390	0	14.05	1	1.30E-05	1.30E-05	F	0.89
ESE	17390	0	18.80	1	1.24E-05	1.24E-05	F	0.89
SE	20630	0	10.83	1	9.51E-06	9.51E-06	G	2.65
SSE	18830	0	4.78	1	5.16E-06	5.16E-06	G	4.70

GXQ Output for Release Durations < 1 Hour

CVDF & 100-KW -- 95% Overall Site

GXQ Version 4.0
December 19, 1994

General Purpose Atmospheric Dispersion Code
Produced by Westinghouse Hanford Company

Users Guide documented in WHC-SD-GN-SWD-30002 Rev. 1.
Validation documented in WHC-SD-GN-SWD-30003 Rev. 1.
Code Custodian is: Brit E. Hey
                        Westinghouse Hanford Company
                        P.O. Box 1970
                        Richland, WA 99352
                        (509) 376-2921

Run Date = 04/12/99
Run Time = 08:26:18.46


```
INPUT ECHO:
Acute -- Ground Level Release Height
c GXQ Version 4.0 Input File
    1
c MODE SELECTION:
c   1 - X/Q based on Hanford site specific meteorology
c   2 - X/Q based on atmospheric stability class and wind speed
c   3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
c   ifox  inorm icdf  ichk  isite ipop
      T      F     F     F     T     F
c   ifox  = t then joint frequency used to compute frequency-to-exceed X/Q
c         = f then joint frequency used to compute annual average X/Q
c   inorm = t then joint frequency data is normalized (as in GENII)
c         = f then joint frequency data is un-normalized
c   icdf  = t then cumulative distribution file created (CDF.OUT)
c         = f then no cumulative distribution file created
c   ichk  = t then X/Q parameter print option turned on
c         = f then no parameter print
c   isite = t then X/Q based on joint frequency data for all 16 sectors
c         = f then X/Q based on joint frequency data of individual sectors
c   ipop  = t then X/Q is population weighted
c         = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c   ipuff idep  isrc  iwind
      0     0     0     0
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c   iwake ipm   iflow ientr
      0     0     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c   (irise igrnd)iwash igrav
      0     0     0     0
c   ipuff = 1 then X/Q calculated using puff model
c         = 0 then X/Q calculated using default continuous plume model
c   idep  = 1 then plume depletion model turned on (Chamberlain model)
c   isrc  = 1 then X/Q multiplied by scalar
c         = 2 then X/Q adjusted by wind speed function
c   iwind = 1 then wind speed corrected for plume height
c   iwake = 1 then NRC RG 1.145 building wake model turned on
c         = 2 then MACCS virtual distance building wake model turned on
c   ipm   = 1 then NRC RG 1.145 plume meander model turned on
c         = 2 then 5th Power Law plume meander model turned on
c         = 3 then sector average model turned on
c   iflow = 1 then sigmas adjusted for volume flow rate
c   ientr = 1 then method of Pasquill used to account for entrainment
c   irise = 1 then MACCS buoyant plume rise model turned on
c         = 2 then ISC2 momentum/buoyancy plume rise model turned on
```

```
c    igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c    iwash = 1 then stack downwash model turned on
c    igrav = 1 then gravitational settling model turned on
c          = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c    release        anemometer     mixing         frequency
c    height         height         height         to
c    (m)            (m)            (m)            exceed
     0.00000E+00    1.00000E+01    1.00000E+03    5.00000E+00
c
c    initial        initial                                      gravitational
c    plume          plume          release        deposition     settling
c    width          height         duration       velocity       velocity
c    Wb(m)          Hb(m)          (hour)         (m/s)          (m/s)
     0.00000E+00    0.00000E+00    0.00000E+00    1.00000E-03    1.00000E-03
c
c                   initial        initial                       convective
c    ambient        plume          plume          release        heat release
c    temperature    temperature    flow rate      diameter       rate*
c    (°C)           (°C)           (m3/s)         (m)            (watts)
     2.00000E+01    2.20000E+01    1.00000E+00    1.00000E+00    0.00000E+00
c    *If zero then buoyant flux based on plume/ambient temperature difference.
c
c    X/Q            Wind
c    scaling        Speed
c    factor         Exponent
     1.00000E+00    7.80000E-01
c
c RECEPTOR LOCATIONS (no line limit)
c    MODE                 RECEPTOR DEPENDENT DATA
c    1 (site winds)       sector, distance, receptor height
c    2 (special case)     class, windspeed, distance, offset, receptor height
c    3 (plot file)        class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
c    sector = 0, 1, 2... (all, S, SSW, etc.)
c    distance = receptor distance (m)
c    receptor height = height of receptor (m)
c
c    CVDF (& KW Reactor) Receptor Locations
c    **** site overall values -- ground level
c
```

MODE:
Site specific X/Q calculated.

LOGICAL CHOICES:
Joint frequency used to calculate X/Q based on frequency of exceedance.
No normalization of joint frequency.
X/Q calculated for overall site.

MODELS SELECTED:
Default Gaussian plume model selected.

WARNING/ERROR MESSAGES:

JOINT FREQUENCY DATA:
100 N AREA - 10 M - Pasquill A - G (1983 - 1991 Average)
Created 8/26/92 KR

Acute -- Ground Level Release Height

SECTOR	DISTANCE (m)	RECEPT HEIGHT (m)	SECT. FREQ. (%)	POPULATION	TOTAL POPULATION SCALED X/Q (s/m3)	AVERAGE INDIVIDUAL SCALED X/Q (s/m3)	ATM. STAB. CLASS	WIND SPEED (m/s)
ALL	100	0	99.80	1	6.10E-02	6.10E-02	G	0.89
ALL	100	0	99.80	1	3.44E-02	3.44E-02	F	0.89
ALL	15600	0	99.80	1	1.22E-03	1.22E-03	G	2.65
ALL	15600	0	99.80	1	1.22E-03	1.22E-03	G	2.65
ALL	24960	0	99.80	1	2.62E-05	2.62E-05	G	2.65

ALL	24960	0	99.80	1	2.62E-05	2.62E-05 G	2.65
ALL	15800	0	99.80	1	1.58E-03	1.58E-03 G	0.89
ALL	15800	0	99.80	1	1.58E-03	1.58E-03 G	0.89
ALL	25150	0	99.80	1	2.65E-05	2.65E-05 G	2.65
ALL	25150	0	99.80	1	2.66E-05	2.66E-05 G	2.65

GXQ Output for Release Durations < 1 Hour

CSB -- 95% Overall Site

GXQ Version 4.0
December 19, 1994

General Purpose Atmospheric Dispersion Code
Produced by Westinghouse Hanford Company

Users Guide documented in WHC-SD-GN-SWD-30002 Rev. 1.
Validation documented in WHC-SD-GN-SWD-30003 Rev. 1.
Code Custodian is: Brit E. Hey
                    Westinghouse Hanford Company
                    P.O. Box 1970
                    Richland, WA 99352
                    (509) 376-2921

Run Date = 04/12/99
Run Time = 08:26:29.56


```
INPUT ECHO:
Acute -- Ground Level Release Height
c GXQ Version 4.0 Input File
    1
c MODE SELECTION:
c    1 - X/Q based on Hanford site specific meteorology
c    2 - X/Q based on atmospheric stability class and wind speed
c    3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
c    ifox  inorm icdf  ichk  isite ipop
     T     F     F     F     T     F
c    ifox  = t then joint frequency used to compute frequency-to-exceed X/Q
c          = f then joint frequency used to compute annual average X/Q
c    inorm = t then joint frequency data is normalized (as in GENII)
c          = f then joint frequency data is un-normalized
c    icdf  = t then cumulative distribution file created (CDF.OUT)
c          = f then no cumulative distribution file created
c    ichk  = t then X/Q parameter print option turned on
c          = f then no parameter print
c    isite = t then X/Q based on joint frequency data for all 16 sectors
c          = f then X/Q based on joint frequency data of individual sectors
c    ipop  = t then X/Q is population weighted
c          = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c    ipuff idep  isrc  iwind
     0     0     0     0
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c    iwake ipm   iflow ientr
     0     0     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c    (irise igrnd)iwash igrav
     0     0     0     0
c    ipuff = 1 then X/Q calculated using puff model
c          = 0 then X/Q calculated using default continuous plume model
c    idep  = 1 then plume depletion model turned on (Chamberlain model)
c    isrc  = 1 then X/Q multiplied by scalar
c          = 2 then X/Q adjusted by wind speed function
c    iwind = 1 then wind speed corrected for plume height
c    iwake = 1 then NRC RG 1.145 building wake model turned on
c          = 2 then MACCS virtual distance building wake model turned on
c    ipm   = 1 then NRC RG 1.145 plume meander model turned on
c          = 2 then 5th Power Law plume meander model turned on
c          = 3 then sector average model turned on
c    iflow = 1 then sigmas adjusted for volume flow rate
c    ientr = 1 then method of Pasquill used to account for entrainment
c    irise = 1 then MACCS buoyant plume rise model turned on
c          = 2 then ISC2 momentum/buoyancy plume rise model turned on
c    igrnd = 1 then Mills' buoyant plume rise modification for ground effects
```

```
c    iwash = 1 then stack downwash model turned on
c    igrav = 1 then gravitational settling model turned on
c          = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c    release        anemometer      mixing          frequency
c    height         height          height          to
c    (m)            (m)             (m)             exceed
     0.00000E+00    1.00000E+01     1.00000E+03     5.00000E+00
c
c    initial        initial                                         gravitational
c    plume          plume           release         deposition      settling
c    width          height          duration        velocity        velocity
c    Wb(m)          Hb(m)           (hour)          (m/s)           (m/s)
     0.00000E+00    0.00000E+00     0.00000E+00     1.00000E-03     1.00000E-03
c
c                   initial         initial                         convective
c    ambient        plume           plume           release         heat release
c    temperature    temperature     flow rate       diameter        rate*
c    (°C)           (°C)            (m3/s)          (m)             (watts)
     2.00000E+01    2.20000E+01     1.00000E+00     1.00000E+00     0.00000E+00
c    *If zero then buoyant flux based on plume/ambient temperature difference.
c
c    X/Q            Wind
c    scaling        Speed
c    factor         Exponent
     1.00000E+00    7.80000E-01
c
c RECEPTOR LOCATIONS (no line limit)
c    MODE                RECEPTOR DEPENDENT DATA
c    1 (site winds)      sector, distance, receptor height
c    2 (special case)    class, windspeed, distance, offset, receptor height
c    3 (plot file)       class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
c    sector = 0, 1, 2... (all, S, SSW, etc.)
c    distance = receptor distance (m)
c    receptor height = height of receptor (m)
c
c  CSB Receptor Locations
c  **** site overall values -- ground level
c
```

MODE:
Site specific X/Q calculated.

LOGICAL CHOICES:
Joint frequency used to calculate X/Q based on frequency of exceedance.
No normalization of joint frequency.
X/Q calculated for overall site.

MODELS SELECTED:
Default Gaussian plume model selected.

WARNING/ERROR MESSAGES:

JOINT FREQUENCY DATA:
200 AREA (HMS) - 10 M - Pasquill A - G (1983 - 1991 Average)
Created 8/26/92 KR

Acute -- Ground Level Release Height

SECTOR	DISTANCE (m)	RECEPT HEIGHT (m)	SECT. FREQ. (%)	POPULATION	TOTAL POPULATION SCALED X/Q (s/m3)	AVERAGE INDIVIDUAL SCALED X/Q (s/m3)	ATM. STAB. CLASS	WIND SPEED (m/s)
ALL	100	0	99.94	1	3.28E-02	3.28E-02	F	0.89
ALL	100	0	99.94	1	3.44E-02	3.44E-02	F	0.89
ALL	8490	0	99.94	1	2.02E-05	2.02E-05	G	2.65
ALL	8490	0	99.94	1	2.02E-05	2.02E-05	G	2.65
ALL	18830	0	99.94	1	1.16E-05	1.16E-05	F	0.89
ALL	18830	0	99.94	1	1.16E-05	1.16E-05	F	0.89

GXQ Input for Release Durations from 1 Hour to 2 Hours

```
Acute with Plume Meander -- Ground Level Release Height
c GXQ Version 4.0 Input File
     1
c MODE SELECTION:
c    1 - X/Q based on Hanford site specific meteorology
c    2 - X/Q based on atmospheric stability class and wind speed
c    3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
c    ifox  inorm icdf  ichk  isite ipop
     t     f     f     f     f     f
c    ifox  = t then joint frequency used to compute frequency-to-exceed X/Q
c          = f then joint frequency used to compute annual average X/Q
c    inorm = t then joint frequency data is normalized (as in GENII)
c          = f then joint frequency data is un-normalized
c    icdf  = t then cumulative distribution file created (CDF.OUT)
c          = f then no cumulative distribution file created
c    ichk  = t then X/Q parameter print option turned on
c          = f then no parameter print
c    isite = t then X/Q based on joint frequency data for all 16 sectors
c          = f then X/Q based on joint frequency data of individual sectors
c    ipop  = t then X/Q is population weighted
c          = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c    ipuff idep  isrc  iwind
     0     0     0     0
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c    iwake ipm   iflow ientr
     0     1     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c    (irise igrnd)iwash igrav
     0     0     0     0
c    ipuff = 1 then X/Q calculated using puff model
c          = 0 then X/Q calculated using default continuous plume model
c    idep  = 1 then plume depletion model turned on (Chamberlain model)
c    isrc  = 1 then X/Q multiplied by scalar
c          = 2 then X/Q adjusted by wind speed function
c    iwind = 1 then wind speed corrected for plume height
c    iwake = 1 then NRC RG 1.145 building wake model turned on
c          = 2 then MACCS virtual distance building wake model turned on
c    ipm   = 1 then NRC RG 1.145 plume meander model turned on
c          = 2 then 5th Power Law plume meander model turned on
c          = 3 then sector average model turned on
c    iflow = 1 then sigmas adjusted for volume flow rate
c    ientr = 1 then method of Pasquill used to account for entrainment
c    irise = 1 then MACCS buoyant plume rise model turned on
c          = 2 then ISC2 momentum/buoyancy plume rise model turned on
c    igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c    iwash = 1 then stack downwash model turned on
c    igrav = 1 then gravitational settling model turned on
c          = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c    release     anemometer  mixing      frequency
c    height      height      height      to
c    (m)         (m)         (m)         exceed
     0.0         10          1000        0.5
c
c    initial     initial                             gravitational
c    plume       plume       release     deposition  settling
c    width       height      duration    velocity    velocity
c    Wb(m)       Hb(m)       (hour)      (m/s)       (m/s)
     0           0           0           0.001       0.001
c
c                initial     initial                 convective
c    ambient     plume       plume       release     heat release
c    temperature temperature flow rate   diameter    rate*
c    (°C)        (°C)        (m3/s)      (m)         (watts)
     20          22          1           1           0
c    *If zero then buoyant flux based on plume/ambient temperature difference.
c
c    X/Q         Wind
c    scaling     Speed
```

```
c    factor        Exponent
     1             .78
c
c RECEPTOR LOCATIONS (no line limit)
c    MODE                 RECEPTOR DEPENDENT DATA
c    1 (site winds)       sector, distance, receptor height
c    2 (special case)     class, windspeed, distance, offset, receptor height
c    3 (plot file)        class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
c    sector = 0, 1, 2... (all, S, SSW, etc.)
c    distance = receptor distance (m)
c    receptor height = height of receptor (m)
c    class = 1,2,3,4,5,6,7 (Pasquill stability A,B,C,D,E,F,G)
c    windspeed = anemometer wind speed (m/s)
c    offset = offset from plume centerline (m)
c    xmax  = maximum distance to plot or calculate to (m)
c    imax  = distance intervals
c    ymax  = maximum offset to plot (m)
c    jmax  = offset intervals
c    xqmin = minimum scaled X/Q to calculate
c    power = exponent in power function step size
```

Note: The GXQ input for overall site X/Q is identical except that the "isite" flag is "t" and the "frequency to exceed" is changed from 0.5 to 5.0.

GXQ Input for Chronic Releases

```
Chronic -- Ground Level Release Height
c GXQ Version 4.0 Input File
    1
c MODE SELECTION:
c    1 - X/Q based on Hanford site specific meteorology
c    2 - X/Q based on atmospheric stability class and wind speed
c    3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
c    ifox  inorm icdf  ichk  isite ipop
     f     f     f     f     f     f
c    ifox  = t then joint frequency used to compute frequency-to-exceed X/Q
c          = f then joint frequency used to compute annual average X/Q
c    inorm = t then joint frequency data is normalized (as in GENII)
c          = f then joint frequency data is un-normalized
c    icdf  = t then cumulative distribution file created (CDF.OUT)
c          = f then no cumulative distribution file created
c    ichk  = t then X/Q parameter print option turned on
c          = f then no parameter print
c    isite = t then X/Q based on joint frequency data for all 16 sectors
c          = f then X/Q based on joint frequency data of individual sectors
c    ipop  = t then X/Q is population weighted
c          = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c    ipuff idep  isrc  iwind
     0     0     0     0
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c    iwake ipm   iflow ientr
     0     3     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c   (irise igrnd)iwash igrav
     0     0     0     0
c    ipuff = 1 then X/Q calculated using puff model
c          = 0 then X/Q calculated using default continuous plume model
c    idep  = 1 then plume depletion model turned on (Chamberlain model)
c    isrc  = 1 then X/Q multiplied by scalar
c          = 2 then X/Q adjusted by wind speed function
c    iwind = 1 then wind speed corrected for plume height
c    iwake = 1 then NRC RG 1.145 building wake model turned on
c          = 2 then MACCS virtual distance building wake model turned on
c    ipm   = 1 then NRC RG 1.145 plume meander model turned on
c          = 2 then 5th Power Law plume meander model turned on
c          = 3 then sector average model turned on
c    iflow = 1 then sigmas adjusted for volume flow rate
c    ientr = 1 then method of Pasquill used to account for entrainment
c    irise = 1 then MACCS buoyant plume rise model turned on
c          = 2 then ISC2 momentum/buoyancy plume rise model turned on
c    igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c    iwash = 1 then stack downwash model turned on
c    igrav = 1 then gravitational settling model turned on
c          = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c    release       anemometer      mixing        frequency
c    height        height          height        to
c    (m)           (m)             (m)           exceed
     0.0           10              1000          0.5
c
c    initial       initial                                     gravitational
c    plume         plume           release       deposition    settling
c    width         height          duration      velocity      velocity
c    Wb(m)         Hb(m)           (hour)        (m/s)         (m/s)
     0             0               0             0.001         0.001
c
c                  initial         initial                     convective
c    ambient       plume           plume         release       heat release
c    temperature   temperature     flow rate     diameter      rate*
c    (°C)          (°C)            (m3/s)        (m)           (watts)
     20            22              1             1             0
c    *If zero then buoyant flux based on plume/ambient temperature difference.
c
c    X/Q           Wind
c    scaling       Speed
```

```
c    factor          Exponent
     1               .78
c
c RECEPTOR LOCATIONS (no line limit)
c   MODE                RECEPTOR DEPENDENT DATA
c   1 (site winds)      sector, distance, receptor height
c   2 (special case)    class, windspeed, distance, offset, receptor height
c   3 (plot file)       class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
c   sector = 0, 1, 2... (all, S, SSW, etc.)
c   distance = receptor distance (m)
c   receptor height = height of receptor (m)
c   class = 1,2,3,4,5,6,7 (Pasquill stability A,B,C,D,E,F,G)
c   windspeed = anemometer wind speed (m/s)
c   offset = offset from plume centerline (m)
c   xmax  = maximum distance to plot or calculate to (m)
c   imax  = distance intervals
c   ymax  = maximum offset to plot (m)
c   jmax  = offset intervals
c   xqmin = minimum scaled X/Q to calculate
c   power = exponent in power function step size
```

Note: The GXQ input for overall site X/Q is identical except that the "isite" flag is "t" and the "frequency to exceed" is changed from 0.5 to 5.0.

GXQ Input for Puff Releases

```
Acute Puff (1 sec) -- Ground Level Release Height
c GXQ Version 4.0 Input File
    1
c MODE SELECTION:
c   1 - X/Q based on Hanford site specific meteorology
c   2 - X/Q based on atmospheric stability class and wind speed
c   3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
c   ifox  inorm icdf  ichk  isite ipop
c   t     f     f     f     f     f
c   ifox  = t then joint frequency used to compute frequency-to-exceed X/Q
c         = f then joint frequency used to compute annual average X/Q
c   inorm = t then joint frequency data is normalized (as in GENII)
c         = f then joint frequency data is un-normalized
c   icdf  = t then cumulative distribution file created (CDF.OUT)
c         = f then no cumulative distribution file created
c   ichk  = t then X/Q parameter print option turned on
c         = f then no parameter print
c   isite = t then X/Q based on joint frequency data for all 16 sectors
c         = f then X/Q based on joint frequency data of individual sectors
c   ipop  = t then X/Q is population weighted
c         = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c   ipuff idep  isrc  iwind
    1     0     0     0
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c   iwake ipm   iflow ientr
    0     0     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c   (irise igrnd)iwash igrav
    0     0     0     0
c   ipuff = 1 then X/Q calculated using puff model
c         = 0 then X/Q calculated using default continuous plume model
c   idep  = 1 then plume depletion model turned on (Chamberlain model)
c   isrc  = 1 then X/Q multiplied by scalar
c         = 2 then X/Q adjusted by wind speed function
c   iwind = 1 then wind speed corrected for plume height
c   iwake = 1 then NRC RG 1.145 building wake model turned on
c         = 2 then MACCS virtual distance building wake model turned on
c   ipm   = 1 then NRC RG 1.145 plume meander model turned on
c         = 2 then 5th Power Law plume meander model turned on
c         = 3 then sector average model turned on
c   iflow = 1 then sigmas adjusted for volume flow rate
c   ientr = 1 then method of Pasquill used to account for entrainment
c   irise = 1 then MACCS buoyant plume rise model turned on
c         = 2 then ISC2 momentum/buoyancy plume rise model turned on
c   igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c   iwash = 1 then stack downwash model turned on
c   igrav = 1 then gravitational settling model turned on
c         = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c   release       anemometer    mixing        frequency
c   height        height        height        to
c   (m)           (m)           (m)           exceed
    0.0           10            1000          0.5
c
c   initial       initial                                   gravitational
c   plume         plume         release       deposition    settling
c   width         height        duration      velocity      velocity
c   Wb(m)         Hb(m)         (hour)        (m/s)         (m/s)
    0             0             2.7778E-4     0.001         0.001
c
c                 initial       initial                     convective
c   ambient       plume         plume         release       heat release
c   temperature   temperature   flow rate     diameter      rate*
c   (°C)          (°C)          (m3/s)        (m)           (watts)
    20            22            1             1             0
c   *If zero then buoyant flux based on plume/ambient temperature difference.
c
c   X/Q           Wind
c   scaling       Speed
```

```
c   factor          Exponent
    1               .78
c
c RECEPTOR LOCATIONS (no line limit)
c   MODE                 RECEPTOR DEPENDENT DATA
c   1 (site winds)    sector, distance, receptor height
c   2 (special case)  class, windspeed, distance, offset, receptor height
c   3 (plot file)     class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
c   sector = 0, 1, 2... (all, S, SSW, etc.)
c   distance = receptor distance (m)
c   receptor height = height of receptor (m)
c   class = 1,2,3,4,5,6,7 (Pasquill stability A,B,C,D,E,F,G)
c   windspeed = anemometer wind speed (m/s)
c   offset = offset from plume centerline (m)
c   xmax  = maximum distance to plot or calculate to (m)
c   imax  = distance intervals
c   ymax  = maximum offset to plot (m)
c   jmax  = offset intervals
c   xqmin = minimum scaled X/Q to calculate
c   power = exponent in power function step size
```

Note: The GXQ input for overall site X/Q is identical except that the "isite" flag is "t" and the "frequency to exceed" is changed from 0.5 to 5.0.

GXQ Input for Receptor Locations

```
c
c   CVDF (& KW Reactor) Receptor Locations
c   **** sector maximum values -- ground level
c
 0        100      0    100 meter
14       3750      0    Fire Station
 1      12650      0    CVDF -- Near Bank of Columbia
 2      11340      0            River and Highway 240
 3       1690      0
 4        700      0
 5        650      0
 6        580      0
 7        580      0
 8        580      0
 9        580      0
10        640      0
11        860      0
12       2540      0
13      11470      0
14      12060      0
15      15150      0
16      15600      0
 1      24960      0    CVDF -- Legal Boundary
 2      17130      0
 3      15510      0
 4      11990      0
 5      10090      0
 6       8740      0
 7       8740      0
 8       8740      0
 9       8930      0
10      10750      0
11      15390      0
12      20080      0
13      20510      0
14      20670      0
15      21790      0
16      24960      0
 1      12850      0    100-KW -- Near Bank of Columbia
 2      11400      0            River and Highway 240
 3       1060      0
 4        710      0
 5        520      0
 6        480      0
 7        480      0
 8        480      0
 9        480      0
10        530      0
11        730      0
12       2250      0
13      11330      0
14      11780      0
15      15050      0
16      15800      0
 1      25150      0    100-KW -- Legal Boundary
 2      17310      0
 3      15660      0
 4      12040      0
 5      10070      0
 6       8650      0
 7       8650      0
 8       8650      0
 9       8810      0
10      10910      0
11      15190      0
12      19880      0
13      20380      0
14      20570      0
15      21700      0
16      25150      0

c
c   CVDF (& KW Reactor) Receptor Locations
c   **** site overall values -- ground level
```

```
c
0        100       0    100 meter
1        100.01    0    100 meter -- PDR method
2        100.02    0
3        100.03    0
4        100.04    0
5        100.05    0
6        100.06    0
7        100.07    0
8        100.08    0
9        100.09    0
10       100.10    0
11       100.11    0
12       100.12    0
13       100.13    0
14       100.14    0
15       100.15    0
16       100.16    0
1        12650     0    CVDF -- Near Bank of Columbia
2        11340     0           River and Highway 240
3         1690     0
4          700     0
5          650     0
6          580     0
7          580     0
8          580     0
9          580     0
10         640     0
11         860     0
12        2540     0
13       11470     0
14       12060     0
15       15150     0
16       15600     0
1        12650     0    CVDF -- Near Bank of Columbia
2        11340     0           River and Highway 240
3         1690     0
4          700     0
5          650     0
6          580     0
7          580.02  0
8          580.03  0
9          580.04  0
10         640     0
11         860     0
12        2540     0
13       11470     0
14       12060     0
15       15150     0
16       15600     0
1        24960     0    CVDF -- Legal Boundary
2        17130     0
3        15510     0
4        11990     0
5        10090     0
6         8740     0
7         8740     0
8         8740     0
9         8930     0
10       10750     0
11       15390     0
12       20080     0
13       20510     0
14       20670     0
15       21790     0
16       24960     0
1        24960.02  0    CVDF -- Legal Boundary
2        17130     0
3        15510     0
4        11990     0
5        10090     0
6         8740.02  0
7         8740     0
8         8740.04  0
9         8930     0
10       10750     0
11       15390     0
```

```
12      20080      0
13      20510      0
14      20670      0
15      21790      0
16      24960      0
 1      12850      0      100-KW -- Near Bank of Columbia
 2      11400      0             River and Highway 240
 3       1060      0   .
 4        710      0
 5        520      0
 6        480      0
 7        480      0
 8        480      0
 9        480      0
10        530      0
11        730      0
12       2250      0
13      11330      0
14      11780      0
15      15050      0
16      15800      0
 1      12850      0      100-KW -- Near Bank of Columbia
 2      11400      0             River and Highway 240
 3       1060      0
 4        710      0
 5        520      0
 6        480      0
 7     480.02      0
 8     480.03      0
 9     480.04      0
10        530      0
11        730      0
12       2250      0
13      11330      0
14      11780      0
15      15050      0
16      15800      0
 1      25150      0      100-KW -- Legal Boundary
 2      17310      0
 3      15660      0
 4      12040      0
 5      10070      0
 6       8650      0
 7       8650      0
 8       8650      0
 9       8810      0
10      10910      0
11      15190      0
12      19880      0
13      20380      0
14      20570      0
15      21700      0
16      25150      0
 1   25150.02      0      100-KW -- Legal Boundary
 2      17310      0
 3      15660      0
 4      12040      0
 5      10070      0
 6    8650.02      0
 7       8650      0
 8    8650.04      0
 9       8810      0
10      10910      0
11      15190      0
12      19880      0
13      20380      0
14      20570      0
15      21700      0
16      25150      0

c
c   CSB Receptor Locations
c   **** sector maximum values -- ground level
c
 0        100      0      100 meter
 1       7830      0      CSB -- Near Bank of Columbia
 2       7830      0             River and Highway 240
```

```
3      7830      0
4      7830      0
5      9280      0
6     10510      0                        .
7     11250      0
8     11250      0
9     11250      0
10     12750      0
11     12670      0
12     12670      0
13     12670      0
14     14230      0
15     11070      0
16      8490      0
1     16260      0          CSB -- Legal Boundary
2     16260      0
3     16260      0
4     17910      0
5     18400      0
6     18400      0
7     18870      0
8     19450      0
9     19450      0
10     20390      0
11     17540      0
12     17390      0
13     17390      0
14     17390      0
15     20630      0
16     18830      0

c
c  CSB Receptor Locations
c  **** site overall values -- ground level
c
0       100       0      100 meter
1     100.01      0      100 meter -- PDR method
2     100.02      0
3     100.03      0
4     100.04      0
5     100.05      0
6     100.06      0
7     100.07      0
8     100.08      0
9     100.09      0
10     100.10      0
11     100.11      0
12     100.12      0
13     100.13      0
14     100.14      0
15     100.15      0
16     100.16      0
1      7830       0          CSB -- Near Bank of Columbia
2      7830       0              River and Highway 240
3      7830       0
4      7830       0
5      9280       0
6     10510       0
7     11250       0
8     11250       0
9     11250       0
10     12750       0
11     12670       0
12     12670       0
13     12670       0
14     14230       0
15     11070       0
16      8490       0
1      7830.04     0          CSB -- Near Bank of Columbia
2      7830.03     0              River and Highway 240
3      7830.02     0
4      7830        0
5      9280        0
6     10510        0
7     11250.02     0
8     11250        0
9     11250.04     0
```

10	12750	0	
11	12670.02	0	
12	12670	0	
13	12670.04	0	
14	14230	0	
15	11070	0	
16	8490	0	
1	16260	0	CSB -- Legal Boundary
2	16260	0	
3	16260	0	
4	17910	0	
5	18400	0	
6	18400	0	
7	18870	0	
8	19450	0	
9	19450	0	
10	20390	0	
11	17540	0	
12	17390	0	
13	17390	0	
14	17390	0	
15	20630	0	
16	18830	0	
1	16260.04	0	CSB -- Legal Boundary
2	16260.02	0	
3	16260	0	
4	17910	0	
5	18400	0	
6	18400.02	0	
7	18870	0	
8	19450	0	
9	19450.02	0	
10	20390	0	
11	17540	0	
12	17390.02	0	
13	17390	0	
14	17390.04	0	
15	20630	0	
16	18830	0	

DOS Batch File to Combine Distances with Ground-Level Release Input Files and Run GXQ

```
@Echo Off
:    XQG.BAT by Paul D. Rittmann, PhD CHP
:    Runs GXQ ground-level release cases for SNF
:    Combines input file & distance file first
:    Specify which case to run on the command line

:START
Echo ^[37m
IF "%1"=="1"  Goto OK-1
IF "%1"=="2"  Goto OK-2
Echo ^[36m
Echo   Need to specify 100 or 200 Area cases on the command line.^[32m
Echo      1 == run CVDF & 100-KW cases
Echo      2 == run CSB cases^[36m
Echo   Example:  to run both cases type  ^[33m XQG  1  2
Goto End

:OK-1
CD\GXQ
Call JFP 1 10 B
Copy TI-059\XQ2\SS01.IN
Call RN SS01
Del SS01.IN
Goto XQ

:OK-2
CD\GXQ
Call JFP 2 10 B
Copy TI-059\XQ2\SS02.IN
Copy TI-059\XQ2\SS03.IN
Call RN SS02 SS03
Del SS02.IN
Del SS03.IN

:XQ
:  first, the sector X/Q calcs for <1h, 1h-2h, chronic, and puff
For %%f in (A B C D) Do Copy TI-059\XQ2\GS%%f.IN+TI-059\XQ2\GS%1.DST GS%%f%1.IN
Call RN GSA%1 GSB%1 GSC%1 GSD%1
Del GS?%1.IN
:  second, the overall site X/Q calcs for <1h, 1h-2h, chronic, and puff
For %%f in (A B C D) Do Copy TI-059\XQ2\GO%%f.IN+TI-059\XQ2\GO%1.DST GO%%f%1.IN
Call RN GOA%1 GOB%1 GOC%1 GOD%1
Del GO?%1.IN
Shift
IF not "%1"=="" Goto START

:End
PD /6
```

APPENDIX C

AIR TRANSPORT FACTORS FOR ELEVATED RELEASES

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APPENDIX C

AIR TRANSPORT FACTORS FOR ELEVATED RELEASES

In the analysis of stack emissions from the Cold Vacuum Drying Facility (CVDF) and Canister Storage Building (CSB), it will be assumed that the main building is intact and causes wind eddies, which have two main effects. The first effect is to entrain the heating, ventilation, and air conditioning (HVAC) stack emissions and reduce the effective height of the release. The second effect is to dilute the emitted air near the point of release thereby reducing the air concentration at all downwind locations. Note that ground-level emissions were assumed to come from point sources with no building wake effects.

Cold Vacuum Drying Facility Layout

The HVAC emission stack for the CVDF is located about 4.57 m (15 ft) west of the building (based on the 100 K Area grid, which is rotated 27.3° counterclockwise from true north). The CVDF stack is 14.63 m (48 ft) tall and 0.76 m (30 in.) in diameter. The expected flow rate from the stack is 8.33 m³/s (17,650 ft³/min), so the linear exit speed of the gases is 18.3 m/s (40.9 mi/hr). This vertical jet will rise considerably because of its own momentum. The next section discusses the modeling of plume rise.

The CVDF itself is about 10.67 m (35 ft) tall. The building is 51.68 m (170 ft) in the north-south direction (100 K grid) and 24.38 m (80 ft) in the east-west direction (100 K grid). Because the process bay HVAC stack and the building are close together and about the same height, the building will have a significant effect on the projected downwind concentrations.

Canister Storage Building Facility Layout

The HVAC emission stack for the CSB is located about 8.53 m (28 ft) north of the building. The CSB stack is 22.86 m (75 ft) tall and 0.71 m (28 in.) in diameter. The expected flow rate from the stack is 2.12 m³/s (4,500 ft³/min), so the linear exit speed of the gases is 5.35 m/s (12.0 mi/hr). This vertical jet will rise very little because of its own momentum. The next section discusses the modeling of plume rise.

The CSB itself is about 18.29 m (60 ft) tall. The building is 70.41 m (231 ft) in the north-south direction and 42.37 m (139 ft) in the east-west direction. Because the HVAC stack and the building are close together and about the same height, the building will have a significant effect on the projected downwind concentrations.

The natural circulation emission stacks for the CSB are located on the east side of the building. These stacks are 47.55 m (156 ft) tall and 2.13 m (7 ft) in diameter at the top. The assumed flow rate from each stack is 3.8 m³/s (8,000 ft³/min), so the linear exit speed of the gases is 1.06 m/s (2.4 mi/hr). This vertical jet will rise very little because of its own momentum. The stack is more than 2.5 times the height of the CSB, so it will be modeled as a free stack.

The proximity of the CSB will normally have no influence on the air concentrations downwind. The factor of 2.5 comes from various NRC Regulatory Guides (e.g., NRC Regulatory Guide 1.145).

Modeling Plume Rise

The industrial source complex plume rise model found in the GXQ computer code (WHC-SD-GN-SWD-30002, WHC-SD-GN-SWD-30003) is used for the Spent Nuclear Fuel Project facility stacks described above. To be conservative, only momentum effects and stack downwash effects are considered. It is assumed that the temperature of the exhaust air is the same as the air temperature at the top of the stack, so buoyant effects are not included. The tables below show the GXQ results for the height the plume rises above the top of the stack, the total final height of the plume, and the effective wind speed at the final height. The GXQ program adjusts the wind speed as the plume rises in a manner similar to the MACCS software (WHC-SD-GN-SWD-30002, NUREG/CR-4691).

Tables C-1, C-2, and C-3 show the expected plume rise and elevated wind speeds for CVDF and CSB emissions using the GXQ software (WHC-SD-GN-SWD-30002). Note that the negative plume rise values for the CSB are due to stack downwash exceeding the plume rise. To approximate the expected plume rise for the fumigation model, the average effective plume height for the stable categories (class E, F, and G) was determined. For CVDF this was 31 m. For CSB it was 30 m (HVAC) and 48 m (natural circulation).

Air Transport Factors

The GXQ program (WHC-SD-GN-SWD-30002) has been used to calculate air transport factors. The methods described in Section 4.0 of this document were used. Sample input files are contained in Appendixes E. The air transport factors were calculated for all 16 wind transport directions to identify the worst direction (sector maximum 99.5%). The overall site (95%) air transport factor was also computed. In addition, the air transport factors were calculated at 100, 150, 200, 250, 300, 350, 400, 450, 500, 550, and 600 m for the onsite worker to ensure that the worst-case distance was identified. Resulting air transport factors for each wind transport direction are shown in Tables C-4 through C-12. The worst-case results are shown in Table 2 of this document. Note that in all cases the receptor height was increased to 2 m. This increase represents the receptor being in a standing position. In most cases, this receptor height increases the air transport factor. In all cases, the effect of changing the release height from zero meters to 2 m is very small.

REFERENCES

NRC Regulatory Guide 1.145, 1982, *Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants*, U.S. Nuclear Regulatory Commission, Washington, D.C.

NUREG/CR-4691 (SAND86-1562), 1990, *MELCOR Accident Consequence Code System (MACCS)*, Sandia National Laboratories, Albuquerque, New Mexico.

WHC-SD-GN-SWD-30002, 1993, *GXQ Program Users' Guide*, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-GN-SWD-30003, 1993, *GXQ Program Verification and Validation*, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

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Table C-1. Plume Rise for the Cold Vacuum Drying Facility 48-Foot
Heating, Ventilation, and Air Conditioning Stack.

Stability class	Wind speed (m/s) at 10-m elevation				
	0.89	2.65	4.70	7.15	9.80
Plume rise (m) due to exhaust momentum					
A	43.48	14.95	8.51	5.62	4.11
B	43.48	14.95	8.51	5.62	4.11
C	42.12	14.64	8.35	5.53	4.05
D	39.98	14.13	8.09	5.38	3.95
E	18.38	12.34	7.24	4.86	3.56
F	15.05	10.64	6.50	4.40	3.27
G	13.40	9.47	6.34	4.30	
Final plume height (m)					
A	58.11	29.58	23.14	20.25	18.74
B	58.11	29.58	23.14	20.25	18.74
C	56.75	29.27	22.98	20.16	18.68
D	54.61	28.76	22.72	20.01	18.58
E	33.01	26.97	21.87	19.49	18.19
F	29.69	25.27	21.13	19.03	17.90
G	28.03	24.11	20.97	18.93	
Stable average	30.2	25.4	21.3	19.1	18.0
Wind speed (m/s) at the plume height					
A	0.96	2.79	4.91	7.43	10.15
B	0.96	2.79	4.91	7.43	10.15
C	0.99	2.85	5.00	7.55	10.31
D	1.05	2.96	5.15	7.75	10.56
E	1.18	3.39	5.78	8.60	11.64
F	1.36	3.84	6.44	9.50	12.79
G	1.38	3.91	6.62	9.73	

Note: The above values were computed by the GXQ computer code using the industrial source complex momentum rise model with the MACCS plume rise/wind speed adjustment. The CVDF HVAC stack height and diameter are 48 ft and 30 in., and the exhaust flow rate is 17,650 ft^3/min.

Table C-2. Plume Rise for the Canister Storage Building 75-Foot
Heating, Ventilation, and Air Conditioning Stack.

Stability class	Wind speed (m/s) at 10-m elevation				
	0.89	2.65	4.70	7.15	9.80
Plume rise (m) due to exhaust momentum					
A	11.91	4.04	1.68	0.47	-0.23
B	11.91	4.04	1.68	0.47	-0.23
C	11.56	3.93	1.59	0.44	-0.25
D	10.99	3.75	1.43	0.40	-0.28
E	7.58	3.15	0.88	0.26	-0.39
F	6.13	2.35	0.41	0.14	
G	5.42	2.17	0.31		
Final plume height (m)					
A	34.77	26.90	24.54	23.33	22.63
B	34.77	26.90	24.54	23.33	22.63
C	34.42	26.79	24.45	23.30	22.61
D	33.85	26.61	24.29	23.26	22.58
E	30.44	26.01	23.74	23.12	22.47
F	28.99	25.21	23.27	23.00	
G	28.28	25.03	23.17		
Stable average	29.2	25.4	23.4	15.4	11.2
Wind wpeed (m/s) at the plume height					
A	0.96	2.82	4.99	7.58	10.38
B	0.96	2.82	4.99	7.58	10.38
C	0.99	2.90	5.12	7.77	10.64
D	1.04	3.03	5.34	8.10	11.08
E	1.25	3.62	6.32	9.57	13.05
F	1.50	4.29	7.44	11.29	
G	1.56	4.47	7.75		

Note: The above values were computed by the GXQ computer code using the industrial source
complex momentum rise model with the MACCS plume rise/wind speed adjustment. The CSB HVAC
stack height and diameter are 75 ft and 28 in., and the exhaust flow rate is 4,500 ft³/min.

Table C-3. Plume Rise for the Canister Storage Building
156-Foot Natural Circulation Stack.

Stability class	Wind speed (m/s) at 10-m elevation				
	0.89	2.65	4.70	7.15	9.80
Plume rise (m) due to exhaust momentum					
A	4.36	-3.20	-4.73	-5.36	-5.67
B	4.36	-3.20	-4.73	-5.36	-5.67
C	3.83	-3.37	-4.81	-5.41	-5.71
D	2.98	-3.62	-4.95	-5.49	-5.76
E	-0.17	-4.45	-5.37	-5.76	-5.95
F	0.22	-5.02	-5.67	-5.94	
G	-0.40	-5.15	-5.73		
Final plume height (m)					
A	51.91	44.35	42.82	42.19	41.88
B	51.91	44.35	42.82	42.19	41.88
C	51.37	44.18	42.74	42.14	41.84
D	50.53	43.93	42.60	42.06	41.79
E	47.38	43.10	42.18	41.79	41.60
F	47.77	42.53	41.88	41.61	
G	47.15	42.40	41.82		
Stable average	47.4	42.7	42.0	27.8	20.8
Wind speed (m/s) at the plume height					
A	1.00	2.95	5.22	7.94	10.88
B	1.00	2.95	5.22	7.94	10.88
C	1.04	3.09	5.46	8.31	11.38
D	1.13	3.33	5.89	8.95	12.26
E	1.54	4.50	· 7.94	12.07	16.53
F	2.10	6.06	10.71	16.26	
G	2.26	6.53	11.53		

Note: The above values were computed by the GXQ computer code using the industrial source complex momentum rise model with the MACCS plume rise/wind speed adjustment. The Canister Storage Building natural circulation stack height and diameter are 156 ft and 7 ft, and the exhaust flow rate is assumed to be 8,000 ft³/min.

Table C-4. Air Transport Factors for Releases from the Cold Vacuum Drying Facility's Heating, Ventilation, and Air Conditioning Stack (48 Feet) to Onsite Workers.

Transport direction	Air transport factors, s/m^3			
	Fumigation	<0.5 hr	0.5 to 2 hr	Annual
S	5.07E-03	5.11E-04	6.73E-04	1.65E-05
SSW	4.05E-03	4.47E-04	3.71E-04	1.06E-05
SW	4.40E-03	4.44E-04	3.71E-04	9.69E-06
WSW	4.67E-03	4.52E-04	3.82E-04	9.54E-06
W	6.14E-03	5.41E-04	6.63E-04	1.97E-05
WNW	4.67E-03	5.31E-04	5.82E-04	1.58E-05
NW	4.37E-03	5.08E-04	5.13E-04	1.35E-05
NNW	3.60E-03	4.71E-04	4.02E-04	9.94E-06
N	4.22E-03	5.15E-04	5.40E-04	1.25E-05
NNE	3.82E-03	4.66E-04	3.75E-04	9.34E-06
NE	4.56E-03	4.86E-04	4.46E-04	1.30E-05
ENE	5.75E-03	4.84E-04	5.13E-04	1.72E-05
E	6.88E-03	5.32E-04	6.66E-04	2.76E-05
ESE	6.06E-03	4.98E-04	6.28E-04	1.88E-05
SE	5.50E-03	4.95E-04	6.42E-04	1.51E-05
SSE	5.11E-03	4.84E-04	6.04E-04	1.29E-05
Sector Maximum (99.5%)	6.88E-03 100 m E	5.41E-04 250 m W	6.73E-04 100 m S	2.76E-05 150 m E
Overall Site (95%)	6.24E-03 100 m	5.41E-04 250 m	6.98E-04 100 m	1.45E-05 150 m

Note: "Sector Maximum" is the largest value of the 16 wind transport directions. Distances ranging from 100 m to 600 m in 50-m increments were used to determine the worst-case location. The distance with the largest air transport factors is listed at the bottom of each column.

Table C-5. Air Transport Factors for Releases from the Cold Vacuum Drying Facility's
Heating, Ventilation, and Air Conditioning Stack (48 Feet) to the
Nearest Point of Public Access.

Transport direction	Distance (meters)	Air transport factors, s/m³			
		Fumigation	<0.5 hr	0.5 to 2 hr	Annual
S	12,650	4.12E-05	2.06E-05	1.61E-05	6.58E-08
SSW	11,340	3.70E-05	1.67E-05	1.39E-05	4.96E-08
SW	1,690	2.22E-04	1.93E-04	8.55E-05	8.14E-07
WSW	700	6.19E-04	3.94E-04	1.62E-04	3.31E-06
W	650	9.93E-04	4.39E-04	1.92E-04	7.16E-06
WNW	580	7.74E-04	4.30E-04	2.01E-04	5.69E-06
NW	580	7.15E-04	4.29E-04	1.96E-04	4.69E-06
NNW	580	5.61E-04	4.17E-04	1.85E-04	3.34E-06
N	580	6.85E-04	4.28E-04	1.94E-04	4.21E-06
NNE	640	4.39E-04	3.91E-04	1.64E-04	2.92E-06
NE	860	4.66E-04	2.97E-04	1.41E-04	2.79E-06
ENE	2,540	2.15E-04	1.73E-04	8.40E-05	9.09E-07
E	11,470	5.97E-05	4.14E-05	2.98E-05	1.75E-07
ESE	12,060	5.07E-05	3.12E-05	2.32E-05	9.93E-08
SE	15,150	3.77E-05	1.97E-05	1.55E-05	5.39E-08
SSE	15,600	3.44E-05	1.63E-05	1.31E-05	4.41E-08
Sector Maximum (99.5%)		9.93E-04	4.39E-04	2.01E-04	7.16E-06
Overall Site (95%)		5.22E-04	4.18E-04	1.83E-04	2.27E-06

Table C-6. Air Transport Factors for Releases from the Cold Vacuum Drying Facility's
Heating, Ventilation, and Air Conditioning Stack (48 Feet) to the Hanford Site Boundary.

Transport direction	Distance (meters)	Air transport factors, s/m³			
		Fumigation	<0.5 hr	0.5 to 2 hr	Annual
S	24,960	2.23E-05	9.09E-06	7.77E-06	2.60E-08
SSW	17,130	2.55E-05	1.03E-05	8.95E-06	2.80E-08
SW	15,510	3.01E-05	1.30E-05	1.09E-05	3.46E-08
WSW	11,990	4.01E-05	1.91E-05	1.51E-05	6.11E-08
W	10,090	6.02E-05	3.95E-05	2.82E-05	1.48E-07
WNW	8,740	5.33E-05	2.78E-05	2.08E-05	1.14E-07
NW	8,740	5.02E-05	2.52E-05	1.95E-05	9.25E-08
NNW	8,740	4.21E-05	1.76E-05	1.16E-05	6.47E-08
N	8,930	4.77E-05	2.23E-05	1.79E-05	7.96E-08
NNE	10,750	3.68E-05	9.74E-06	9.63E-06	4.99E-08
NE	15,390	3.13E-05	1.36E-05	1.13E-05	4.44E-08
ENE	20,080	3.04E-05	1.54E-05	1.26E-05	4.96E-08
E	20,510	3.53E-05	2.09E-05	1.68E-05	7.91E-08
ESE	20,670	3.11E-05	1.65E-05	1.34E-05	4.76E-08
SE	21,790	2.72E-05	1.28E-05	1.06E-05	3.29E-08
SSE	24,960	2.25E-05	9.25E-06	7.90E-06	2.33E-08
Sector Maximum (99.5%)		6.02E-05	3.95E-05	2.82E-05	1.48E-07
Overall Site (95%)		4.03E-05	2.43E-05	1.88E-05	6.10E-08

Table C-7. Air Transport Factors for Releases from the Canister Storage Building's Heating, Ventilation, and Air Conditioning Stack (75 Feet) to the Onsite Worker.

Transport direction	Air transport factors, s/m³			
	Fumigation	<0.5 hr	0.5 to 2 hr	Annual
S	3.45E-03	5.60E-04	2.61E-04	6.08E-06
SSW	2.53E-03	2.58E-04	1.16E-04	4.05E-06
SW	2.60E-03	2.35E-04	1.06E-04	3.27E-06
WSW	2.59E-03	3.32E-04	1.53E-04	3.54E-06
W	4.06E-03	5.74E-04	2.66E-04	5.66E-06
WNW	3.49E-03	2.46E-04	1.11E-04	3.91E-06
NW	3.68E-03	2.28E-04	1.03E-04	3.18E-06
NNW	3.61E-03	1.94E-04	8.98E-05	2.05E-06
N	4.24E-03	1.87E-04	8.72E-05	1.99E-06
NNE	2.95E-03	7.57E-05	4.61E-05	1.07E-06
NE	3.09E-03	1.06E-04	4.93E-05	1.38E-06
ENE	3.34E-03	1.32E-04	5.96E-05	2.12E-06
E	4.85E-03	1.86E-04	8.70E-05	2.64E-06
ESE	4.24E-03	1.97E-04	9.12E-05	2.94E-06
SE	4.12E-03	2.31E-04	1.05E-04	4.08E-06
SSE	3.40E-03	2.46E-04	1.11E-04	3.99E-06
Sector Maximum (99.5%)	4.85E-03 100 m E	5.74E-04 100 m W	2.66E-04 150 m W	6.08E-06 100 m S
Overall Site (95%)	4.63E-03 100 m	5.60E-04 250 m	2.12E-04 150 m	3.25E-06 100 m

Note: Distances ranging from 100 m to 600 m in 50-m increments were used to determine the worst-case location. The air transport factors are shown for the largest distance, which is listed at the bottom of each column.

Table C-8. Air Transport Factors for Releases from the Canister Storage Building's Heating, Ventilation, and Air Conditioning Stack (75 Feet) to the Nearest Point of Public Access.

Transport direction	Distance (meters)	Air transport factors, s/m^3			
		Fumigation	<0.5 hr	0.5 to 2 hr	Annual
S	7,830	4.51E-05	1.78E-05	1.08E-05	7.07E-08
SSW	7,830	3.16E-05	9.05E-06	6.93E-06	4.36E-08
SW	7,830	3.17E-05	1.18E-05	7.43E-06	4.18E-08
WSW	7,830	3.17E-05	1.18E-05	7.46E-06	4.14E-08
W	9,280	4.47E-05	2.02E-05	1.17E-05	5.72E-08
WNW	10,510	3.49E-05	1.01E-05	8.93E-06	3.89E-08
NW	11,250	3.44E-05	1.68E-05	9.89E-06	4.06E-08
NNW	11,250	3.39E-05	1.69E-05	9.93E-06	4.04E-08
N	11,250	3.91E-05	1.87E-05	1.07E-05	4.24E-08
NNE	12,750	2.41E-05	7.71E-06	5.39E-06	2.02E-08
NE	12,670	2.58E-05	7.91E-06	6.18E-06	2.42E-08
ENE	12,670	2.84E-05	1.27E-05	8.11E-06	3.21E-08
E	12,670	3.97E-05	1.83E-05	1.03E-05	8.60E-08
ESE	14,230	3.16E-05	1.49E-05	8.71E-06	7.85E-08
SE	11,070	3.87E-05	1.87E-05	1.07E-05	6.77E-08
SSE	8,490	4.13E-05	1.71E-05	1.03E-05	5.58E-08
Sector Maximum (99.5%)		4.51E-05	2.02E-05	1.17E-05	8.60E-08
Overall Site (95%)		4.36E-05	1.95E-05	1.05E-05	4.88E-08

Table C-9. Air Transport Factors for Releases from the Canister Storage Building's Heating, Ventilation, and Air Conditioning Stack (75 Feet) to the Hanford Site Boundary.

Transport direction	Distance (meters)	Air transport factors, s/m³			
		Fumigation	<0.5 hr	0.5 to 2 hr	Annual
S	16,260	2.33E-05	5.75E-06	3.96E-06	2.52E-08
SSW	16,260	1.63E-05	3.69E-06	2.97E-06	1.54E-08
SW	16,260	1.64E-05	4.75E-06	3.20E-06	1.49E-08
WSW	17,910	1.50E-05	4.23E-06	2.87E-06	1.30E-08
W	18,400	2.41E-05	9.07E-06	5.68E-06	2.22E-08
WNW	18,400	2.11E-05	5.15E-06	3.44E-06	1.81E-08
NW	18,870	2.16E-05	9.14E-06	5.70E-06	2.01E-08
NNW	19,450	2.07E-05	8.87E-06	5.54E-06	1.93E-08
N	19,450	2.38E-05	9.73E-06	5.99E-06	2.04E-08
NNE	20,390	1.58E-05	4.21E-06	3.02E-06	1.07E-08
NE	17,540	1.92E-05	5.29E-06	3.63E-06	1.56E-08
ENE	17,390	2.13E-05	8.75E-06	5.49E-06	2.09E-08
E	17,390	2.99E-05	1.25E-05	7.42E-06	5.63E-08
ESE	17,390	2.64E-05	1.17E-05	7.05E-06	5.99E-08
SE	20,630	2.20E-05	8.90E-06	5.53E-06	2.89E-08
SSE	18,830	2.01E-05	4.87E-06	3.34E-06	1.85E-08
Sector Maximum (99.5%)		2.99E-05	1.25E-05	7.42E-06	5.99E-08
Overall Site (95%)		2.80E-05	1.12E-05	6.74E-06	2.37E-08

Table C-10. Air Transport Factors for Releases from the Canister Storage Building
Natural Circulation Stack (156 Feet) to the Onsite Worker.

Transport direction	Air transport factors, s/m³			
	Fumigation	<0.5 hr	0.5 to 2 hr	Annual
S	2.20E-03	1.77E-04	4.20E-05	7.89E-07
SSW	1.53E-03	8.90E-05	2.40E-05	5.22E-07
SW	1.54E-03	8.54E-05	2.29E-05	4.09E-07
WSW	1.54E-03	1.04E-04	2.37E-05	4.33E-07
W	2.56E-03	1.93E-04	4.84E-05	7.12E-07
WNW	2.23E-03	8.66E-05	2.40E-05	5.05E-07
NW	2.34E-03	8.46E-05	2.32E-05	4.18E-07
NNW	2.30E-03	6.36E-05	2.01E-05	2.78E-07
N	2.67E-03	5.50E-05	1.84E-05	2.63E-07
NNE	1.82E-03	1.38E-05	3.47E-06	1.44E-07
NE	1.94E-03	3.69E-05	1.12E-05	1.98E-07
ENE	2.14E-03	4.79E-05	1.31E-05	3.12E-07
E	3.04E-03	5.84E-05	1.84E-05	3.73E-07
ESE	2.67E-03	7.16E-05	2.06E-05	4.12E-07
SE	2.60E-03	8.50E-05	2.31E-05	5.64E-07
SSE	2.17E-03	8.67E-05	2.41E-05	5.17E-07
Sector Maximum (99.5%)	3.04E-03 100 m E	1.93E-04 150 m W	4.84E-05 300 m W	7.89E-07 250 m S
Overall Site (95%)	2.90E-03 100 m	1.83E-04 400 m	3.36E-05 250 m	4.28E-07 250 m

Note: Distances ranging from 100 m to 600 m in 50-m increments were used to determine the worst-case location. The air transport factors are shown for the largest distance, which is listed at the bottom of each column.

Table C-11. Air Transport Factors for Releases from the Canister Storage Building Natural Circulation Stack (156 Feet) to the Nearest Point of Public Access.

Transport direction	Distance (meters)	Air transport factors, s/m³			
		Fumigation	<0.5 hr	0.5 to 2 hr	Annual
S	7,830	2.81E-05	1.07E-05	6.66E-06	4.30E-08
SSW	7,830	2.38E-05	6.25E-06	5.72E-06	2.76E-08
SW	7,830	2.47E-05	6.93E-06	5.90E-06	2.51E-08
WSW	7,830	2.47E-05	6.99E-06	5.85E-06	2.44E-08
W	9,280	2.79E-05	9.55E-06	5.93E-06	3.28E-08
WNW	10,510	2.18E-05	7.92E-06	5.01E-06	2.16E-08
NW	11,250	2.15E-05	8.12E-06	4.79E-06	2.18E-08
NNW	11,250	2.12E-05	8.21E-06	4.73E-06	2.05E-08
N	11,250	2.44E-05	9.85E-06	5.23E-06	2.05E-08
NNE	12,750	1.61E-05	5.55E-06	3.13E-06	1.03E-08
NE	12,670	1.67E-05	5.93E-06	3.44E-06	1.27E-08
ENE	12,670	1.77E-05	6.79E-06	3.92E-06	1.68E-08
E	12,670	2.48E-05	1.05E-05	5.12E-06	4.29E-08
ESE	14,230	1.98E-05	8.27E-06	4.10E-06	4.24E-08
SE	11,070	2.42E-05	9.66E-06	5.41E-06	3.78E-08
SSE	8,490	2.58E-05	9.80E-06	6.23E-06	3.20E-08
Sector Maximum (99.5%)		2.81E-05	1.07E-05	6.66E-06	4.30E-08
Overall Site (95%)		2.72E-05	1.08E-05	5.83E-06	2.70E-08

Table C-12. Air Transport Factors for Releases from the Canister Storage Building
Natural Circulation Stack (156 Feet) to the Hanford Site Boundary.

Transport direction	Distance (meters)	Air transport factors, s/m³			
		Fumigation	<0.5 hr	0.5 to 2 hr	Annual
S	16,260	1.46E-05	4.44E-06	2.98E-06	1.64E-08
SSW	16,260	1.12E-05	2.62E-06	2.01E-06	1.04E-08
SW	16,260	1.14E-05	2.88E-06	2.09E-06	9.55E-09
WSW	17,910	1.03E-05	2.58E-06	1.94E-06	8.24E-09
W	18,400	1.51E-05	4.67E-06	2.99E-06	1.36E-08
WNW	18,400	1.32E-05	4.20E-06	2.60E-06	1.06E-08
NW	18,870	1.35E-05	4.70E-06	2.66E-06	1.14E-08
NNW	19,450	1.29E-05	4.59E-06	2.52E-06	1.05E-08
N	19,450	1.49E-05	5.34E-06	2.94E-06	1.06E-08
NNE	20,390	1.02E-05	3.04E-06	1.98E-06	5.78E-09
NE	17,540	1.23E-05	3.99E-06	2.43E-06	8.49E-09
ENE	17,390	1.33E-05	4.82E-06	2.68E-06	1.14E-08
E	17,390	1.87E-05	7.23E-06	3.75E-06	2.93E-08
ESE	17,390	1.65E-05	6.57E-06	3.31E-06	3.31E-08
SE	20,630	1.38E-05	4.85E-06	2.68E-06	1.71E-08
SSE	18,830	1.26E-05	3.85E-06	2.47E-06	1.14E-08
Sector Maximum (99.5%)		1.87E-05	7.23E-06	3.75E-06	3.31E-08
Overall Site (95%)		1.75E-05	6.56E-06	3.49E-06	1.36E-08

APPENDIX D

GXQ INPUT FILES FOR ELEVATED RELEASES

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Cold Vacuum Drying Facility, Heating, Ventilating, and Air Conditioning Stack — Plume Rise Only

```
CVDF -- 48 foot Stack -- Plume Rise Output
c
c GXQ Version 4.0 Input File
    1
c MODE SELECTION:
c   1 - X/Q based on Hanford site specific meteorology
c   2 - X/Q based on atmospheric stability class and wind speed
c   3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
c   ifox  inorm icdf  ichk  isite ipop
      t     f     t     t     f     f
c   ifox  = t then joint frequency used to compute frequency-to-exceed X/Q
c         = f then joint frequency used to compute annual average X/Q
c   inorm = t then joint frequency data is normalized (as in GENII)
c         = f then joint frequency data is un-normalized
c   icdf  = t then cumulative distribution file created (CDF.OUT)
c         = f then no cumulative distribution file created
c   ichk  = t then X/Q parameter print option turned on
c         = f then no parameter print
c   isite = t then X/Q based on joint frequency data for all 16 sectors
c         = f then X/Q based on joint frequency data of individual sectors
c   ipop  = t then X/Q is population weighted
c         = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c   ipuff idep  isrc  iwind
      0    0     0     1
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c   iwake ipm   iflow ientr
      0    0     1     1
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c   (irise igrnd)iwash igrav
      2    0     1     0
c   ipuff = 1 then X/Q calculated using puff model
c         = 0 then X/Q calculated using default continuous plume model
c   idep  = 1 then plume depletion model turned on (Chamberlain model)
c   isrc  = 1 then X/Q multiplied by scalar
c         = 2 then X/Q adjusted by wind speed function
c   iwind = 1 then wind speed corrected for plume height
c   iwake = 1 then NRC RG 1.145 building wake model turned on
c         = 2 then MACCS virtual distance building wake model turned on
c   ipm   = 1 then NRC RG 1.145 plume meander model turned on
c         = 2 then 5th Power Law plume meander model turned on
c         = 3 then sector average model turned on
c   iflow = 1 then sigmas adjusted for volume flow rate
c   ientr = 1 then method of Pasquill used to account for entrainment
c   irise = 1 then MACCS buoyant plume rise model turned on
c         = 2 then ISC2 momentum/buoyancy plume rise model turned on
c   igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c   iwash = 1 then stack downwash model turned on
c   igrav = 1 then gravitational settling model turned on
c         = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c   release       anemometer    mixing        frequency
c   height        height        height        to
c   (m)           (m)           (m)           exceed
    14.63         10            1000          0.5
c
c   building      building      release       deposition    grav settling
c   width         height        duration      velocity      velocity
c   Wb(m)         Hb(m)         (hour)        (m/s)         (m/s)
    24.4          10.7          1             0.001         0.001
c
c                 initial       initial                     convective
c   ambient       plume         plume         release       heat release
c   temperature   temperature   flow rate     diameter      rate*
c   (°C)          (°C)          (m3/s)        (m)           (watts)
    20            20            8.33          0.762         0
```

```
c   *If zero then buoyant flux based on plume/ambient temperature difference.
c
c   X/Q             Wind
c   scaling         Speed
c   factor          Exponent
    1               .78
c
c RECEPTOR LOCATIONS (no line limit)
c   MODE                RECEPTOR DEPENDENT DATA
c   1 (site winds)      sector, distance, receptor height
c   2 (special case)    class, windspeed, distance, offset, receptor height
c   3 (plot file)       class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
c   sector = 0, 1, 2... (all, S, SSW, etc.)
c   distance = receptor distance (m)
c   receptor height = height of receptor (m)
c   class = 1,2,3,4,5,6,7 (Pasquill stability A,B,C,D,E,F,G)
c   windspeed = anemometer wind speed (m/s)
c   offset = offset from plume centerline (m)
c   xmax  = maximum distance to plot or calculate to (m)
c   imax  = distance intervals
c   ymax  = maximum offset to plot (m)
c   jmax  = offset intervals
c   xqmin = minimum scaled X/Q to calculate
c   power = exponent in power function step size
c
c  CVDF Plume Rise & Elevated Wind Speeds
c
13    100     2    100 meter
```

Cold Vacuum Drying Facility, Heating, Ventilating, and
Air Conditioning Stack — Fumigation - Sector Maximum 99.5%

```
CVDF -- 48 foot Stack -- Fumigation
c
c GXQ Version 4.0 Input File
      1
c MODE SELECTION:
c   1 - X/Q based on Hanford site specific meteorology
c   2 - X/Q based on atmospheric stability class and wind speed
c   3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
c   ifox  inorm icdf  ichk  isite ipop
    t     f     f     f     f
c   ifox  = t then joint frequency used to compute frequency-to-exceed X/Q
c         = f then joint frequency used to compute annual average X/Q
c   inorm = t then joint frequency data is normalized (as in GENII)
c         = f then joint frequency data is un-normalized
c   icdf  = t then cumulative distribution file created (CDF.OUT)
c         = f then no cumulative distribution file created
c   ichk  = t then X/Q parameter print option turned on
c         = f then no parameter print
c   isite = t then X/Q based on joint frequency data for all 16 sectors
c         = f then X/Q based on joint frequency data of individual sectors
c   ipop  = t then X/Q is population weighted
c         = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c   ipuff idep  isrc  iwind
    0     0     0     0
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c   iwake ipm   iflow ientr
    2     0     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c   (irise igrnd)iwash igrav
    0      0     0     0
c   ipuff = 1 then X/Q calculated using puff model
c         = 0 then X/Q calculated using default continuous plume model
c   idep  = 1 then plume depletion model turned on (Chamberlain model)
c   isrc  = 1 then X/Q multiplied by scalar
```

```
c            = 2 then X/Q adjusted by wind speed function
c    iwind = 1 then wind speed corrected for plume height
c    iwake = 1 then NRC RG 1.145 building wake model turned on
c            = 2 then MACCS virtual distance building wake model turned on
c    ipm   = 1 then NRC RG 1.145 plume meander model turned on
c            = 2 then 5th Power Law plume meander model turned on
c            = 3 then sector average model turned on
c    iflow = 1 then sigmas adjusted for volume flow rate
c    ientr = 1 then method of Pasquill used to account for entrainment
c    irise = 1 then MACCS buoyant plume rise model turned on
c            = 2 then ISC2 momentum/buoyancy plume rise model turned on
c    igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c    iwash = 1 then stack downwash model turned on
c    igrav = 1 then gravitational settling model turned on
c            = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c    release      anemometer    mixing        frequency
c    height       height        height        to
c    (m)          (m)           (m)           exceed
c    0            10            31            0.5
c
c    building     building      release       deposition    gravsettling
c    width        height        duration      velocity      velocity
c    Wb(m)        Hb(m)         (hour)        (m/s)         (m/s)
c    0.762        31            0.5           0.001         0.001
c
c                 initial       initial                     convective
c    ambient      plume         plume         release       heat release
c    temperature  temperature   flow rate     diameter      rate*
c    (°C)         (°C)          (m3/s)        (m)           (watts)
c    20           20            8.33          0.762         0
c    *If zero then buoyant flux based on plume/ambient temperature difference.
c
c    X/Q          Wind
c    scaling      Speed
c    factor       Exponent
c    1            .78
c
c RECEPTOR LOCATIONS (no line limit)
c    MODE               RECEPTOR DEPENDENT DATA
c    1 (site winds)     sector, distance, receptor height
c    2 (special case)   class, windspeed, distance, offset, receptor height
c    3 (plot file)      class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
c    sector = 0, 1, 2... (all, S, SSW, etc.)
c    distance = receptor distance (m)
c    receptor height = height of receptor (m)
c    class = 1,2,3,4,5,6,7 (Pasquill stability A,B,C,D,E,F,G)
c    windspeed = anemometer wind speed (m/s)
c    offset = offset from plume centerline (m)
c    xmax  = maximum distance to plot or calculate to (m)
c    imax  = distance intervals
c    ymax  = maximum offset to plot (m)
c    jmax  = offset intervals
c    xqmin = minimum scaled X/Q to calculate
c    power = exponent in power function step size
```

Cold Vacuum Drying Facility, Heating, Ventilating, and Air Conditioning Stack — Less than 0.5 Hour - Sector Maximum 99.5%

```
CVDF -- 48 foot Stack -- Less Than 0.5 h
c
c GXQ Version 4.0 Input File
    1
c MODE SELECTION:
c    1 - X/Q based on Hanford site specific meteorology
c    2 - X/Q based on atmospheric stability class and wind speed
c    3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
```

```
c    ifox  inorm icdf  ichk  isite ipop
     t     f     f     f     f     f
c    ifox  = t then joint frequency used to compute frequency-to-exceed X/Q
c          = f then joint frequency used to compute annual average X/Q
c    inorm = t then joint frequency data is normalized (as in GENII)
c          = f then joint frequency data is un-normalized
c    icdf  = t then cumulative distribution file created (CDF.OUT)
c          = f then no cumulative distribution file created
c    ichk  = t then X/Q parameter print option turned on
c          = f then no parameter print
c    isite = t then X/Q based on joint frequency data for all 16 sectors
c          = f then X/Q based on joint frequency data of individual sectors
c    ipop  = t then X/Q is population weighted
c          = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c    ipuff idep  isrc  iwind
     0     0     0     0
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c    iwake ipm   iflow ientr
     0     0     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c    (irise igrnd)iwash igrav
     0     0     0     0
c    ipuff = 1 then X/Q calculated using puff model
c          = 0 then X/Q calculated using default continuous plume model
c    idep  = 1 then plume depletion model turned on (Chamberlain model)
c    isrc  = 1 then X/Q multiplied by scalar
c          = 2 then X/Q adjusted by wind speed function
c    iwind = 1 then wind speed corrected for plume height
c    iwake = 1 then NRC RG 1.145 building wake model turned on
c          = 2 then MACCS virtual distance building wake model turned on
c    ipm   = 1 then NRC RG 1.145 plume meander model turned on
c          = 2 then 5th Power Law plume meander model turned on
c          = 3 then sector average model turned on
c    iflow = 1 then sigmas adjusted for volume flow rate
c    ientr = 1 then method of Pasquill used to account for entrainment
c    irise = 1 then MACCS buoyant plume rise model turned on
c          = 2 then ISC2 momentum/buoyancy plume rise model turned on
c    igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c    iwash = 1 then stack downwash model turned on
c    igrav = 1 then gravitational settling model turned on
c          = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:  (release height is half the mixing depth for fumigation)
c    release           anemometer     mixing         frequency
c    height            height         height         to
c    (m)               (m)            (m)            exceed
     15.5              10             1000           0.5
c
c    building          building       release        deposition     grav settling
c    width             height         duration       velocity       velocity
c    Wb(m)             Hb(m)          (hour)         (m/s)          (m/s)
     24.4              10.7           2              0.001          0.001
c
c                      initial        initial                       convective
c    ambient           plume          plume          release        heat release
c    temperature       temperature    flow rate      diameter       rate*
c    (°C)              (°C)           (m3/s)         (m)            (watts)
     20                20             8.33           0.762          0
c    *If zero then buoyant flux based on plume/ambient temperature difference.
c
c    X/Q               Wind
c    scaling           Speed
c    factor            Exponent
     1                 .78
c
c RECEPTOR LOCATIONS (no line limit)
c    MODE                   RECEPTOR DEPENDENT DATA
c    1 (site winds)         sector, distance, receptor height
c    2 (special case)       class, windspeed, distance, offset, receptor height
c    3 (plot file)          class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
c    sector = 0, 1, 2... (all, S, SSW, etc.)
c    distance = receptor distance (m)
```

```
c    receptor height = height of receptor (m)
c    class = 1,2,3,4,5,6,7 (Pasquill stability A,B,C,D,E,F,G)
c    windspeed = anemometer wind speed (m/s)
c    offset = offset from plume centerline (m)
c    xmax  = maximum distance to plot or calculate to (m)
c    imax  = distance intervals
c    ymax  = maximum offset to plot (m)
c    jmax  = offset intervals
c    xqmin = minimum scaled X/Q to calculate
c    power = exponent in power function step size
```

Cold Vacuum Drying Facility, Heating, Ventilating, and Air Conditioning Stack — 0.5 to 2 Hours - Sector Maximum 99.5%

```
CVDF -- 37 foot Stack -- 0.5 to 2 hr
c
c GXQ Version 4.0 Input File
    1
c MODE SELECTION:
c    1 - X/Q based on Hanford site specific meteorology
c    2 - X/Q based on atmospheric stability class and wind speed
c    3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
c    ifox  inorm icdf  ichk  isite ipop
     t     f     f     f     f     f
c    ifox  = t then joint frequency used to compute frequency-to-exceed X/Q
c          = f then joint frequency used to compute annual average X/Q
c    inorm = t then joint frequency data is normalized (as in GENII)
c          = f then joint frequency data is un-normalized
c    icdf  = t then cumulative distribution file created (CDF.OUT)
c          = f then no cumulative distribution file created
c    ichk  = t then X/Q parameter print option turned on
c          = f then no parameter print
c    isite = t then X/Q based on joint frequency data for all 16 sectors
c          = f then X/Q based on joint frequency data of individual sectors
c    ipop  = t then X/Q is population weighted
c          = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c    ipuff idep  isrc  iwind
     0     0     0     1
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c    iwake ipm   iflow ientr
     1     1     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c    (irise igrnd)iwash igrav
     0     0     0     0
c    ipuff = 1 then X/Q calculated using puff model
c          = 0 then X/Q calculated using default continuous plume model
c    idep  = 1 then plume depletion model turned on (Chamberlain model)
c    isrc  = 1 then X/Q multiplied by scalar
c          = 2 then X/Q adjusted by wind speed function
c    iwind = 1 then wind speed corrected for plume height
c    iwake = 1 then NRC RG 1.145 building wake model turned on
c          = 2 then MACCS virtual distance building wake model turned on
c    ipm   = 1 then NRC RG 1.145 plume meander model turned on
c          = 2 then 5th Power Law plume meander model turned on
c          = 3 then sector average model turned on
c    iflow = 1 then sigmas adjusted for volume flow rate
c    ientr = 1 then method of Pasquill used to account for entrainment
c    irise = 1 then MACCS buoyant plume rise model turned on
c          = 2 then ISC2 momentum/buoyancy plume rise model turned on
c    igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c    iwash = 1 then stack downwash model turned on
c    igrav = 1 then gravitational settling model turned on
c          = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c    release       anemometer    mixing        frequency
c    height        height        height        to
c    (m)           (m)           (m)           exceed
```

```
         10.7           10            1000          0.5
c
c    building       building      release       deposition    grav settling
c    width          height        duration      velocity      velocity
c    Wb(m)          Hb(m)         (hour)        (m/s)         (m/s)
     24.4           10.7          2             0.001         0.001
c
c                   initial       initial                     convective
c    ambient        plume         plume         release       heat release
c    temperature    temperature   flow rate     diameter      rate*
c    (°C)           (°C)          (m3/s)        (m)           (watts)
     20             20            8.33          0.762         0
c    *If zero then buoyant flux based on plume/ambient temperature difference.
c
c    X/Q            Wind
c    scaling        Speed
c    factor         Exponent
     1              .78
c
c RECEPTOR LOCATIONS (no line limit)
c    MODE               RECEPTOR DEPENDENT DATA
c    1 (site winds)     sector, distance, receptor height
c    2 (special case)   class, windspeed, distance, offset, receptor height
c    3 (plot file)      class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
c    sector = 0, 1, 2... (all, S, SSW, etc.)
c    distance = receptor distance (m)
c    receptor height = height of receptor (m)
c    class = 1,2,3,4,5,6,7 (Pasquill stability A,B,C,D,E,F,G)
c    windspeed = anemometer wind speed (m/s)
c    offset = offset from plume centerline (m)
c    xmax  = maximum distance to plot or calculate to (m)
c    imax  = distance intervals
c    ymax  = maximum offset to plot (m)
c    jmax  = offset intervals
c    xqmin = minimum scaled X/Q to calculate
c    power = exponent in power function step size
```

Cold Vacuum Drying Facility, Heating, Ventilating, and Air Conditioning Stack — Annual Average - Sector Maximum

```
CVDF -- 48 foot Stack -- Annual Average
c
c GXQ Version 4.0 Input File
     1
c MODE SELECTION:
c    1 - X/Q based on Hanford site specific meteorology
c    2 - X/Q based on atmospheric stability class and wind speed
c    3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
c    ifox  inorm icdf  ichk  isite ipop
     f     f     f     f     f     f
c    ifox  = t then joint frequency used to compute frequency-to-exceed X/Q
c          = f then joint frequency used to compute annual average X/Q
c    inorm = t then joint frequency data is normalized (as in GENII)
c          = f then joint frequency data is un-normalized
c    icdf  = t then cumulative distribution file created (CDF.OUT)
c          = f then no cumulative distribution file created
c    ichk  = t then X/Q parameter print option turned on
c          = f then no parameter print
c    isite = t then X/Q based on joint frequency data for all 16 sectors
c          = f then X/Q based on joint frequency data of individual sectors
c    ipop  = t then X/Q is population weighted
c          = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c    ipuff idep  isrc  iwind
     0     0     0     1
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c    iwake ipm   iflow ientr
```

```
      0     3     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c   (irise igrnd)iwash igrav
      0     0     0     0
c   ipuff = 1 then X/Q calculated using puff model
c         = 0 then X/Q calculated using default continuous plume model
c   idep  = 1 then plume depletion model turned on (Chamberlain model)
c   isrc  = 1 then X/Q multiplied by scalar
c         = 2 then X/Q adjusted by wind speed function
c   iwind = 1 then wind speed corrected for plume height
c   iwake = 1 then NRC RG 1.145 building wake model turned on
c         = 2 then MACCS virtual distance building wake model turned on
c   ipm   = 1 then NRC RG 1.145 plume meander model turned on
c         = 2 then 5th Power Law plume meander model turned on
c         = 3 then sector average model turned on
c   iflow = 1 then sigmas adjusted for volume flow rate
c   ientr = 1 then method of Pasquill used to account for entrainment
c   irise = 1 then MACCS buoyant plume rise model turned on
c         = 2 then ISC2 momentum/buoyancy plume rise model turned on
c   igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c   iwash = 1 then stack downwash model turned on
c   igrav = 1 then gravitational settling model turned on
c         = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c   release         anemometer      mixing          frequency
c   height          height          height          to
c   (m)             (m)             (m)             exceed
    10.7            10              1000            0.5
c
c   building        building        release         deposition      grav settling
c   width           height          duration        velocity        velocity
c   Wb(m)           Hb(m)           (hour)          (m/s)           (m/s)
    24.4            10.7            2               0.001           0.001
c
c                   initial         initial                         convective
c   ambient         plume           plume           release         heat release
c   temperature     temperature     flow rate       diameter        rate*
c   (°C)            (°C)            (m3/s)          (m)             (watts)
    20              20              8.33            0.762           0
c   *If zero then buoyant flux based on plume/ambient temperature difference.
c
c   X/Q             Wind
c   scaling         Speed
c   factor          Exponent
    1               .78
c
c RECEPTOR LOCATIONS (no line limit)
c   MODE                RECEPTOR DEPENDENT DATA
c   1 (site winds)      sector, distance, receptor height
c   2 (special case)    class, windspeed, distance, offset, receptor height
c   3 (plot file)       class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
c   sector = 0, 1, 2... (all, S, SSW, etc.)
c   distance = receptor distance (m)
c   receptor height = height of receptor (m)
c   class = 1,2,3,4,5,6,7 (Pasquill stability A,B,C,D,E,F,G)
c   windspeed = anemometer wind speed (m/s)
c   offset = offset from plume centerline (m)
c   xmax  = maximum distance to plot or calculate to (m)
c   imax  = distance intervals
c   ymax  = maximum offset to plot (m)
c   jmax  = offset intervals
c   xqmin = minimum scaled X/Q to calculate
c   power = exponent in power function step size
```

GXQ Input for Cold Vacuum Drying Facility Receptor Distances and Elevations

```
c
c   CVDF Receptor Locations
c   **** sector maximum values -- stack releases
c
  0        100       2    100 meter
  0        150       2
  0        200       2    200 meter
  0        250       2
  0        300       2    300 meter
  0        350       2
  0        400       2    400 meter
  0        450       2
  0        500       2    500 meter
  0        550       2
  0        600       2    600 meter
 14       3750       2    Fire Station
  1      12650       2    CVDF -- Near Bank of Columbia
  2      11340       2            River and Highway 240
  3       1690       2
  4        700       2
  5        650       2
  6        580       2
  7        580       2
  8        580       2
  9        580       2
 10        640       2
 11        860       2
 12       2540       2
 13      11470       2
 14      12060       2
 15      15150       2
 16      15600       2
  1      24960       2    CVDF -- Legal Boundary
  2      17130       2
  3      15510       2
  4      11990       2
  5      10090       2
  6       8740       2
  7       8740       2
  8       8740       2
  9       8930       2
 10      10750       2
 11      15390       2
 12      20080       2
 13      20510       2
 14      20670       2
 15      21790       2
 16      24960       2

c
c   CVDF Receptor Locations
c   **** site overall values -- stack releases
c
  0        100       2    100 meter
  1     100.01       2    100 meter -- PDR method
  2     100.02       2
  3     100.03       2
  4     100.04       2
  5     100.05       2
  6     100.06       2
  7     100.07       2
  8     100.08       2
  9     100.09       2
 10     100.10       2
 11     100.11       2
 12     100.12       2
 13     100.13       2
 14     100.14       2
 15     100.15       2
 16     100.16       2
  0        150       2    150 meter
  1     150.01       2    150 meter -- PDR method
  2     150.02       2
```

3	150.03	2	
4	150.04	2	
5	150.05	2	
6	150.06	2	
7	150.07	2	
8	150.08	2	
9	150.09	2	
10	150.10	2	
11	150.11	2	
12	150.12	2	
13	150.13	2	
14	150.14	2	
15	150.15	2	
16	150.16	2	
0	200	2	200 meter
1	200.01	2	200 meter -- PDR method
2	200.02	2	
3	200.03	2	
4	200.04	2	
5	200.05	2	
6	200.06	2	
7	200.07	2	
8	200.08	2	
9	200.09	2	
10	200.10	2	
11	200.11	2	
12	200.12	2	
13	200.13	2	
14	200.14	2	
15	200.15	2	
16	200.16	2	
0	250	2	250 meter
1	250.01	2	250 meter -- PDR method
2	250.02	2	
3	250.03	2	
4	250.04	2	
5	250.05	2	
6	250.06	2	
7	250.07	2	
8	250.08	2	
9	250.09	2	
10	250.10	2	
11	250.11	2	
12	250.12	2	
13	250.13	2	
14	250.14	2	
15	250.15	2	
16	250.16	2	
0	300	2	300 meter
1	300.01	2	300 meter -- PDR method
2	300.02	2	
3	300.03	2	
4	300.04	2	
5	300.05	2	
6	300.06	2	
7	300.07	2	
8	300.08	2	
9	300.09	2	
10	300.10	2	
11	300.11	2	
12	300.12	2	
13	300.13	2	
14	300.14	2	
15	300.15	2	
16	300.16	2	
0	350	2	350 meter
1	350.01	2	350 meter -- PDR method
2	350.02	2	
3	350.03	2	
4	350.04	2	
5	350.05	2	
6	350.06	2	
7	350.07	2	
8	350.08	2	
9	350.09	2	
10	350.10	2	

11	350.11	2	
12	350.12	2	
13	350.13	2	
14	350.14	2	
15	350.15	2	
16	350.16	2	
0	400	2	400 meter
1	400.01	2	400 meter -- PDR method
2	400.02	2	
3	400.03	2	
4	400.04	2	
5	400.05	2	
6	400.06	2	
7	400.07	2	
8	400.08	2	
9	400.09	2	
10	400.10	2	
11	400.11	2	
12	400.12	2	
13	400.13	2	
14	400.14	2	
15	400.15	2	
16	400.16	2	
0	450	2	450 meter
1	450.01	2	450 meter -- PDR method
2	450.02	2	
3	450.03	2	
4	450.04	2	
5	450.05	2	
6	450.06	2	
7	450.07	2	
8	450.08	2	
9	450.09	2	
10	450.10	2	
11	450.11	2	
12	450.12	2	
13	450.13	2	
14	450.14	2	
15	450.15	2	
16	450.16	2	
0	500	2	500 meter
1	500.01	2	500 meter -- PDR method
2	500.02	2	
3	500.03	2	
4	500.04	2	
5	500.05	2	
6	500.06	2	
7	500.07	2	
8	500.08	2	
9	500.09	2	
10	500.10	2	
11	500.11	2	
12	500.12	2	
13	500.13	2	
14	500.14	2	
15	500.15	2	
16	500.16	2	
0	550	2	550 meter
1	550.01	2	550 meter -- PDR method
2	550.02	2	
3	550.03	2	
4	550.04	2	
5	550.05	2	
6	550.06	2	
7	550.07	2	
8	550.08	2	
9	550.09	2	
10	550.10	2	
11	550.11	2	
12	550.12	2	
13	550.13	2	
14	550.14	2	
15	550.15	2	
16	550.16	2	
0	600	2	600 meter
1	600.01	2	600 meter -- PDR method

2	600.02	2	
3	600.03	2	
4	600.04	2	
5	600.05	2	
6	600.06	2	
7	600.07	2	
8	600.08	2	
9	600.09	2	
10	600.10	2	
11	600.11	2	
12	600.12	2	
13	600.13	2	
14	600.14	2	
15	600.15	2	
16	600.16	2	
1	12650	2	CVDF -- Near Bank of Columbia
2	11340	2	River and Highway 240
3	1690	2	
4	700	2	
5	650	2	
6	580	2	
7	580	2	
8	580	2	
9	580	2	
10	640	2	
11	860	2	
12	2540	2	
13	11470	2	
14	12060	2	
15	15150	2	
16	15600	2	
1	12650	2	CVDF -- Near Bank of Columbia
2	11340	2	River and Highway 240
3	1690	2	
4	700	2	
5	650	2	
6	580	2	
7	580.02	2	
8	580.03	2	
9	580.04	2	
10	640	2	
11	860	2	
12	2540	2	
13	11470	2	
14	12060	2	
15	15150	2	
16	15600	2	
1	24960	2	CVDF -- Legal Boundary
2	17130	2	
3	15510	2	
4	11990	2	
5	10090	2	
6	8740	2	
7	8740	2	
8	8740	2	
9	8930	2	
10	10750	2	
11	15390	2	
12	20080	2	
13	20510	2	
14	20670	2	
15	21790	2	
16	24960	2	
1	24960.02	2	CVDF -- Legal Boundary
2	17130	2	
3	15510	2	
4	11990	2	
5	10090	2	
6	8740.02	2	
7	8740	2	
8	8740.04	2	
9	8930	2	
10	10750	2	
11	15390	2	
12	20080	2	
13	20510	2	

```
14      20670       2
15      21790       2
16      24960       2
```

Note: The GXQ inputs for overall site X/Q are identical to the above except that the "isite" flag is "t" and the "frequency to exceed" is changed from 0.5 to 5.0. An example output file is shown below.

Cold Vacuum Drying Facility, Heating, Ventilating, and Air Conditioning Stack — Fumigation - Overall Site 95%

```
                    GXQ Version 4.0
                   December 19, 1994


General Purpose Atmospheric Dispersion Code
Produced by Westinghouse Hanford Company

Users Guide documented in WHC-SD-GN-SWD-30002 Rev. 1.
Validation documented in WHC-SD-GN-SWD-30003 Rev. 1.
Code Custodian is: Brit E. Hey
                    Westinghouse Hanford Company
                    P.O. Box 1970
                    Richland, WA 99352
                    (509) 376-2921


Run Date = 04/12/99
Run Time = 08:27:01.47


INPUT ECHO:
CVDF -- 48 foot Stack -- Fumigation
c
c GXQ Version 4.0 Input File
      1
c MODE SELECTION:
c   1 - X/Q based on Hanford site specific meteorology
c   2 - X/Q based on atmospheric stability class and wind speed
c   3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
c   ifox  inorm icdf  ichk  isite ipop
     T     F     F     F     T     F
c   ifox  = t then joint frequency used to compute frequency-to-exceed X/Q
c         = f then joint frequency used to compute annual average X/Q
c   inorm = t then joint frequency data is normalized (as in GENII)
c         = f then joint frequency data is un-normalized
c   icdf  = t then cumulative distribution file created (CDF.OUT)
c         = f then no cumulative distribution file created
c   ichk  = t then X/Q parameter print option turned on
c         = f then no parameter print
c   isite = t then X/Q based on joint frequency data for all 16 sectors
c         = f then X/Q based on joint frequency data of individual sectors
c   ipop  = t then X/Q is population weighted
c         = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c   ipuff idep  isrc  iwind
     0     0     0     0
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c   iwake ipm   iflow ientr
     2     0     0     0
```

```
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c  (irise igrnd)iwash igrav
      0     0    0    0
c   ipuff = 1 then X/Q calculated using puff model
c         = 0 then X/Q calculated using default continuous plume model
c   idep  = 1 then plume depletion model turned on (Chamberlain model)
c   isrc  = 1 then X/Q multiplied by scalar
c         = 2 then X/Q adjusted by wind speed function
c   iwind = 1 then wind speed corrected for plume height
c   iwake = 1 then NRC RG 1.145 building wake model turned on
c         = 2 then MACCS virtual distance building wake model turned on
c   ipm   = 1 then NRC RG 1.145 plume meander model turned on
c         = 2 then 5th Power Law plume meander model turned on
c         = 3 then sector average model turned on
c   iflow = 1 then sigmas adjusted for volume flow rate
c   ientr = 1 then method of Pasquill used to account for entrainment
c   irise = 1 then MACCS buoyant plume rise model turned on
c         = 2 then ISC2 momentum/buoyancy plume rise model turned on
c . igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c   iwash = 1 then stack downwash model turned on
c   igrav = 1 then gravitational settling model turned on
c         = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c   release      anemometer   mixing       frequency
c   height       height       height       to
c   (m)          (m)          (m)          exceed
    0.00000E+00  1.00000E+01  3.10000E+01  5.00000E+00
c
c   building     building     release      deposition   gravsettling
c   width        height       duration     velocity     velocity
c   Wb(m)        Hb(m)        (hour)       (m/s)        (m/s)
    7.62000E-01  3.10000E+01  5.00000E-01  1.00000E-03  1.00000E-03
c
c                initial      initial                   convective
c   ambient      plume        plume        release      heat release
c   temperature  temperature  flow rate    diameter     rate*
c   (°C)         (°C)         (m3/s)       (m)          (watts)
    2.00000E+01  2.00000E+01  8.33000E+00  7.62000E-01  0.00000E+00
c   *If zero then buoyant flux based on plume/ambient temperature difference.
c .
c   X/Q          Wind
c   scaling      Speed
c   factor       Exponent
    1.00000E+00  7.80000E-01
c
c RECEPTOR LOCATIONS (no line limit)
c   MODE               RECEPTOR DEPENDENT DATA
c   1 (site winds)     sector, distance, receptor height
c   2 (special case)   class, windspeed, distance, offset, receptor height
c   3 (plot file)      class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
c   sector = 0, 1, 2... (all, S, SSW, etc.)
c   distance = receptor distance (m)
c   receptor height = height of receptor (m)
c   class = 1,2,3,4,5,6,7 (Pasquill stability A,B,C,D,E,F,G)
c   windspeed = anemometer wind speed (m/s)
c   offset = offset from plume centerline (m)
c   xmax  = maximum distance to plot or calculate to (m)
c   imax  = distance intervals
c   ymax  = maximum offset to plot (m)
c   jmax  = offset intervals
c   xqmin = minimum scaled X/Q to calculate
c   power = exponent in power function step size
c
c  CVDF Receptor Locations
c  **** site overall values -- stack releases
c


MODE:
Site specific X/Q calculated.

LOGICAL CHOICES:
Joint frequency used to calculate X/Q based on frequency of exceedance.
No normalization of joint frequency.
```

X/Q calculated for overall site.

MODELS SELECTED:
MACCS Virtual source building wake model selected.
Default Gaussian plume model selected.

WARNING/ERROR MESSAGES:

JOINT FREQUENCY DATA:
100 N AREA - 10 M - Pasquill A - G (1983 - 1991 Average)
Created 8/26/92 KR

CVDF -- 48 foot Stack -- Fumigation

SECTOR	DISTANCE (m)	RECEPT HEIGHT (m)	SECT. FREQ. (%)	POPULATION	TOTAL POPULATION SCALED X/Q (s/m3)	AVERAGE INDIVIDUAL SCALED X/Q (s/m3)	ATM. STAB. CLASS	WIND SPEED (m/s)
ALL	100	2	99.80	1	6.24E-03	6.24E-03	G	0.89
ALL	100	2	99.80	1	4.85E-03	4.85E-03	F	0.89
ALL	150	2	99.80	1	4.29E-03	4.29E-03	G	0.89
ALL	150	2	99.80	1	3.28E-03	3.28E-03	F	0.89
ALL	200	2	99.80	1	3.27E-03	3.27E-03	G	0.89
ALL	200	2	99.80	1	2.47E-03	2.47E-03	F	0.89
ALL	250	2	99.80	1	2.64E-03	2.64E-03	G	0.89
ALL	250	2	99.80	1	1.97E-03	1.97E-03	F	0.89
ALL	300	2	99.80	1	2.21E-03	2.21E-03	G	0.89
ALL	300	2	99.80	1	1.63E-03	1.63E-03	F	0.89
ALL	350	2	99.80	1	1.90E-03	1.90E-03	G	0.89
ALL	350	2	99.80	1	1.39E-03	1.39E-03	F	0.89
ALL	400	2	99.80	1	1.66E-03	1.66E-03	G	0.89
ALL	400	2	99.80	1	1.21E-03	1.21E-03	F	0.89
ALL	450	2	99.80	1	1.48E-03	1.48E-03	G	0.89
ALL	450	2	99.80	1	1.06E-03	1.06E-03	F	0.89
ALL	500	2	99.80	1	1.33E-03	1.33E-03	G	0.89
ALL	500	2	99.80	1	9.50E-04	9.50E-04	F	0.89
ALL	550	2	99.80	1	1.20E-03	1.20E-03	G	0.89
ALL	550	2	99.80	1	8.57E-04	8.57E-04	F	0.89
ALL	600	2	99.80	1	1.10E-03	1.10E-03	G	0.89
ALL	600	2	99.80	1	7.80E-04	7.80E-04	F	0.89
ALL	15600	2	99.80	1	5.22E-04	5.22E-04	F	0.89
ALL	15600	2	99.80	1	5.17E-04	5.17E-04	F	0.89
ALL	24960	2	99.80	1	4.03E-05	4.03E-05	F	0.89
ALL	24960	2	99.80	1	4.03E-05	4.03E-05	F	0.89

Canister Storage Building, Heating, Ventilating, and Air Conditioning Stack — Plume Rise Only

```
CSB -- 75 foot Stack -- Plume Rise Output
c
c GXQ Version 4.0 Input File
     1
c MODE SELECTION:
c   1 - X/Q based on Hanford site specific meteorology
c   2 - X/Q based on atmospheric stability class and wind speed
c   3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
c   ifox  inorm icdf  ichk  isite ipop
     t     f     f     t     f     f
c   ifox  = t then joint frequency used to compute frequency-to-exceed X/Q
c         = f then joint frequency used to compute annual average X/Q
c   inorm = t then joint frequency data is normalized (as in GENII)
c         = f then joint frequency data is un-normalized
c   icdf  = t then cumulative distribution file created (CDF.OUT)
c         = f then no cumulative distribution file created
c   ichk  = t then X/Q parameter print option turned on
c         = f then no parameter print
```

```
c    isite = t then X/Q based on joint frequency data for all 16 sectors
c          = f then X/Q based on joint frequency data of individual sectors
c    ipop  = t then X/Q is population weighted
c          = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c    ipuff idep. isrc  iwind
        0     0    0     1
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c    iwake ipm   iflow ientr
        0     0     1     1
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c   (irise igrnd)iwash igrav
        2     0     1     0
c    ipuff = 1 then X/Q calculated using puff model
c          = 0 then X/Q calculated using default continuous plume model
c    idep  = 1 then plume depletion model turned on (Chamberlain model)
c    isrc  = 1 then X/Q multiplied by scalar
c          = 2 then X/Q adjusted by wind speed function
c    iwind = 1 then wind speed corrected for plume height
c    iwake = 1 then NRC RG 1.145 building wake model turned on
c          = 2 then MACCS virtual distance building wake model turned on
c    ipm   = 1 then NRC RG 1.145 plume meander model turned on
c          = 2 then 5th Power Law plume meander model turned on
c          = 3 then sector average model turned on
c    iflow = 1 then sigmas adjusted for volume flow rate
c    ientr = 1 then method of Pasquill used to account for entrainment
c    irise = 1 then MACCS buoyant plume rise model turned on
c          = 2 then ISC2 momentum/buoyancy plume rise model turned on
c    igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c    iwash = 1 then stack downwash model turned on
c    igrav = 1 then gravitational settling model turned on
c          = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c    release      anemometer     mixing         frequency
c    height       height         height         to
c    (m)          (m)            (m)            exceed
     22.86        10             1000           0.5
c
c    building     building       release        deposition     grav settling
c    width        height         duration       velocity       velocity
c    Wb(m)        Hb(m)          (hour)         (m/s)          (m/s)
     42.4         18.3           1              0.001          0.001
c
c                 initial        initial                       convective
c    ambient      plume          plume          release        heat release
c    temperature  temperature    flow rate      diameter       rate*
c    (°C)         (°C)           (m3/s)         (m)            (watts)
     20           20             2.12           0.71           0
c    *If zero then buoyant flux based on plume/ambient temperature difference.
c
c    X/Q          Wind
c    scaling      Speed
c    factor       Exponent
     1            .78
c
c RECEPTOR LOCATIONS (no line limit)
c    MODE                  RECEPTOR DEPENDENT DATA
c    1 (site winds)        sector, distance, receptor height
c    2 (special case)      class, windspeed, distance, offset, receptor height
c    3 (plot file)         class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
c    sector = 0, 1, 2... (all, S, SSW, etc.)
c    distance = receptor distance (m)
c    receptor height = height of receptor (m)
c    class = 1,2,3,4,5,6,7 (Pasquill stability A,B,C,D,E,F,G)
c    windspeed = anemometer wind speed (m/s)
c    offset = offset from plume centerline (m)
c    xmax  = maximum distance to plot or calculate to (m)
c    imax  = distance intervals
c    ymax  = maximum offset to plot (m)
c    jmax  = offset intervals
c    xqmin = minimum scaled X/Q to calculate
c    power = exponent in power function step size
```

```
c
c  CVDF Plume Rise & Elevated Wind Speeds
c
13    100    2    100 meter
```

Canister Storage Building, Heating, Ventilating, and Air Conditioning Stack — Fumigation - Sector Maximum 99.5%

```
CSB -- HVAC (75 ft) Stack -- Fumigation
c
c GXQ Version 4.0 Input File
    1
c MODE SELECTION:
c    1 - X/Q based on Hanford site specific meteorology
c    2 - X/Q based on atmospheric stability class and wind speed
c    3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
c    ifox  inorm icdf  ichk  isite ipop
      t     f     f     f     f     f
c    ifox  = t then joint frequency used to compute frequency-to-exceed X/Q
c          = f then joint frequency used to compute annual average X/Q
c    inorm = t then joint frequency data is normalized (as in GENII)
c          = f then joint frequency data is un-normalized
c    icdf  = t then cumulative distribution file created (CDF.OUT)
c          = f then no cumulative distribution file created
c    ichk  = t then X/Q parameter print option turned on
c          = f then no parameter print
c    isite = t then X/Q based on joint frequency data for all 16 sectors
c          = f then X/Q based on joint frequency data of individual sectors
c    ipop  = t then X/Q is population weighted
c          = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c    ipuff idep  isrc  iwind
      0     0     0     0
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c    iwake ipm   iflow ientr
      2     0     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c    (irise igrnd)iwash igrav
      0     0     0     0
c    ipuff = 1 then X/Q calculated using puff model
c          = 0 then X/Q calculated using default continuous plume model
c    idep  = 1 then plume depletion model turned on (Chamberlain model)
c    isrc  = 1 then X/Q multiplied by scalar
c          = 2 then X/Q adjusted by wind speed function
c    iwind = 1 then wind speed corrected for plume height
c    iwake = 1 then NRC RG 1.145 building wake model turned on
c          = 2 then MACCS virtual distance building wake model turned on
c    ipm   = 1 then NRC RG 1.145 plume meander model turned on
c          = 2 then 5th Power Law plume meander model turned on
c          = 3 then sector average model turned on
c    iflow = 1 then sigmas adjusted for volume flow rate
c    ientr = 1 then method of Pasquill used to account for entrainment
c    irise = 1 then MACCS buoyant plume rise model turned on
c          = 2 then ISC2 momentum/buoyancy plume rise model turned on
c    igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c    iwash = 1 then stack downwash model turned on
c    igrav = 1 then gravitational settling model turned on
c          = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c    release        anemometer     mixing         frequency
c    height         height         height         to
c    (m)            (m)            (m)            exceed
     0              10             30             0.5
c
c    building       building       release        deposition     grav settling
c    width          height         duration       velocity       velocity
c    Wb(m)          Hb(m)          (hour)         (m/s)          (m/s)
     0.711          30             0.5            0.001          0.001
```

```
c    convective
c    initial        initial        plume        release      heat release
c    temperature    temperature    flow rate    diameter     rate*
c    (°C)           (°C)           (m3/s)       (m)          (watts)
c    20             20             0.711        2.12         0
c *if zero then buoyant flux based on plume/ambient temperature difference.
c
c    X/Q            Wind
c    scaling        Speed
c    factor         Exponent
c    1              .78
c
c RECEPTOR LOCATIONS (no line limit)
c    MODE           RECEPTOR DEPENDENT DATA
c    1 (site winds)         sector, distance, receptor height
c    2 (special case)       class, windspeed, distance, offset, receptor height
c    3 (plot file)          class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c RECEPTOR PARAMETERS
c    sector = 0, 1, 2... (all, S, SSW, etc.)
c    distance = receptor distance (m)
c    receptor height = height of receptor (m)
c    class = 1,2,3,4,5,6,7 (Pasquill stability A,B,C,D,E,F,G)
c    windspeed = anemometer wind speed (m/s)
c    offset = offset from plume centerline (m)
c    xmax = maximum distance to plot or calculate to (m)
c    imax = distance intervals
c    ymax = maximum offset to plot (m)
c    jmax = offset intervals
c    xqmin = minimum scaled X/Q to calculate
c    power = exponent in power function step size
```

Canister Storage Building, Heating, Ventilating, and Air Conditioning Stack — Less than 0.5 Hour - Sector Maximum 99.5%

```
CSB -- HVAC (75 ft) Stack -- Less Than 0.5 h
c
c GXQ Version 4.0 Input File
1
c MODE SELECTION:
c    1 - X/Q based on Hanford site specific meteorology
c    2 - X/Q based on atmospheric stability class and wind speed
c    3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
c    ifox   inorm  icdf   ichk   isite  ipop
c      f      f      f      f      f      f
c ifox = t then joint frequency used to compute frequency-to-exceed X/Q
c      = f then joint frequency used to compute annual average X/Q
c inorm = t then joint frequency data is normalized (as in GENII)
c      = f then joint frequency data is un-normalized
c icdf = t then cumulative distribution file created (CDF.OUT)
c      = f then no cumulative distribution file created
c ichk = t then X/Q parameter print option turned on
c      = f then no parameter print
c isite = t then X/Q based on joint frequency data for all 16 sectors
c      = t then X/Q based on joint frequency data of individual sectors
c ipop = t then X/Q is population weighted
c      = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c    iwind  isrc   idep   ipuff
c      0      0      0      0
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c    ientr  iflow  ipm    iwake
c      0      0      0      0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c    igrav  iwash(igrnd)(irise)
c      0      0      0      0
c      ipuff = 1 then X/Q calculated using puff model
c      = 0 then X/Q calculated using default continuous plume model
```

```
c   idep  = 1 then plume depletion model turned on (Chamberlain model)
c   isrc  = 1 then X/Q multiplied by scalar
c         = 2 then X/Q adjusted by wind speed function
c   iwind = 1 then wind speed corrected for plume height
c   iwake = 1 then NRC RG 1.145 building wake model turned on
c         = 2 then MACCS virtual distance building wake model turned on
c   ipm   = 1 then NRC RG 1.145 plume meander model turned on
c         = 2 then 5th Power Law plume meander model turned on
c         = 3 then sector average model turned on
c   iflow = 1 then sigmas adjusted for volume flow rate
c   ientr = 1 then method of Pasquill used to account for entrainment
c   irise = 1 then MACCS buoyant plume rise model turned on
c         = 2 then ISC2 momentum/buoyancy plume rise model turned on
c   igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c   iwash = 1 then stack downwash model turned on
c   igrav = 1 then gravitational settling model turned on
c         = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT: (release height is half the mixing depth for fumigation)
c   release        anemometer     mixing         frequency
c   height         height         height         to
c   (m)            (m)            (m)            exceed
    15.0           10             1000           0.5
c
c   building       building       release        deposition     grav settling
c   width          height         duration       velocity       velocity
c   Wb(m)          Hb(m)          (hour)         (m/s)          (m/s)
    42.4           18.3           2              0.001          0.001
c
c                  initial        initial                       convective
c   ambient        plume          plume          release        heat release
c   temperature    temperature    flow rate      diameter       rate*
c   (°C)           (°C)           (m3/s)         (m)            (watts)
    20             20             2.12           0.711          0
c   *If zero then buoyant flux based on plume/ambient temperature difference.
c
c   X/Q            Wind
c   scaling        Speed
c   factor         Exponent
    1              .78
c
c RECEPTOR LOCATIONS (no line limit)
c   MODE                 RECEPTOR DEPENDENT DATA
c   1 (site winds)       sector, distance, receptor height
c   2 (special case)     class, windspeed, distance, offset, receptor height
c   3 (plot file)        class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
c   sector = 0, 1, 2... (all, S, SSW, etc.)
c   distance = receptor distance (m)
c   receptor height = height of receptor (m)
c   class = 1,2,3,4,5,6,7 (Pasquill stability A,B,C,D,E,F,G)
c   windspeed = anemometer wind speed (m/s)
c   offset = offset from plume centerline (m)
c   xmax = maximum distance to plot or calculate to (m)
c   imax = distance intervals
c   ymax = maximum offset to plot (m)
c   jmax = offset intervals
c   xqmin = minimum scaled X/Q to calculate
c   power = exponent in power function step size
```

Canister Storage Building, Heating, Ventilating, and Air Conditioning Stack — 0.5 to 2 Hours - Sector Maximum 99.5%

```
CSB -- HVAC (75 ft) Stack -- 0.5 to 2 hr
c
c GXQ Version 4.0 Input File
    1
c MODE SELECTION:
c   1 - X/Q based on Hanford site specific meteorology
c   2 - X/Q based on atmospheric stability class and wind speed
c   3 - X/Q plot file is created
```

```
c
c SITE WIND & POPULATION OPTIONS:
c   ifox  inorm icdf  ichk  isite ipop
      t     f     f     f     f     f
c   ifox  = t then joint frequency used to compute frequency-to-exceed X/Q
c         = f then joint frequency used to compute annual average X/Q
c   inorm = t then joint frequency data is normalized (as in GENII)
c         = f then joint frequency data is un-normalized
c   icdf  = t then cumulative distribution file created (CDF.OUT)
c         = f then no cumulative distribution file created
c   ichk  = t then X/Q parameter print option turned on
c         = f then no parameter print
c   isite = t then X/Q based on joint frequency data for all 16 sectors
c         = f then X/Q based on joint frequency data of individual sectors
c   ipop  = t then X/Q is population weighted
c         = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c   ipuff idep  isrc  iwind
      0    0     0     1
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c   iwake ipm   iflow ientr
      1    1     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c  (irise igrnd)iwash igrav
      0    0     0     0
c   ipuff = 1 then X/Q calculated using puff model
c         = 0 then X/Q calculated using default continuous plume model
c   idep  = 1 then plume depletion model turned on (Chamberlain model)
c   isrc  = 1 then X/Q multiplied by scalar
c         = 2 then X/Q adjusted by wind speed function
c   iwind = 1 then wind speed corrected for plume height
c   iwake = 1 then NRC RG 1.145 building wake model turned on
c         = 2 then MACCS virtual distance building wake model turned on
c   ipm   = 1 then NRC RG 1.145 plume meander model turned on
c         = 2 then 5th Power Law plume meander model turned on
c         = 3 then sector average model turned on
c   iflow = 1 then sigmas adjusted for volume flow rate
c   ientr = 1 then method of Pasquill used to account for entrainment
c   irise = 1 then MACCS buoyant plume rise model turned on
c         = 2 then ISC2 momentum/buoyancy plume rise model turned on
c   igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c   iwash = 1 then stack downwash model turned on
c   igrav = 1 then gravitational settling model turned on
c         = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c   release         anemometer      mixing          frequency
c   height          height          height          to
c   (m)             (m)             (m)             exceed
    18.3            10              1000            0.5
c
c   building        building        release         deposition      grav settling
c   width           height          duration        velocity        velocity
c   Wb(m)           Hb(m)           (hour)          (m/s)           (m/s)
    42.4            18.3            2               0.001           0.001
c
c                   initial         initial                         convective
c   ambient         plume           plume           release         heat release
c   temperature     temperature     flow rate       diameter        rate*
c   (°C)            (°C)            (m3/s)          (m)             (watts)
    20              20              2.12            0.711           0
c   *If zero then buoyant flux based on plume/ambient temperature difference.
c
c   X/Q             Wind
c   scaling         Speed
c   factor          Exponent
    1               .78
c
c RECEPTOR LOCATIONS (no line limit)
c   MODE                RECEPTOR DEPENDENT DATA
c   1 (site winds)      sector, distance, receptor height
c   2 (special case)    class, windspeed, distance, offset, receptor height
c   3 (plot file)       class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
```

```
c   sector = 0, 1, 2... (all, S, SSW, etc.)
c   distance = receptor distance (m)
c   receptor height = height of receptor (m)
c   class = 1,2,3,4,5,6,7 (Pasquill stability A,B,C,D,E,F,G)
c   windspeed = anemometer wind speed (m/s)
c   offset = offset from plume centerline (m)
c   xmax  = maximum distance to plot or calculate to (m)
c   imax  = distance intervals
c   ymax  = maximum offset to plot (m)
c   jmax  = offset intervals
c   xqmin = minimum scaled X/Q to calculate
c   power = exponent in power function step size
```

Canister Storage Building, Heating, Ventilating, and Air Conditioning Stack — Annual Average - Sector Maximum

```
CSB -- HVAC (75 ft) Stack -- Annual Average
c
c GXQ Version 4.0 Input File
    1
c MODE SELECTION:
c   1 - X/Q based on Hanford site specific meteorology
c   2 - X/Q based on atmospheric stability class and wind speed
c   3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
c   ifox  inorm icdf  ichk  isite ipop
    f     f     f     f     f     f
c   ifox  = t then joint frequency used to compute frequency-to-exceed X/Q
c         = f then joint frequency used to compute annual average X/Q
c   inorm = t then joint frequency data is normalized (as in GENII)
c         = f then joint frequency data is un-normalized
c   icdf  = t then cumulative distribution file created (CDF.OUT)
c         = f then no cumulative distribution file created
c   ichk  = t then X/Q parameter print option turned on
c         = f then no parameter print
c   isite = t then X/Q based on joint frequency data for all 16 sectors
c         = f then X/Q based on joint frequency data of individual sectors
c   ipop  = t then X/Q is population weighted
c         = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c   ipuff idep  isrc  iwind
    0     0     0     1
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c   iwake ipm   iflow ientr
    0     3     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c   (irise igrnd)iwash igrav
    0     0     0     0
c   ipuff = 1 then X/Q calculated using puff model
c         = 0 then X/Q calculated using default continuous plume model
c   idep  = 1 then plume depletion model turned on (Chamberlain model)
c   isrc  = 1 then X/Q multiplied by scalar
c         = 2 then X/Q adjusted by wind speed function
c   iwind = 1 then wind speed corrected for plume height
c   iwake = 1 then NRC RG 1.145 building wake model turned on
c         = 2 then MACCS virtual distance building wake model turned on
c   ipm   = 1 then NRC RG 1.145 plume meander model turned on
c         = 2 then 5th Power Law plume meander model turned on
c         = 3 then sector average model turned on
c   iflow = 1 then sigmas adjusted for volume flow rate
c   ientr = 1 then method of Pasquill used to account for entrainment
c   irise = 1 then MACCS buoyant plume rise model turned on
c         = 2 then ISC2 momentum/buoyancy plume rise model turned on
c   igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c   iwash = 1 then stack downwash model turned on
c   igrav = 1 then gravitational settling model turned on
c         = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c   release        anemometer    mixing          frequency
```

```
c  height          height          height          to
c  (m)             (m)             (m)             exceed
   18.3            10              1000            0.5
c
c  building        building        release         deposition      grav settling
c  width           height          duration        velocity        velocity
c  Wb(m)           Hb(m)           (hour)          (m/s)           (m/s)
   42.4            18.3            2               0.001           0.001
c
c                  initial         initial                         convective
c  ambient         plume           plume           release         heat release
c  temperature     temperature     flow rate       diameter        rate*
c  (°C)            (°C)            (m3/s)          (m)             (watts)
   20              20              2.12            0.711           0
c  *If zero then buoyant flux based on plume/ambient temperature difference.
c
c  X/Q             Wind
c  scaling         Speed
c  factor          Exponent
   1               .78
c
c RECEPTOR LOCATIONS (no line limit)
c    MODE                   RECEPTOR DEPENDENT DATA
c    1 (site winds)    sector, distance, receptor height
c    2 (special case)  class, windspeed, distance, offset, receptor height
c    3 (plot file)     class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
c    sector = 0, 1, 2... (all, S, SSW, etc.)
c    distance = receptor distance (m)
c    receptor height = height of receptor (m)
c    class = 1,2,3,4,5,6,7 (Pasquill stability A,B,C,D,E,F,G)
c    windspeed = anemometer wind speed (m/s)
c    offset = offset from plume centerline (m)
c    xmax  = maximum distance to plot or calculate to (m)
c    imax  = distance intervals
c    ymax  = maximum offset to plot (m)
c    jmax  = offset intervals
c    xqmin = minimum scaled X/Q to calculate
c    power = exponent in power function step size
```

GXQ Input for Canister Storage Building Receptor Distances and Elevations

```
c
c  CSB Receptor Locations
c  **** sector maximum values -- stack releases
c
  0       100       2     100 meter
  0       150       2
  0       200       2     200 meter
  0       250       2
  0       300       2     300 meter
  0       350       2
  0       400       2     400 meter
  0       450       2
  0       500       2     500 meter
  0       550       2
  0       600       2     600 meter
  1      7830       2     CSB -- Near Bank of Columbia
  2      7830       2             River and Highway 240
  3      7830       2
  4      7830       2
  5      9280       2
  6     10510       2
  7     11250       2
  8     11250       2
  9     11250       2
 10     12750       2
 11     12670       2
 12     12670       2
 13     12670       2
 14     14230       2
 15     11070       2
 16      8490       2
  1     16260       2     CSB -- Legal Boundary
  2     16260       2
  3     16260       2
  4     17910       2
  5     18400       2
  6     18400       2
  7     18870       2
  8     19450       2
  9     19450       2
 10     20390       2
 11     17540       2
 12     17390       2
 13     17390       2
 14     17390       2
 15     20630       2
 16     18830       2


c
c  CSB Receptor Locations
c  **** site overall values -- stack releases
c
  0       100       2     100 meter
  1    100.01       2     100 meter -- PDR method
  2    100.02       2
  3    100.03       2
  4    100.04       2
  5    100.05       2
  6    100.06       2
  7    100.07       2
  8    100.08       2
  9    100.09       2
 10    100.10       2
 11    100.11       2
 12    100.12       2
 13    100.13       2
 14    100.14       2
 15    100.15       2
 16    100.16       2
  0       150       2     150 meter
  1    150.01       2     150 meter -- PDR method
  2    150.02       2
```

3	150.03	2	
4	150.04	2	
5	150.05	2	
6	150.06	2	
7	150.07	2	
8	150.08	2	
9	150.09	2	
10	150.10	2	
11	150.11	2	
12	150.12	2	
13	150.13	2	
14	150.14	2	
15	150.15	2	
16	150.16	2	
0	200	2	200 meter
1	200.01	2	200 meter -- PDR method
2	200.02	2	
3	200.03	2	
4	200.04	2	
5	200.05	2	
6	200.06	2	
7	200.07	2	
8	200.08	2	
9	200.09	2	
10	200.10	2	
11	200.11	2	
12	200.12	2	
13	200.13	2	
14	200.14	2	
15	200.15	2	
16	200.16	2	
0	250	2	250 meter
1	250.01	2	250 meter -- PDR method
2	250.02	2	
3	250.03	2	
4	250.04	2	
5	250.05	2	
6	250.06	2	
7	250.07	2	
8	250.08	2	
9	250.09	2	
10	250.10	2	
11	250.11	2	
12	250.12	2	
13	250.13	2	
14	250.14	2	
15	250.15	2	
16	250.16	2	
0	300	2	300 meter
1	300.01	2	300 meter -- PDR method
2	300.02	2	
3	300.03	2	
4	300.04	2	
5	300.05	2	
6	300.06	2	
7	300.07	2	
8	300.08	2	
9	300.09	2	
10	300.10	2	
11	300.11	2	
12	300.12	2	
13	300.13	2	
14	300.14	2	
15	300.15	2	
16	300.16	2	
0	350	2	350 meter
1	350.01	2	350 meter -- PDR method
2	350.02	2	
3	350.03	2	
4	350.04	2	
5	350.05	2	
6	350.06	2	
7	350.07	2	
8	350.08	2	
9	350.09	2	
10	350.10	2	

11	350.11	2	
12	350.12	2	
13	350.13	2	
14	350.14	2	
15	350.15	2	
16	350.16	2	
0	400	2	400 meter
1	400.01	2	400 meter -- PDR method
2	400.02	2	
3	400.03	2	
4	400.04	2	
5	400.05	2	
6	400.06	2	
7	400.07	2	
8	400.08	2	
9	400.09	2	
10	400.10	2	
11	400.11	2	
12	400.12	2	
13	400.13	2	
14	400.14	2	
15	400.15	2	
16	400.16	2	
0	450	2	450 meter
1	450.01	2	450 meter -- PDR method
2	450.02	2	
3	450.03	2	
4	450.04	2	
5	450.05	2	
6	450.06	2	
7	450.07	2	
8	450.08	2	
9	450.09	2	
10	450.10	2	
11	450.11	2	
12	450.12	2	
13	450.13	2	
14	450.14	2	
15	450.15	2	
16	450.16	2	
0	500	2	500 meter
1	500.01	2	500 meter -- PDR method
2	500.02	2	
3	500.03	2	
4	500.04	2	
5	500.05	2	
6	500.06	2	
7	500.07	2	
8	500.08	2	
9	500.09	2	
10	500.10	2	
11	500.11	2	
12	500.12	2	
13	500.13	2	
14	500.14	2	
15	500.15	2	
16	500.16	2	
0	550	2	550 meter
1	550.01	2	550 meter -- PDR method
2	550.02	2	
3	550.03	2	
4	550.04	2	
5	550.05	2	
6	550.06	2	
7	550.07	2	
8	550.08	2	
9	550.09	2	
10	550.10	2	
11	550.11	2	
12	550.12	2	
13	550.13	2	
14	550.14	2	
15	550.15	2	
16	550.16	2	
0	600	2	600 meter
1	600.01	2	600 meter -- PDR method

2	600.02	2	
3	600.03	2	
4	600.04	2	
5	600.05	2	
6	600.06	2	
7	600.07	2	
8	600.08	2	
9	600.09	2	
10	600.10	2	
11	600.11	2	
12	600.12	2	
13	600.13	2	
14	600.14	2	
15	600.15	2	
16	600.16	2	
1	7830	2	CSB -- Near Bank of Columbia
2	7830	2	River and Highway 240
3	7830	2	
4	7830	2	
5	9280	2	
6	10510	2	
7	11250	2	
8	11250	2	
9	11250	2	
10	12750	2	
11	12670	2	
12	12670	2	
13	12670	2	
14	14230	2	
15	11070	2	
16	8490	2	
1	7830.04	2	CSB -- Near Bank of Columbia
2	7830.03	2	River and Highway 240
3	7830.02	2	
4	7830	2	
5	9280	2	
6	10510	2	
7	11250.02	2	
8	11250	2	
9	11250.04	2	
10	12750	2	
11	12670.02	2	
12	12670	2	
13	12670.04	2	
14	14230	2	
15	11070	2	
16	8490	2	
1	16260	2	CSB -- Legal Boundary
2	16260	2	
3	16260	2	
4	17910	2	
5	18400	2	
6	18400	2	
7	18870	2	
8	19450	2	
9	19450	2	
10	20390	2	
11	17540	2	
12	17390	2	
13	17390	2	
14	17390	2	
15	20630	2	
16	18830	2	
1	16260.04	2	CSB -- Legal Boundary
2	16260.02	2	
3	16260	2	
4	17910	2	
5	18400	2	
6	18400.02	2	
7	18870	2	
8	19450	2	
9	19450.02	2	
10	20390	2	
11	17540	2	
12	17390.02	2	
13	17390	2	

```
14      17390.04    2
15      20630       2
16      18830       2
```

Note: The GXQ inputs for overall site X/Q are identical to the above except that the "isite" flag is "t" and the "frequency to exceed" is changed from 0.5 to 5.0. An example output file is shown below.

Canister Storage Building, Heating, Ventilating, and Air Conditioning Stack — Fumigation - Overall Site 95%

```
                        GXQ Version 4.0
                        December 19, 1994


General Purpose Atmospheric Dispersion Code
Produced by Westinghouse Hanford Company

Users Guide documented in WHC-SD-GN-SWD-30002 Rev. 1.
Validation documented in WHC-SD-GN-SWD-30003 Rev. 1.
Code Custodian is: Brit E. Hey
                        Westinghouse Hanford Company
                        P.O. Box 1970
                        Richland, WA 99352
                        (509) 376-2921


Run Date = 04/12/99
Run Time = 08:27:23.88


INPUT ECHO:
CSB -- HVAC (75 ft) Stack -- Fumigation
c
c GXQ Version 4.0 Input File
      1
c MODE SELECTION:
c   1 - X/Q based on Hanford site specific meteorology
c   2 - X/Q based on atmospheric stability class and wind speed
c   3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
c   ifox  inorm  icdf  ichk  isite ipop
      T     F     F     F     T     F
c   ifox  = t then joint frequency used to compute frequency-to-exceed X/Q
c         = f then joint frequency used to compute annual average X/Q
c   inorm = t then joint frequency data is normalized (as in GENII)
c         = f then joint frequency data is un-normalized
c   icdf  = t then cumulative distribution file created (CDF.OUT)
c         = f then no cumulative distribution file created
c   ichk  = t then X/Q parameter print option turned on
c         = f then no parameter print
c   isite = t then X/Q based on joint frequency data for all 16 sectors
c         = f then X/Q based on joint frequency data of individual sectors
c   ipop  = t then X/Q is population weighted
c         = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c   ipuff idep  isrc  iwind
      0     0     0     0
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c   iwake ipm   iflow ientr
      2     0     0     0
```

```
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c  (irise igrnd)iwash igrav
      0    0    0    0
c    ipuff = 1 then X/Q calculated using puff model
c          = 0 then X/Q calculated using default continuous plume model
c    idep  = 1 then plume depletion model turned on (Chamberlain model)
c    isrc  = 1 then X/Q multiplied by scalar
c          = 2 then X/Q adjusted by wind speed function
c    iwind = 1 then wind speed corrected for plume height
c    iwake = 1 then NRC RG 1.145 building wake model turned on
c          = 2 then MACCS virtual distance building wake model turned on
c    ipm   = 1 then NRC RG 1.145 plume meander model turned on
c          = 2 then 5th Power Law plume meander model turned on
c          = 3 then sector average model turned on
c    iflow = 1 then sigmas adjusted for volume flow rate
c    ientr = 1 then method of Pasquill used to account for entrainment
c    irise = 1 then MACCS buoyant plume rise model turned on
c          = 2 then ISC2 momentum/buoyancy plume rise model turned on
c    igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c    iwash = 1 then stack downwash model turned on
c    igrav = 1 then gravitational settling model turned on
c          = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c    release        anemometer     mixing         frequency
c    height         height         height         to
c    (m)            (m)            (m)            exceed
     0.00000E+00    1.00000E+01    3.00000E+01    5.00000E+00
c
c    building       building       release        deposition     grav settling
c    width          height         duration       velocity       velocity
c    Wb(m)          Hb(m)          (hour)         (m/s)          (m/s)
     7.11000E-01    3.00000E+01    5.00000E-01    1.00000E-03    1.00000E-03
c
c                   initial        initial                       convective
c    ambient        plume          plume          release        heat release
c    temperature    temperature    flow rate      diameter       rate*
c    (°C)           (°C)           (m3/s)         (m)            (watts)
     2.00000E+01    2.00000E+01    2.12000E+00    7.11000E-01    0.00000E+00
c    *If zero then buoyant flux based on plume/ambient temperature difference.
c
c    X/Q            Wind
c    scaling        Speed
c    factor         Exponent
     1.00000E+00    7.80000E-01
c
c RECEPTOR LOCATIONS (no line limit)
c    MODE                 RECEPTOR DEPENDENT DATA
c    1 (site winds)       sector, distance, receptor height
c    2 (special case)     class, windspeed, distance, offset, receptor height
c    3 (plot file)        class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
c    sector = 0, 1, 2... (all, S, SSW, etc.)
c    distance = receptor distance (m)
c    receptor height = height of receptor (m)
c    class = 1,2,3,4,5,6,7 (Pasquill stability A,B,C,D,E,F,G)
c    windspeed = anemometer wind speed (m/s)
c    offset = offset from plume centerline (m)
c    xmax  = maximum distance to plot or calculate to (m)
c    imax  = distance intervals
c    ymax  = maximum offset to plot (m)
c    jmax  = offset intervals
c    xqmin = minimum scaled X/Q to calculate
c    power = exponent in power function step size
c
c  CSB Receptor Locations
c  **** site overall values -- stack releases
c


MODE:
Site specific X/Q calculated.

LOGICAL CHOICES:
Joint frequency used to calculate X/Q based on frequency of exceedance.
No normalization of joint frequency.
```

X/Q calculated for overall site.

MODELS SELECTED:
MACCS Virtual source building wake model selected.
Default Gaussian plume model selected.

WARNING/ERROR MESSAGES:

JOINT FREQUENCY DATA:
200 AREA (HMS) - 10 M - Pasquill A - G (1983 - 1991 Average)
Created 8/26/92 KR

CSB -- HVAC (75 ft) Stack -- Fumigation

SECTOR	DISTANCE (m)	RECEPT HEIGHT (m)	SECT. FREQ. (%)	POPULATION	TOTAL POPULATION SCALED X/Q (s/m3)	AVERAGE INDIVIDUAL SCALED X/Q (s/m3)	ATM. STAB. CLASS	WIND SPEED (m/s)
ALL	100	2	99.94	1	4.63E-03	4.63E-03	F	0.89
ALL	100	2	99.94	1	4.99E-03	4.99E-03	F	0.89
ALL	150	2	99.94	1	3.12E-03	3.12E-03	F	0.89
ALL	150	2	99.94	1	3.37E-03	3.37E-03	F	0.89
ALL	200	2	99.94	1	2.34E-03	2.34E-03	F	0.89
ALL	200	2	99.94	1	2.53E-03	2.53E-03	F	0.89
ALL	250	2	99.94	1	1.86E-03	1.86E-03	F	0.89
ALL	250	2	99.94	1	2.02E-03	2.02E-03	F	0.89
ALL	300	2	99.94	1	1.53E-03	1.53E-03	F	0.89
ALL	300	2	99.94	1	1.67E-03	1.67E-03	F	0.89
ALL	350	2	99.94	1	1.30E-03	1.30E-03	F	0.89
ALL	350	2	99.94	1	1.42E-03	1.42E-03	F	0.89
ALL	400	2	99.94	1	1.13E-03	1.13E-03	F	0.89
ALL	400	2	99.94	1	1.23E-03	1.23E-03	F	0.89
ALL	450	2	99.94	1	9.94E-04	9.94E-04	F	0.89
ALL	450	2	99.94	1	1.09E-03	1.09E-03	F	0.89
ALL	500	2	99.94	1	8.86E-04	8.86E-04	F	0.89
ALL	500	2	99.94	1	9.69E-04	9.69E-04	F	0.89
ALL	550	2	99.94	1	7.98E-04	7.98E-04	F	0.89
ALL	550	2	99.94	1	8.74E-04	8.74E-04	F	0.89
ALL	600	2	99.94	1	7.05E-04	7.05E-04	F	0.89
ALL	600	2	99.94	1	7.94E-04	7.94E-04	F	0.89
ALL	8490	2	99.94	1	4.36E-05	4.36E-05	E	0.89
ALL	8490	2	99.94	1	4.35E-05	4.35E-05	E	0.89
ALL	18830	2	99.94	1	2.80E-05	2.80E-05	F	0.89
ALL	18830	2	99.94	1	2.80E-05	2.80E-05	F	0.89

Canister Storage Building, Natural Circulation
Stack — Plume Rise Only

```
CSB -- 156 foot Stack -- Plume Rise Output
c
c GXQ Version 4.0 Input File
   1
c MODE SELECTION:
c  1 - X/Q based on Hanford site specific meteorology
c  2 - X/Q based on atmospheric stability class and wind speed
c  3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
c  ifox  inorm icdf  ichk  isite ipop
   t     f     f     t     f     f
c  ifox  = t then joint frequency used to compute frequency-to-exceed X/Q
c        = f then joint frequency used to compute annual average X/Q
c  inorm = t then joint frequency data is normalized (as in GENII)
c        = f then joint frequency data is un-normalized
c  icdf  = t then cumulative distribution file created (CDF.OUT)
c        = f then no cumulative distribution file created
c  ichk  = t then X/Q parameter print option turned on
c        = f then no parameter print
c  isite = t then X/Q based on joint frequency data for all 16 sectors
c        = f then X/Q based on joint frequency data of individual sectors
c  ipop  = t then X/Q is population weighted
c        = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c  ipuff idep  isrc  iwind
   0     0     0     1
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c  iwake ipm   iflow ientr
   0     0     1     1
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c  (irise igrnd)iwash igrav
   2      0     1     0
c  ipuff = 1 then X/Q calculated using puff model
c        = 0 then X/Q calculated using default continuous plume model
c  idep  = 1 then plume depletion model turned on (Chamberlain model)
c  isrc  = 1 then X/Q multiplied by scalar
c        = 2 then X/Q adjusted by wind speed function
c  iwind = 1 then wind speed corrected for plume height
c  iwake = 1 then NRC RG 1.145 building wake model turned on
c        = 2 then MACCS virtual distance building wake model turned on
c  ipm   = 1 then NRC RG 1.145 plume meander model turned on
c        = 2 then 5th Power Law plume meander model turned on
c        = 3 then sector average model turned on
c  iflow = 1 then sigmas adjusted for volume flow rate
c  ientr = 1 then method of Pasquill used to account for entrainment
c  irise = 1 then MACCS buoyant plume rise model turned on
c        = 2 then ISC2 momentum/buoyancy plume rise model turned on
c  igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c  iwash = 1 then stack downwash model turned on
c  igrav = 1 then gravitational settling model turned on
c        = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c  release      anemometer   mixing       frequency
c  height       height       height       to
c  (m)          (m)          (m)          exceed
   47.55        10           1000         0.5
c
c  building     building     release      deposition   grav settling
c  width        height       duration     velocity     velocity
c  Wb(m)        Hb(m)        (hour)       (m/s)        (m/s)
   42.4         18.3         1            0.001        0.001
c
c               initial      initial                   convective
c  ambient      plume        plume        release      heat release
c  temperature  temperature  flow rate    diameter     rate*
c  (°C)         (°C)         (m3/s)       (m)          (watts)
   20           20           3.78         2.13         0
c  *If zero then buoyant flux based on plume/ambient temperature difference.
```

```
c
c   X/Q            Wind
c   scaling        Speed
c   factor         Exponent
    1              .78
c
c RECEPTOR LOCATIONS (no line limit) ·
c   MODE                RECEPTOR DEPENDENT DATA
c   1 (site winds)      sector, distance, receptor height
c   2 (special case)    class, windspeed, distance, offset, receptor height
c   3 (plot file)       class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
c   sector = 0, 1, 2... (all, S, SSW, etc.)
c   distance = receptor distance (m)
c   receptor height = height of receptor (m)
c   class = 1,2,3,4,5,6,7 (Pasquill stability A,B,C,D,E,F,G)
c   windspeed = anemometer wind speed (m/s)
c   offset = offset from plume centerline (m)
c   xmax  = maximum distance to plot or calculate to (m)
c   imax  = distance intervals
c   ymax  = maximum offset to plot (m)
c   jmax  = offset intervals
c   xqmin = minimum scaled X/Q to calculate
c   power = exponent in power function step size
c
c   CVDF Plume Rise & Elevated Wind Speeds
c
13     100     2     100 meter
```

Canister Storage Building, Natural Circulation
Stack — Fumigation - Sector Maximum 99.5%

```
CSB -- Natural Circulation (156 ft) Stack -- Fumigation
c
c GXQ Version 4.0 Input File
    1
c MODE SELECTION:
c   1 - X/Q based on Hanford site specific meteorology
c   2 - X/Q based on atmospheric stability class and wind speed
c   3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
c   ifox  inorm icdf  ichk  isite ipop
     t     f     f     f     f     f
c   ifox  = t then joint frequency used to compute frequency-to-exceed X/Q
c         = f then joint frequency used to compute annual average X/Q
c   inorm = t then joint frequency data is normalized (as in GENII)
c         = f then joint frequency data is un-normalized
c   icdf  = t then cumulative distribution file created (CDF.OUT)
c         = f then no cumulative distribution file created
c   ichk  = t then X/Q parameter print option turned on
c         = f then no parameter print
c   isite = t then X/Q based on joint frequency data for all 16 sectors
c         = f then X/Q based on joint frequency data of individual sectors
c   ipop  = t then X/Q is population weighted
c         = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c   ipuff idep  isrc  iwind
     0     0     0     0
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c   iwake ipm   iflow ientr
     2     0     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c   (irise igrnd)iwash igrav
     0     0     0     0
c   ipuff = 1 then X/Q calculated using puff model
c         = 0 then X/Q calculated using default continuous plume model
c   idep  = 1 then plume depletion model turned on (Chamberlain model)
c   isrc  = 1 then X/Q multiplied by scalar
c         = 2 then X/Q adjusted by wind speed function
```

```
c    iwind = 1 then wind speed corrected for plume height
c    iwake = 1 then NRC RG 1.145 building wake model turned on
c          = 2 then MACCS virtual distance building wake model turned on
c    ipm   = 1 then NRC RG 1.145 plume meander model turned on
c          = 2 then 5th Power Law plume meander model turned on
c          = 3 then sector average model turned on
c    iflow = 1 then sigmas adjusted for volume flow rate
c    ientr = 1 then method of Pasquill used to account for entrainment
c    irise = 1 then MACCS buoyant plume rise model turned on
c          = 2 then ISC2 momentum/buoyancy plume rise model turned on
c    igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c    iwash = 1 then stack downwash model turned on
c    igrav = 1 then gravitational settling model turned on
c          = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c    release         anemometer      mixing          frequency
c    height          height          height          to
c    (m)             (m)             (m)             exceed
     0               10              48.0            0.5
c
c    building        building        release         deposition      grav settling
c    width           height          duration        velocity        velocity
c    Wb(m)           Hb(m)           (hour)          (m/s)           (m/s)
     2.13            48.0            0.5             0.001           0.001
c
c                    initial         initial                         convective
c    ambient         plume           plume           release         heat release
c    temperature     temperature     flow rate       diameter        rate*
c    (°C)            (°C)            (m3/s)          (m)             (watts)
     20              20              3.78            2.13            0
c    *If zero then buoyant flux based on plume/ambient temperature difference.
c
c    X/Q             Wind
c    scaling         Speed
c    factor          Exponent
     1               .78
c
c RECEPTOR LOCATIONS (no line limit)
c    MODE               RECEPTOR DEPENDENT DATA
c    1 (site winds)     sector, distance, receptor height
c    2 (special case)   class, windspeed, distance, offset, receptor height
c    3 (plot file)      class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
c    sector = 0, 1, 2... (all, S, SSW, etc.)
c    distance = receptor distance (m)
c    receptor height = height of receptor (m)
c    class = 1,2,3,4,5,6,7 (Pasquill stability A,B,C,D,E,F,G)
c    windspeed = anemometer wind speed (m/s)
c    offset = offset from plume centerline (m)
c    xmax  = maximum distance to plot or calculate to (m)
c    imax  = distance intervals
c    ymax  = maximum offset to plot (m)
c    jmax  = offset intervals
c    xqmin = minimum scaled X/Q to calculate
c    power = exponent in power function step size
```

Canister Storage Building, Natural Circulation
Stack — Less than 0.5 Hour - Sector Maximum 99.5%

```
CSB -- Natural Circulation (156 ft) Stack -- Less Than 0.5 h
c
c GXQ Version 4.0 Input File
     1
c MODE SELECTION:
c    1 - X/Q based on Hanford site specific meteorology
c    2 - X/Q based on atmospheric stability class and wind speed
c    3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
c    ifox  inorm icdf  ichk  isite ipop
```

```
        t     f     f     f     f     f
c    ifox  = t then joint frequency used to compute frequency-to-exceed X/Q
c          = f then joint frequency used to compute annual average X/Q
c    inorm = t then joint frequency data is normalized (as in GENII)
c          = f then joint frequency data is un-normalized
c    icdf  = t then cumulative distribution file created (CDF.OUT)
c          = f then no cumulative distribution file created
c    ichk  = t then X/Q parameter print option turned on
c          = f then no parameter print
c    isite = t then X/Q based on joint frequency data for all 16 sectors
c          = f then X/Q based on joint frequency data of individual sectors
c    ipop  = t then X/Q is population weighted
c          = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c    ipuff idep  isrc  iwind
      0     0     0     1
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c    iwake ipm   iflow ientr
      0     0     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c    (irise igrnd)iwash igrav
      0     0     0     0
c    ipuff = 1 then X/Q calculated using puff model
c          = 0 then X/Q calculated using default continuous plume model
c    idep  = 1 then plume depletion model turned on (Chamberlain model)
c    isrc  = 1 then X/Q multiplied by scalar
c          = 2 then X/Q adjusted by wind speed function
c    iwind = 1 then wind speed corrected for plume height
c    iwake = 1 then NRC RG 1.145 building wake model turned on
c          = 2 then MACCS virtual distance building wake model turned on
c    ipm   = 1 then NRC RG 1.145 plume meander model turned on
c          = 2 then 5th Power Law plume meander model turned on
c          = 3 then sector average model turned on
c    iflow = 1 then sigmas adjusted for volume flow rate
c    ientr = 1 then method of Pasquill used to account for entrainment
c    irise = 1 then MACCS buoyant plume rise model turned on
c          = 2 then ISC2 momentum/buoyancy plume rise model turned on
c    igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c    iwash = 1 then stack downwash model turned on
c    igrav = 1 then gravitational settling model turned on
c          = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:  (release height is half the mixing depth for fumigation)
c    release        anemometer     mixing         frequency
c    height         height         height         to
c    (m)            (m)            (m)            exceed
     24.0           10             1000           0.5
c
c    building       building       release        deposition     grav settling
c    width          height         duration       velocity       velocity
c    Wb(m)          Hb(m)          (hour)         (m/s)          (m/s)
     42.4           18.3           2              0.001          0.001
c
c                   initial        initial                       convective
c    ambient        plume          plume          release        heat release
c    temperature    temperature    flow rate      diameter       rate*
c    (°C)           (°C)           (m3/s)         (m)            (watts)
     20             20             3.78           2.13           0
c    *If zero then buoyant flux based on plume/ambient temperature difference.
c
c    X/Q            Wind
c    scaling        Speed
c    factor         Exponent
     1              .78
c
c RECEPTOR LOCATIONS (no line limit)
c    MODE                 RECEPTOR DEPENDENT DATA
c    1 (site winds)       sector, distance, receptor height
c    2 (special case)     class, windspeed, distance, offset, receptor height
c    3 (plot file)        class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
c    sector = 0, 1, 2... (all, S, SSW, etc.)
c    distance = receptor distance (m)
c    receptor height = height of receptor (m)
```

```
c    class = 1,2,3,4,5,6,7 (Pasquill stability A,B,C,D,E,F,G)
c    windspeed = anemometer wind speed (m/s)
c    offset = offset from plume centerline (m)
c    xmax  = maximum distance to plot or calculate to (m)
c    imax  = distance intervals
c    ymax  = maximum offset to plot (m)
c    jmax  = offset intervals
c    xqmin = minimum scaled X/Q to calculate
c    power = exponent in power function step size
```

Canister Storage Building, Natural Circulation
Stack — 0.5 to 2 Hours - Sector Maximum 99.5%

```
CSB -- Natural Circulation (156 ft) Stack -- 0.5 to 2 hr
c
c GXQ Version 4.0 Input File
   1
c MODE SELECTION:
c   1 - X/Q based on Hanford site specific meteorology
c   2 - X/Q based on atmospheric stability class and wind speed
c   3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
c   ifox  inorm icdf  ichk  isite ipop
      t     f     f     f     f     f
c   ifox = t then joint frequency used to compute frequency-to-exceed X/Q
c        = f then joint frequency used to compute annual average X/Q
c   inorm = t then joint frequency data is normalized (as in GENII)
c         = f then joint frequency data is un-normalized
c   icdf  = t then cumulative distribution file created (CDF.OUT)
c         = f then no cumulative distribution file created
c   ichk  = t then X/Q parameter print option turned on
c         = f then no parameter print
c   isite = t then X/Q based on joint frequency data for all 16 sectors
c         = f then X/Q based on joint frequency data of individual sectors
c   ipop  = t then X/Q is population weighted
c         = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c   ipuff idep  isrc  iwind
      0     0     0     1
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c   iwake ipm   iflow ientr
      0     0     1     1
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c   (irise igrnd)iwash igrav
      2      0     1     0
c   ipuff = 1 then X/Q calculated using puff model
c         = 0 then X/Q calculated using default continuous plume model
c   idep  = 1 then plume depletion model turned on (Chamberlain model)
c   isrc  = 1 then X/Q multiplied by scalar
c         = 2 then X/Q adjusted by wind speed function
c   iwind = 1 then wind speed corrected for plume height
c   iwake = 1 then NRC RG 1.145 building wake model turned on
c         = 2 then MACCS virtual distance building wake model turned on
c   ipm   = 1 then NRC RG 1.145 plume meander model turned on
c         = 2 then 5th Power Law plume meander model turned on
c         = 3 then sector average model turned on
c   iflow = 1 then sigmas adjusted for volume flow rate
c   ientr = 1 then method of Pasquill used to account for entrainment
c   irise = 1 then MACCS buoyant plume rise model turned on
c         = 2 then ISC2 momentum/buoyancy plume rise model turned on
c   igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c   iwash = 1 then stack downwash model turned on
c   igrav = 1 then gravitational settling model turned on
c         = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c   release      anemometer      mixing        frequency
c   height       height          height        to
c   (m)          (m)             (m)           exceed
    47.55        10              1000          0.5
```

```
c
c   building      building      release       deposition    grav settling
c   width         height        duration      velocity      velocity
c   Wb(m)         Hb(m)         (hour)        (m/s)         (m/s)
    42.4          18.3          2             0.001         0.001
c
c                 initial       initial                     convective
c   ambient       plume         plume         release       heat release
c   temperature   temperature   flow rate     diameter      rate*
c   (°C)          (°C)          (m3/s)        (m)           (watts)
    20            20            3.78          2.13          0
c   *If zero then buoyant flux based on plume/ambient temperature difference.
c
c   X/Q           Wind
c   scaling       Speed
c   factor        Exponent
    1             .78
c
c RECEPTOR LOCATIONS (no line limit)
c   MODE                RECEPTOR DEPENDENT DATA
c   1 (site winds)      sector, distance, receptor height
c   2 (special case)    class, windspeed, distance, offset, receptor height
c   3 (plot file)       class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
c   sector = 0, 1, 2... (all, S, SSW, etc.)
c   distance = receptor distance (m)
c   receptor height = height of receptor (m)
c   class = 1,2,3,4,5,6,7 (Pasquill stability A,B,C,D,E,F,G)
c   windspeed = anemometer wind speed (m/s)
c   offset = offset from plume centerline (m)
c   xmax  = maximum distance to plot or calculate to (m)
c   imax  = distance intervals
c   ymax  = maximum offset to plot (m)
c   jmax  = offset intervals
c   xqmin = minimum scaled X/Q to calculate
c   power = exponent in power function step size
```

Canister Storage Building, Natural Circulation Stack — Annual Average - Sector Maximum

```
CSB -- Natural Circulation (156 ft) Stack -- Annual Average
c
c GXQ Version 4.0 Input File
    1
c MODE SELECTION:
c   1 - X/Q based on Hanford site specific meteorology
c   2 - X/Q based on atmospheric stability class and wind speed
c   3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
c   ifox  inorm icdf  ichk  isite ipop
    f     f     f     f     f     f
c   ifox  = t then joint frequency used to compute frequency-to-exceed X/Q
c         = f then joint frequency used to compute annual average X/Q
c   inorm = t then joint frequency data is normalized (as in GENII)
c         = f then joint frequency data is un-normalized
c   icdf  = t then cumulative distribution file created (CDF.OUT)
c         = f then no cumulative distribution file created
c   ichk  = t then X/Q parameter print option turned on
c         = f then no parameter print
c   isite = t then X/Q based on joint frequency data for all 16 sectors
c         = f then X/Q based on joint frequency data of individual sectors
c   ipop  = t then X/Q is population weighted
c         = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c   ipuff idep  isrc  iwind
    0     0     0     1
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c   iwake ipm   iflow ientr
    0     3     1     1
```

```
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c  (irise igrnd)iwash igrav
      2     0    1    0
c   ipuff = 1 then X/Q calculated using puff model
c         = 0 then X/Q calculated using default continuous plume model
c   idep  = 1 then plume depletion model turned on (Chamberlain model)
c   isrc  = 1 then X/Q multiplied by scalar
c         = 2 then X/Q adjusted by wind speed function
c   iwind = 1 then wind speed corrected for plume height
c   iwake = 1 then NRC RG 1.145 building wake model turned on
c         = 2 then MACCS virtual distance building wake model turned on
c   ipm   = 1 then NRC RG 1.145 plume meander model turned on
c         = 2 then 5th Power Law plume meander model turned on
c         = 3 then sector average model turned on
c   iflow = 1 then sigmas adjusted for volume flow rate
c   ientr = 1 then method of Pasquill used to account for entrainment
c   irise = 1 then MACCS buoyant plume rise model turned on
c         = 2 then ISC2 momentum/buoyancy plume rise model turned on
c   igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c   iwash = 1 then stack downwash model turned on
c   igrav = 1 then gravitational settling model turned on
c         = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c   release      anemometer      mixing      frequency
c   height       height          height      to
c   (m)          (m)             (m)         exceed
    47.55        10              1000        0.5
c
c   building     building        release     deposition     grav settling
c   width        height          duration    velocity       velocity
c   Wb(m)        Hb(m)           (hour)      (m/s)          (m/s)
    42.4         18.3            2           0.001          0.001
c
c                initial         initial                    convective
c   ambient      plume           plume       release        heat release
c   temperature  temperature     flow rate   diameter       rate*
c   (°C)         (°C)            (m3/s)      (m)            (watts)
    20           20              3.78        2.13           0
c   *If zero then buoyant flux based on plume/ambient temperature difference.
c
c   X/Q          Wind
c   scaling      Speed
c   factor       Exponent
    1            .78
c
c RECEPTOR LOCATIONS (no line limit)
c   MODE                 RECEPTOR DEPENDENT DATA
c   1 (site winds)       sector, distance, receptor height
c   2 (special case)     class, windspeed, distance, offset, receptor height
c   3 (plot file)        class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
c   sector = 0, 1, 2... (all, S, SSW, etc.)
c   distance = receptor distance (m)
c   receptor height = height of receptor (m)
c   class = 1,2,3,4,5,6,7 (Pasquill stability A,B,C,D,E,F,G)
c   windspeed = anemometer wind speed (m/s)
c   offset = offset from plume centerline (m)
c   xmax  = maximum distance to plot or calculate to (m)
c   imax  = distance intervals
c   ymax  = maximum offset to plot (m)
c   jmax  = offset intervals
c   xqmin = minimum scaled X/Q to calculate
c   power = exponent in power function step size
```

Note: The GXQ inputs for overall site X/Q are identical to the above except that the "isite" flag is "t" and the "frequency to exceed" is changed from 0.5 to 5.0.

DOS Batch File to Combine Distances with Elevated
Release Input Files and Run GXQ

```
@Echo Off
:    XQS.BAT by Paul D. Rittmann, PhD CHP
:    Runs GXQ stack release cases for SNF
:    Combines input file & distance file first
:    Specify which case to run on the command line

:START
Echo ^[37m
IF "%1"=="1"  Goto OK-1
IF "%1"=="2"  Goto OK-2
Echo ^[36m
Echo   Need to specify 100 or 200 Area cases on the command line.^[32m
Echo      1 == run CVDF HVAC stack case
Echo      2 == run CSB stack cases^[36m
Echo   Example:  to run both areas type  ^[33m XQS  1  2
Goto End

:OK-1
CD\GXQ
Call JFP 1 10 B
:  first, the sector X/Q calcs for fumigation <1h, 1h-2h, and chronic
For %%f in (F A B C) Do Copy TI-059\XQ2\SS%%f1.IN+TI-059\XQ2\SS1.DST SS%%f1.IN
Call  RN  SSF1 SSA1 SSB1 SSC1
Del SS?1.IN
:  second, the overall site X/Q calcs for fumigation, <0.5h, 1h-2h, and chronic
For %%f in (F A B C) Do Copy TI-059\XQ2\SO%%f1.IN+TI-059\XQ2\SO1.DST SO%%f1.IN
Call  RN  SOF1 SOA1 SOB1 SOC1
Del SO?1.IN
Goto XQ

:OK-2
CD\GXQ
Call JFP 2 10 B
:  first, the sector X/Q calcs for fumigation <1h, 1h-2h, and chronic
For %%f in (F A B C) Do Copy TI-059\XQ2\SS%%f2.IN+TI-059\XQ2\SS2.DST SS%%f2.IN
Call  RN  SSF2 SSA2 SSB2 SSC2
Del SS?2.IN
:  second, the overall site X/Q calcs for fumigation, <0.5h, 1h-2h, and chronic
For %%f in (F A B C) Do Copy TI-059\XQ2\SO%%f2.IN+TI-059\XQ2\SO2.DST SO%%f2.IN
Call  RN  SOF2 SOA2 SOB2 SOC2
Del SO?2.IN
:  first, the sector X/Q calcs for fumigation <1h, 1h-2h, and chronic
For %%f in (F A B C) Do Copy TI-059\XQ2\SS%%f3.IN+TI-059\XQ2\SS2.DST SS%%f3.IN
Call  RN  SSF3 SSA3 SSB3 SSC3
Del SS?3.IN
:  second, the overall site X/Q calcs for fumigation, <0.5h, 1h-2h, and chronic
For %%f in (F A B C) Do Copy TI-059\XQ2\SO%%f3.IN+TI-059\XQ2\SO2.DST SO%%f3.IN
Call  RN  SOF3 SOA3 SOB3 SOC3
Del SO?3.IN

:XQ
Shift
IF not "%1"=="" Goto START

:End
PD /6
```

APPENDIX E

JOINT FREQUENCY DATA AND WIND ROSES

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APPENDIX E

JOINT FREQUENCY DATA AND WIND ROSES

The wind data files begin with two title lines. These show which tower the data was collected at, and who last modified the data in the file.

The third line has some information about the data layout. The first number in the line (8) is the number of wind speeds. The second number in the line is the number of stability classes (7 - A,B,C,D,E,F,G). The next two numbers are not used. The last number (10.0) gives the height in meters at which the wind speeds and other data apply.

The fourth line has the 8 wind speeds, in meters per second. These are the midpoints of the data actually collected. Since the data is collected using wind speed units of miles per hour (mph), the numbers are not exact. The table below shows the binning of the wind data. Note the coarseness of the low wind speed groupings. This contributes to the sharp differences between air transport factors for the various SNF facilities and release durations.

Binning of Wind Speeds for Joint Frequency Tables

Midpoint Wind Speed	Range of Wind Speeds
0.89 m/s	1 to 3 mph
2.65 m/s	4 to 8 mph
4.70 m/s	9 to 12 mph
7.15 m/s	13 to 19 mph
9.80 m/s	20 to 24 mph
12.7 m/s	25 to 32 mph
15.6 m/s	33 to 37 mph
19.0 m/s	38 mph and higher

The remaining 56 lines (8 wind speeds times 7 stability classes) are the percentage of the hours in the period indicated in which the wind blows in a particular wind direction, in a given stability class and wind speed group. Each line contains 16 numbers corresponding to the 16 compass directions. The first column is wind direction (wind from) north. The second column is wind direction (wind from) north-northeast. The fifth column is wind direction (wind from) east, and so forth. The first line is the percents for class A at 0.89 m/s. The second line is class B at 0.89 m/s. The seventh line is class G at 0.89 m/s. The eighth line is class A at 2.65 m/s, and so forth.

No documentation for this data is available. It is derived from readings taken by the Hanford meteorology department at the Pacific Northwest National Laboratory. It is similar to published reports.

100 N AREA - 10 M - Pasquill A - G (1983 - 1991 Average)
Created 8/26/92 KR

```
  8   7   1   1   10.0
.89   2.65   4.7   7.15   9.8   12.7   15.6   19.0
0.34 0.14 0.14 0.13 0.27 0.17 0.13 0.11 0.17 0.11 0.13 0.19 0.35 0.32 0.34 0.30
0.12 0.06 0.07 0.05 0.14 0.10 0.09 0.08 0.07 0.06 0.08 0.08 0.13 0.11 0.12 0.11
0.15 0.07 0.08 0.10 0.13 0.11 0.10 0.07 0.11 0.07 0.07 0.10 0.11 0.11 0.11 0.10
0.71 0.42 0.38 0.45 1.03 0.89 0.70 0.53 0.75 0.51 0.59 0.57 0.90 0.64 0.62 0.57
0.60 0.37 0.42 0.48 0.98 0.68 0.54 0.44 0.56 0.42 0.51 0.61 0.86 0.67 0.54 0.52
0.57 0.32 0.41 0.46 0.88 0.51 0.42 0.25 0.35 0.29 0.40 0.63 0.92 0.67 0.58 0.52
0.25 0.17 0.18 0.22 0.36 0.18 0.15 0.11 0.15 0.13 0.22 0.35 0.63 0.41 0.32 0.28
0.60 0.42 0.32 0.14 0.32 0.28 0.25 0.17 0.16 0.14 0.33 0.45 0.73 0.48 0.40 0.43
0.13 0.12 0.08 0.05 0.13 0.11 0.10 0.07 0.06 0.03 0.08 0.14 0.20 0.09 0.11 0.09
0.11 0.09 0.09 0.06 0.12 0.10 0.10 0.07 0.05 0.03 0.08 0.11 0.18 0.09 0.08 0.09
0.60 0.47 0.37 0.37 0.72 0.71 0.65 0.39 0.39 0.32 0.52 1.05 1.33 0.68 0.50 0.41
0.33 0.23 0.28 0.42 0.86 0.63 0.48 0.32 0.33 0.24 0.50 1.18 1.97 0.76 0.38 0.22
0.18 0.14 0.16 0.41 0.84 0.38 0.23 0.16 0.14 0.16 0.28 0.68 1.08 0.49 0.28 0.16
0.05 0.05 0.08 0.19 0.32 0.13 0.09 0.05 0.05 0.06 0.13 0.29 0.59 0.18 0.09 0.04
0.15 0.24 0.13 0.04 0.08 0.08 0.13 0.06 0.07 0.10 0.23 0.29 0.48 0.35 0.19 0.09
0.03 0.06 0.05 0.02 0.03 0.03 0.03 0.02 0.03 0.02 0.06 0.07 0.13 0.09 0.04 0.02
0.03 0.06 0.03 0.01 0.03 0.02 0.04 0.03 0.02 0.03 0.06 0.05 0.11 0.07 0.04 0.02
0.19 0.21 0.17 0.07 0.09 0.16 0.26 0.16 0.12 0.20 0.33 0.56 1.17 0.59 0.19 0.12
0.14 0.13 0.09 0.05 0.09 0.08 0.22 0.13 0.12 0.13 0.26 0.68 1.79 0.72 0.17 0.09
0.08 0.07 0.03 0.05 0.06 0.04 0.07 0.04 0.02 0.02 0.06 0.25 0.33 0.13 0.04 0.05
0.02 0.01 0.00 0.01 0.04 0.02 0.01 0.01 0.01 0.01 0.01 0.06 0.06 0.02 0.01 0.01
0.05 0.09 0.07 0.02 0.01 0.01 0.03 0.02 0.02 0.05 0.14 0.12 0.28 0.34 0.17 0.03
0.03 0.05 0.02 0.00 0.00 0.00 0.01 0.01 0.01 0.01 0.06 0.03 0.09 0.09 0.04 0.01
0.01 0.02 0.02 0.00 0.00 0.00 0.01 0.01 0.01 0.01 0.05 0.03 0.06 0.07 0.03 0.01
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0.10 0.10 0.04 0.02 0.00 0.01 0.03 0.03 0.03 0.07 0.11 0.15 0.65 0.56 0.13 0.04
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0.39 0.26 0.28 0.25 0.46 0.34 0.31 0.30 0.34 0.21 0.25 0.29 0.49 0.44 0.45 0.39
0.23 0.13 0.12 0.14 0.31 0.23 0.28 0.26 0.35 0.23 0.22 0.27 0.48 0.36 0.32 0.23
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Figure E-1. 100-N Area Wind Rose.

100-N Area Wind Rose
100N Data from 1983 to 1991
(Rings are in 2% increments)

Legend:
- 1-3 mph
- <= 12 mph
- <= 19 mph
- All Speeds

Compass points are standard "wind from" wind directions.
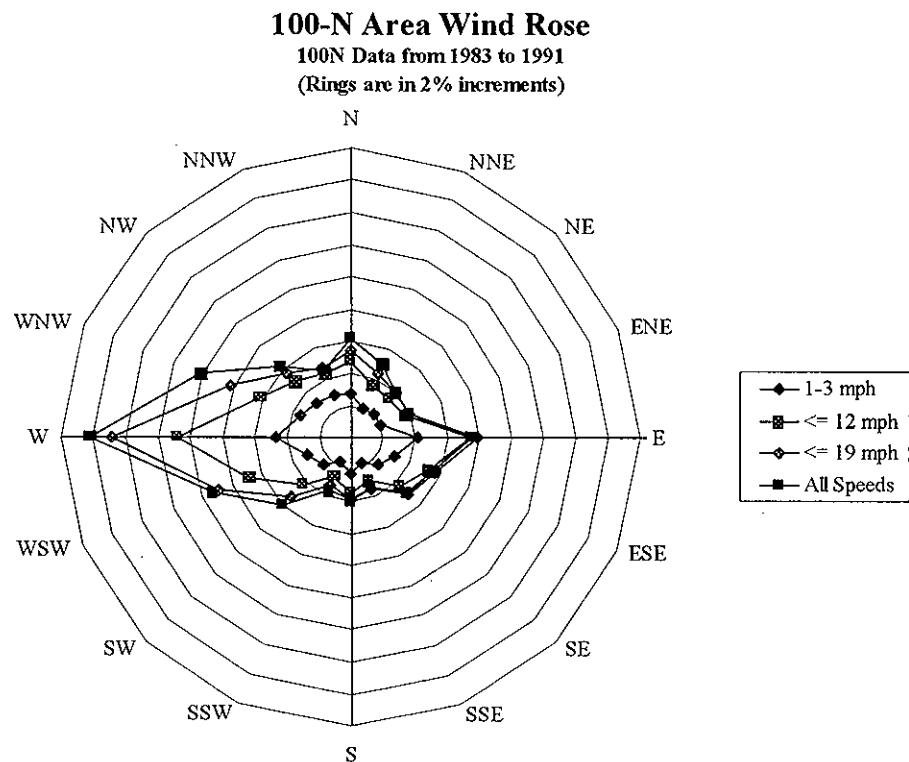
Figure E-2. 200 Area Wind Rose.

200 Area Wind Rose
HMS Data from 1983 to 1991
(Rings are in 2% increments)
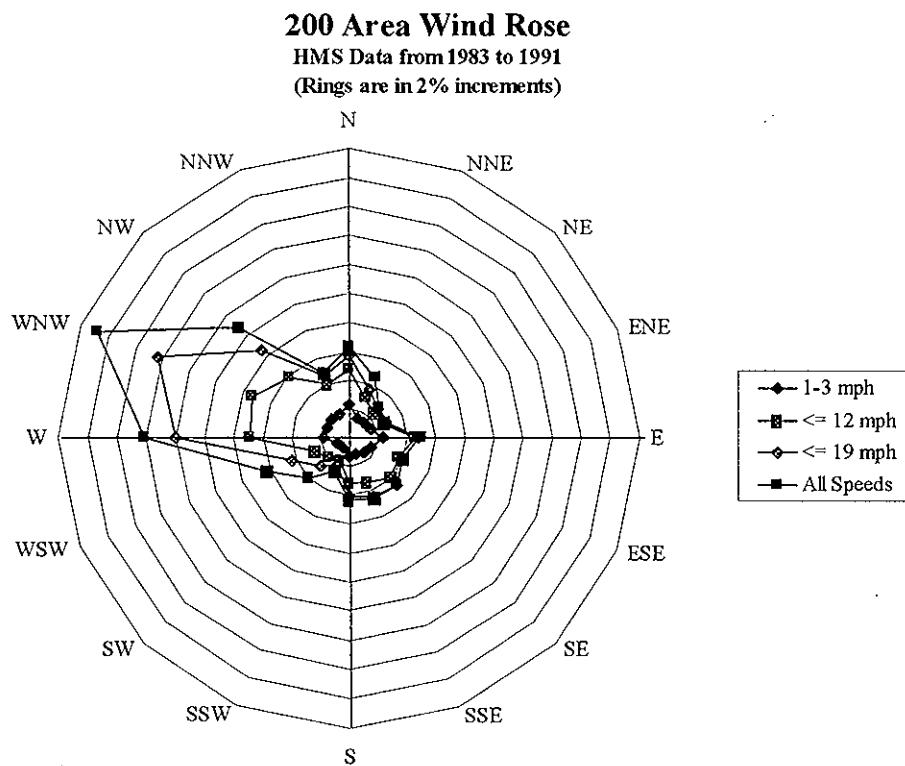
Compass points are standard "wind from" wind directions.

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APPENDIX F

UNIT DOSE WITH INSOLUBLE LUNG CLASSES

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Table F-1. Unit Dose Factor with Insoluble Lung Clearances. (3 sheets)

Nuclide	Activity[a] (Ci/MTU)	Activity (Bq/gU)	Inhalation DF[b]		UD[c] (Sv/gU)	Percent of Total
			(Sv/Bq)	Class		
Fission and Activation Products						
H-3	2.61 E+01	9.66 E+05	2.60 E-11	Vapor	2.51 E-05	0.00%
C-14	5.53 E-01	2.05 E+04	5.64 E-10	Organic	1.15 E-05	0.00%
Fe-55	5.41 E-01	2.00 E+04	3.61 E-10	W	7.23 E-06	0.00%
Co-60	2.09 E+00	7.73 E+04	5.91 E-08	Y	4.57 E-03	0.00%
Ni-59	3.18 E-02	1.18 E+03	2.48 E-10	W	2.92 E-07	0.00%
Ni-63	3.47 E+00	1.28 E+05	6.22 E-10	W	7.99 E-05	0.00%
Se-79	6.54 E-02	2.42 E+03	2.66 E-09	W	6.44 E-06	0.00%
Kr-85	3.70 E+02	1.37 E+07	3.57 E-13	Gas[d]	4.89 E-06	0.00%
Sr-90	6.93 E+03	2.56 E+08	6.47 E-08	D	1.66 E+01	0.46%
Y-90	6.93 E+03	2.56 E+08	2.28 E-09	Y	5.85 E-01	0.02%
Zr-93	2.95 E-01	1.09 E+04	2.00 E-08	Y	2.18 E-04	0.00%
Nb-93m	1.93 E-01	7.14 E+03	7.90 E-09	Y	5.64 E-05	0.00%
Tc-99	2.19 E+00	8.10 E+04	2.25 E-09	W	1.82 E-04	0.00%
Ru-106	2.56 E-02	9.47 E+02	1.29 E-07	Y	1.22 E-04	0.00%
Rh-106	2.56 E-02	9.47 E+02	DP[e]	NA	NA	NA
Pd-107	1.56 E-02	5.77 E+02	3.45 E-09	Y	1.99 E-06	0.00%
Ag-110	7.17 E-10	2.65 E-05	DP[e]	NA	NA	NA
Ag-110m	5.39 E-08	1.99 E-03	2.17 E-08	Y	4.33 E-11	0.00%
Cd-113m	2.78 E+00	1.03 E+05	1.08 E-07	Y	1.11 E-02	0.00%
In-113m	1.36 E-19	5.03 E-15	9.04 E-12	W	4.55 E-26	0.00%
Sn-113	1.36 E-19	5.03 E-15	2.88 E-09	W	1.45 E-23	0.00%
Sn-119m	6.14 E-08	2.27 E-03	1.69 E-09	W	3.84 E-12	0.00%
Sn-121m	6.27 E-02	2.32 E+03	3.11 E-09	W	7.21 E-06	0.00%
Sn-123	1.72 E-16	6.36 E-12	8.79 E-09	W	5.59 E-20	0.00%
Sn-126	1.29 E-01	4.77 E+03	2.69 E-08	W	1.28 E-04	0.00%

Table F-1. Unit Dose Factor with Insoluble Lung Clearances. (3 sheets)

Nuclide	Activity[a] (Ci/MTU)	Activity (Bq/gU)	Inhalation DF[b]		UD[c] (Sv/gU)	Percent of Total
			(Sv/Bq)	Class		
Sb-125	0.00	0.00	3.30 E-09	W	0.00	0.00%
Sb-126	1.81 E-02	6.70 E+02	3.17 E-09	W	2.12 E-06	0.00%
Sb-126m	1.29 E-01	4.77 E+03	7.72 E-12	W	3.68 E-08	0.00%
Te-123m	1.50 E-21	5.55 E-17	2.86 E-09	W	1.59 E-25	0.00%
Te-125m	0.00	0.00	1.97 E-09	W	0.00	0.00%
Te-127	2.12 E-19	7.84 E-15	8.60 E-11	W	6.75 E-25	0.00%
Te-127m	2.16 E-19	7.99 E-15	5.81 E-09	W	4.64 E-23	0.00%
I-129	5.16 E-03	1.91 E+02	4.69 E-08	D	8.95 E-06	0.00%
Cs-134	6.47 E+00	2.39 E+05	1.25 E-08	D	2.99 E-03	0.00%
Cs-135	6.04 E-02	2.23 E+03	1.23 E-09	D	2.75 E-06	0.00%
Cs-137	9.66 E+03	3.57 E+08	8.63 E-09	D	3.08 E+00	0.08%
Ba-137m	9.14 E+03	3.38 E+08	DP[e]	NA	NA	NA
Ce-144	7.91 E-04	2.93 E+01	1.01 E-07	Y	2.96 E-06	0.00%
Pr-144	7.82 E-04	2.89 E+01	1.17 E-11	Y	3.39 E-10	0.00%
Pr-144m	9.48 E-06	3.51 E-01	DP[e]	NA	NA	NA
Pm-147	1.09 E+02	4.03 E+06	1.06 E-08	Y	4.27 E-02	0.00%
Sm-151	1.02 E+02	3.77 E+06	8.10 E-09	W	3.06 E-02	0.00%
Eu-152	8.45 E-01	3.13 E+04	5.97 E-08	W	1.87 E-03	0.00%
Eu-154	1.13 E+02	4.18 E+06	7.73 E-08	W	3.23 E-01	0.01%
Eu-155	1.06 E+01	3.92 E+05	1.12 E-08	W	4.39 E-03	0.00%
Gd-153	5.19 E-19	1.92 E-14	2.56 E-09	W	4.92 E-23	0.00%
Subtotal:	3.34 E+04	1.24 E+09	1.20 E-06		2.07 E+01	0.57%
Actinides						
U-234	3.84 E-01	1.42 E+04	3.58 E-05	Y	5.09 E-01	0.01%
U-235	1.27 E-02	4.70 E+02	3.32 E-05	Y	1.56 E-02	0.00%
U-236	7.16 E-02	2.65 E+03	3.39 E-05	Y	8.98 E-02	0.00%

Table F-1. Unit Dose Factor with Insoluble Lung Clearances. (3 sheets)

Nuclide	Activity[a] (Ci/MTU)	Activity (Bq/gU)	Inhalation DF[b]		UD[c] (Sv/gU)	Percent of Total
			(Sv/Bq)	Class		
U-238	3.31 E-01	1.22 E+04	3.20 E-05	Y	3.92 E-01	0.01%
Np-237	4.66 E-02	1.72 E+03	1.46 E-04	W	2.52 E-01	0.01%
Pu-238	1.33 E+02	4.92 E+06	7.79 E-05	Y	3.83 E+02	10.53%
Pu-239	1.73 E+02	6.40 E+06	8.33 E-05	Y	5.33 E+02	14.65%
Pu-240	1.37 E+02	5.07 E+06	8.33 E-05	Y	4.22 E+02	11.60%
Pu-241	6.82 E+03	2.52 E+08	1.34 E-06	Y	3.38 E+02	9.30%
Pu-242	8.71 E-02	3.22 E+03	7.92 E-05	Y	2.55 E-01	0.01%
Am-241	4.34 E+02	1.61 E+07	1.20 E-04	W	1.93 E+03	52.93%
Am-242	3.71 E-01	1.37 E+04	1.58 E-08	W	2.17 E-04	0.00%
Am-242m	3.72 E-01	1.38 E+04	1.15 E-04	W	1.58 E+00	0.04%
Am-243	2.78 E-01	1.03 E+04	1.19 E-04	W	1.22 E+00	0.03%
Cm-242	3.08 E-01	1.14 E+04	4.67 E-06	W	5.32 E-02	0.00%
Cm-244	4.47 E+00	1.65 E+05	6.70 E-05	W	1.11 E+01	0.30%
Subtotal:	7.70 E+03	2.85 E+08	1.03 E-03		3.62 E+03	99.43%
				Total:	3.64 E+03	Sv/g U

[a]Results are decayed to May 31, 1998. Fuel activities are from HNF-SD-SNF-TI-015 Rev 6, *Spent Nuclear Fuel Project Technical Databook*, 1998, Fluor Daniel Hanford, Incorporated, Richland, Washington.

[b]Inhalation dose factors are from *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion*, Federal Guidance Report Number 11, U.S. Environmental Protection Agency, Washington, D.C. (1988). The internal dose factor for tritium was increased by 50% to include skin absorption.

[c]The unit dose is the product of the normalized activity and the inhalation dose factor. To convert Sv/g to rem/g multiply by 100.

[d]Krypton-85 is a noble gas. It does not accumulate in the body; therefore its internal dose factor is zero. The value shown is the external dose rate factor for submersion in an infinite cloud divided by the light activity breathing rate.

[e]Daughter products are included with parents and not tracked individually. Short half life progeny nuclides not shown are assumed to be in equilibrium with their parent nuclide.

D = very soluble compounds with lung residence times of days
DP = daughter product.
MTU = metric ton of uranium.
NA = not applicable.
W = moderately soluble compounds with lung residence times of weeks
Y = insoluble compounds with lung residence times of years

Table F-2. Organ Dose Factors from Inhalation for Insoluble Lung Categories. (3 sheets)

Nuclide	Inhalation dose factors, Sv/Bq[a]				
	Bone surface	Red marrow	Lungs	Gonads	Remainder
Fission and activation products					
H-3	2.60 E-11	2.60 E-11	2.60 E-11	2.60 E-11	2.60 E-11
C-14	5.64 E-10	5.64 E-10	5.64 E-10	5.64 E-10	5.64 E-10
Fe-55	1.75 E-10	1.76 E-10	1.06 E-09	1.79 E-10	4.37 E-10
Co-60	1.35 E-08	1.72 E-08	3.45 E-07	4.76 E-09	3.60 E-08
Ni-59	1.05 E-10	1.06 E-10	1.20 E-09	1.09 E-10	1.40 E-10
Ni-63	2.47 E-10	2.47 E-10	3.07 E-09	2.47 E-10	3.67 E-10
Se-79	5.98 E-10	5.98 E-10	9.81 E-09	5.98 E-10	3.77 E-09
Kr-85	0.0	0.0	0.0	0.0	0.0
Sr-90	7.27 E-07	3.36 E-07	3.73 E-09	2.64 E-09	3.36 E-09
Y-90	1.51 E-11	1.52 E-11	9.31 E-09	5.17 E-13	3.87 E-09
Zr-93	2.38 E-07	1.93 E-08	8.72 E-08	2.82 E-12	1.73 E-10
Nb-93m	2.84 E-10	1.14 E-10	6.45 E-08	1.55 E-10	3.04 E-10
Tc-99	3.99 E-11	3.99 E-11	1.67 E-08	3.99 E-11	6.26 E-10
Ru-106	1.61 E-09	1.76 E-09	1.04 E-06	1.30 E-09	1.20 E-08
Rh-106	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]
Pd-107	1.51 E-12	5.68 E-13	2.85 E-08	1.05 E-13	9.71 E-11
Ag-110	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]
Ag-110m	5.19 E-09	6.74 E-09	1.20 E-07	2.43 E-09	1.51 E-08
Cd-113m	4.72 E-09	4.72 E-09	4.09 E-07	4.72 E-09	1.86 E-07
In-113m	9.38 E-13	1.41 E-12	5.83 E-11	8.23 E-13	4.99 E-12
Sn-113	1.32 E-09	7.71 E-10	1.84 E-08	3.16 E-10	1.38 E-09
Sn-119m	1.10 E-09	4.62 E-10	1.15 E-08	7.14 E-11	6.28 E-10
Sn-121m	4.06 E-09	1.50 E-09	2.08 E-08	1.97 E-10	1.10 E-09
Sn-123	3.75 E-09	1.36 E-09	6.11 E-08	1.81 E-10	3.70 E-09
Sn-126	3.33 E-08	1.69 E-08	1.51 E-07	4.95 E-09	1.20 E-08

Table F-2. Organ Dose Factors from Inhalation for Insoluble Lung Categories. (3 sheets)

Nuclide	Inhalation dose factors, Sv/Bq[a]				
	Bone surface	Red marrow	Lungs	Gonads	Remainder
Sb-125	9.78 E-10	5.35 E-10	2.17 E-08	3.60 E-10	1.45 E-09
Sb-126	6.75 E-10	7.97 E-10	1.38 E-08	1.32 E-09	3.19 E-09
Sb-126m	7.12 E-13	8.63 E-13	5.57 E-11	4.91 E-13	2.12 E-12
Te-123m	2.40 E-08	2.41 E-09	1.27 E-08	1.88 E-10	8.06 E-10
Te-125m	1.18 E-08	1.15 E-09	1.04 E-08	7.93 E-11	6.75 E-10
Te-127	4.09 E-12	4.09 E-12	4.27 E-10	2.02 E-12	1.11 E-10
Te-127m	2.04 E-08	5.36 E-09	3.34 E-08	1.10 E-10	1.66 E-09
I-129	1.38 E-10	1.40 E-10	3.14 E-10	8.69 E-11	1.18 E-10
Cs-134	1.10 E-08	1.18 E-08	1.18 E-08	1.30 E-08	1.39 E-08
Cs-135	1.20 E-09	1.20 E-09	1.41 E-09	1.20 E-09	1.20 E-09
Cs-137	7.94 E-09	8.30 E-09	8.82 E-09	8.76 E-09	9.12 E-09
Ba-137m	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]
Ce-144	4.72 E-09	2.88 E-09	7.91 E-07	2.39 E-10	1.91 E-08
Pr-144	1.47 E-14	1.38 E-14	9.40 E-11	2.41 E-15	1.40 E-12
Pr-144m	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]
Pm-147	2.01 E-08	1.61 E-09	7.74 E-08	8.25 E-15	1.56 E-09
Sm-151	1.38 E-07	1.10 E-08	3.26 E-09	4.03 E-14	7.51 E-09
Eu-152	2.40 E-07	7.91 E-08	5.76 E-08	1.31 E-08	9.99 E-08
Eu-154	5.23 E-07	1.06 E-07	7.92 E-08	1.17 E-08	1.13 E-07
Eu-155	1.52 E-07	1.43 E-08	1.19 E-08	3.56 E-10	1.11 E-08
Gd-153	2.15 E-08	2.71 E-09	7.75 E-09	1.93 E-10	1.90 E-09
Actinides					
U-234	1.13 E-06	7.22 E-08	2.98 E-04	2.65 E-09	1.06 E-07
U-235	1.05 E-06	7.15 E-08	2.76 E-04	2.85 E-09	1.02 E-07
U-236	1.07 E-06	6.83 E-08	2.82 E-04	2.51 E-09	1.00 E-07
U-238	1.01 E-06	6.91 E-08	2.66 E-04	2.44 E-09	1.02 E-07

Table F-2. Organ Dose Factors from Inhalation for Insoluble Lung Categories. (3 sheets)

Nuclide	Inhalation dose factors, Sv/Bq[a]				
	Bone surface	Red marrow	Lungs	Gonads	Remainder
Np-237	3.27 E-03	2.62 E-04	1.61 E-05	2.96 E-05	2.34 E-05
Pu-238	7.25 E-04	5.80 E-05	3.20 E-04	1.04 E-05	2.74 E-05
Pu-239	8.21 E-04	6.57 E-05	3.23 E-04	1.20 E-05	3.02 E-05
Pu-240	8.21 E-04	6.57 E-05	3.23 E-04	1.20 E-05	3.02 E-05
Pu-241	1.78 E-05	1.43 E-06	3.18 E-06	2.76 E-07	6.02 E-07
Pu-242	7.81 E-04	6.25 E-05	3.07 E-04	1.14 E-05	2.86 E-05
Am-241	2.17 E-03	1.74 E-04	1.84 E-05	3.25 E-05	7.82 E-05
Am-242	1.65 E-07	1.32 E-08	5.20 E-08	1.94 E-09	8.54 E-09
Am-242m	2.12 E-03	1.69 E-04	4.20 E-06	3.21 E-05	7.48 E-05
Am-243	2.17 E-03	1.73 E-04	1.78 E-05	3.26 E-05	7.74 E-05
Cm-242	4.87 E-05	3.90 E-06	1.55 E-05	5.70 E-07	2.45 E-06
Cm-244	1.17 E-03	9.38 E-05	1.93 E-05	1.59 E-05	4.78 E-05

[a]Inhalation dose factors are bounding values from *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion,* Federal Guidance Report Number 11, U.S. Environmental Protection Agency, Washington, D.C. (1988). The internal dose factor for tritium was increased by 50% to include absorption through the skin. To convert Sv/Bq to mrem/pCi multiply by 3700.
[b]Daughter products are included with parents and not tracked individually. Short half life progeny nuclides not shown are assumed to be in equilibrium with their parent nuclide.

Table F-3. Unit Dose Factors for Organs for Insoluble Lung Categories. (3 sheets)

Nuclide	Organ unit dose factors, Sv/g[a]				
	Bone surface	Red marrow	Lungs	Gonads	Remainder
Fission and activation products					
H-3	2.51 E-05	2.51 E-05	2.51 E-05	2.51 E-05	2.51 E-05
C-14	1.15 E-05	1.15 E-05	1.15 E-05	1.15 E-05	1.15 E-05
Fe-55	3.50 E-06	3.52 E-06	2.12 E-05	3.58 E-06	8.75 E-06
Co-60	1.04 E-03	1.33 E-03	2.67 E-02	3.68 E-04	2.78 E-03
Ni-59	1.24 E-07	1.25 E-07	1.41 E-06	1.28 E-07	1.65 E-07
Ni-63	3.17 E-05	3.17 E-05	3.94 E-04	3.17 E-05	4.71 E-05
Se-79	1.45 E-06	1.45 E-06	2.37 E-05	1.45 E-06	9.12 E-06
Kr-85	0.0	0.0	0.0	0.0	0.0
Sr-90	1.86 E+02	8.62 E+01	9.56 E-01	6.77 E-01	8.62 E-01
Y-90	3.87 E-03	3.90 E-03	2.39 E+00	1.33 E-04	9.92 E-01
Zr-93	2.60 E-03	2.11 E-04	9.52 E-04	3.08 E-08	1.89 E-06
Nb-93m	2.03 E-06	8.14 E-07	4.61 E-04	1.11 E-06	2.17 E-06
Tc-99	3.23 E-06	3.23 E-06	1.35 E-03	3.23 E-06	5.07 E-05
Ru-106	1.52 E-06	1.67 E-06	9.85 E-04	1.23 E-06	1.14 E-05
Rh-106	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]
Pd-107	8.72 E-10	3.28 E-10	1.65 E-05	6.06 E-11	5.60 E-08
Ag-110	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]
Ag-110m	1.04 E-11	1.34 E-11	2.39 E-10	4.85 E-12	3.01 E-11
Cd-113m	4.85 E-04	4.85 E-04	4.21 E-02	4.85 E-04	1.91 E-02
In-113m	4.72 E-27	7.10 E-27	2.93 E-25	4.14 E-27	2.51 E-26
Sn-113	6.64 E-24	3.88 E-24	9.26 E-23	1.59 E-24	6.94 E-24
Sn-119m	2.50 E-12	1.05 E-12	2.61 E-11	1.62 E-13	1.43 E-12
Sn-121m	9.42 E-06	3.47 E-06	4.83 E-05	4.56 E-07	2.55 E-06
Sn-123	2.39 E-20	8.66 E-21	3.89 E-19	1.15 E-21	2.35 E-20
Sn-126	1.59 E-04	8.07 E-05	7.21 E-04	2.36 E-05	5.73 E-05

Table F-3. Unit Dose Factors for Organs for Insoluble Lung Categories. (3 sheets)

Nuclide	Organ unit dose factors, Sv/g[a]				
	Bone surface	Red marrow	Lungs	Gonads	Remainder
Sb-125	0.0	0.0	0.0	0.0	0.0
Sb-126	4.52 E-07	5.34 E-07	9.24 E-06	8.84 E-07	2.14 E-06
Sb-126m	3.40 E-09	4.12 E-09	2.66 E-07	2.34 E-09	1.01 E-08
Te-123m	1.33 E-24	1.34 E-25	7.05 E-25	1.04 E-26	4.47 E-26
Te-125m	0.0	0.0	0.0	0.0	0.0
Te-127	3.21 E-26	3.21 E-26	3.35 E-24	1.58 E-26	8.71 E-25
Te-127m	1.63 E-22	4.28 E-23	2.67 E-22	8.79 E-25	1.33 E-23
I-129	2.63 E-08	2.67 E-08	5.99 E-08	1.66 E-08	2.25 E-08
Cs-134	2.63 E-03	2.82 E-03	2.82 E-03	3.11 E-03	3.33 E-03
Cs-135	2.68 E-06	2.68 E-06	3.15 E-06	2.68 E-06	2.68 E-06
Cs-137	2.84 E+00	2.97 E+00	3.15 E+00	3.13 E+00	3.26 E+00
Ba-137m	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]
Ce-144	1.38 E-07	8.43 E-08	2.32 E-05	6.99 E-09	5.59 E-07
Pr-144	4.25 E-13	3.99 E-13	2.72 E-09	6.97 E-14	4.05 E-11
Pr-144m	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]
Pm-147	8.11 E-02	6.49 E-03	3.12 E-01	3.33 E-08	6.29 E-03
Sm-151	5.21 E-01	4.15 E-02	1.23 E-02	1.52 E-07	2.83 E-02
Eu-152	7.50 E-03	2.47 E-03	1.80 E-03	4.10 E-04	3.12 E-03
Eu-154	2.19 E+00	4.43 E-01	3.31 E-01	4.89 E-02	4.72 E-01
Eu-155	5.96 E-02	5.61 E-03	4.67 E-03	1.40 E-04	4.35 E-03
Gd-153	4.13 E-22	5.20 E-23	1.49 E-22	3.71 E-24	3.65 E-23
Subtotal:	1.92 E+02	8.96 E+01	7.23 E+00	3.86 E+00	5.65 E+00
Actinides					
U-234	1.61 E-02	1.03 E-03	4.23 E+00	3.77 E-05	1.51 E-03
U-235	4.93 E-04	3.36 E-05	1.30 E-01	1.34 E-06	4.81 E-05
U-236	2.83 E-03	1.81 E-04	7.47 E-01	6.65 E-06	2.65 E-04

Table F-3. Unit Dose Factors for Organs for Insoluble Lung Categories. (3 sheets)

Nuclide	Organ unit dose factors, Sv/g[a]				
	Bone surface	Red marrow	Lungs	Gonads	Remainder
U-238	1.24 E-02	8.46 E-04	3.26 E+00	2.99 E-05	1.25 E-03
Np-237	5.64 E+00	4.52 E-01	2.78 E-02	5.10 E-02	4.03 E-02
Pu-238	3.57 E+03	2.85 E+02	1.57 E+03	5.12 E+01	1.35 E+02
Pu-239	5.26 E+03	4.21 E+02	2.07 E+03	7.68 E+01	1.93 E+02
Pu-240	4.16 E+03	3.33 E+02	1.64 E+03	6.08 E+01	1.53 E+02
Pu-241	4.49 E+03	3.61 E+02	8.02 E+02	6.96 E+01	1.52 E+02
Pu-242	2.52 E+00	2.01 E-01	9.89 E-01	3.67 E-02	9.22 E-02
Am-241	3.48 E+04	2.79 E+03	2.95 E+02	5.22 E+02	1.26 E+03
Am-242	2.26 E-03	1.81 E-04	7.14 E-04	2.66 E-05	1.17 E-04
Am-242m	2.92 E+01	2.33 E+00	5.78 E-02	4.42 E-01	1.03 E+00
Am-243	2.23 E+01	1.78 E+00	1.83 E-01	3.35 E-01	7.96 E-01
Cm-242	5.55 E-01	4.44 E-02	1.77 E-01	6.50 E-03	2.79 E-02
Cm-244	1.94 E+02	1.55 E+01	3.19 E+00	2.63 E+00	7.91 E+00
Subtotal:	5.26 E+04	4.21 E+03	6.39 E+03	7.84 E+02	1.90 E+03
SNF Total:	5.28 E+04	4.30 E+03	6.40 E+03	7.88 E+02	1.90 E+03

[a]The unit dose is the product of the normalized activity (Table F-1) and the inhalation dose factor (Table F-2). To convert Sv/g to rem/g multiply by 100.

[b]Daughter products are included with parents and not tracked individually. Short half life progeny nuclides not shown are assumed to be in equilibrium with their parent nuclide.

Table F-4. Summary of Unit Dose Factors

Type of Unit Dose	Bounding case	Realistic case
EDE	4,380 Sv/g	3,640 Sv/g
Bone surface	79,400 Sv/g	52,800 Sv/g
Red marrow	6,440 Sv/g	4,300 Sv/g
Lung	606 Sv/g	6,400 Sv/g
Gonads	1,200 Sv/g	788 Sv/g
Remainder	2,810 Sv/g	1,900 Sv/g
Air submersion	0.0303 Sv/g	0.0303 Sv/g

The EDE and organ values for unit dose are from inhalation only. The air submersion value for unit dose is external dose from submersion in the plume. The "Bounding case" uses lung solubilities with the largest inhalation dose factors. The "Realistic case" uses insoluble lung solubility assumptions.

EDE = effective dose equivalent.

APPENDIX G

GENII INPUT FILES FOR INGESTION DOSE CALCULATIONS

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Input File for GENII -- Inhale, External, and Milk Dose Factors

```
######################### Program GENII Input File ############  8 Jul 88 ####
Title: Animal Products
       \GENII\24A.IN                              Created on 01-06-1998 at 07:30
OPTIONS========================= Default ========================================
F    Near-field scenario?      (Far-field)    NEAR-FIELD: narrowly-focused
F    Population dose?          (Individual)                release, single site
T    Acute release?           (Chronic)       FAR-FIELD:  wide-scale release,
     Maximum Individual data set used                     multiple sites
                                Complete                                Complete
TRANSPORT OPTIONS============ Section        EXPOSURE PATHWAY OPTIONS===== Section
T  Air Transport              1             F  Finite plume, external       5
F  Surface Water Transport    2             F  Infinite plume, external     5
F  Biotic Transport (near-field) 3,4        T  Ground, external             5
F  Waste Form Degradation (near) 3,4        F  Recreation, external         5
                                            T  Inhalation uptake            5,6
REPORT OPTIONS========================       F  Drinking water ingestion    7,8
T  Report AEDE only                         F  Aquatic foods ingestion      7,8
F  Report by radionuclide                   F  Terrestrial foods ingestion  7,9
T  Report by exposure pathway               T  Animal product ingestion     7,10
F  Debug report on screen                   F  Inadvertent soil ingestion

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

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

        --------|----Release Terms------|----------Basic Concentrations---------
        Use when|  transport selected   |  near-field scenario, optionally
        --------|------------------------|-------------------------------------
        Release          Surface Buried          Surface Deep     Ground  Surface
        Radio-   Air     Water   Waste   Air     Soil    Soil     Water   Water
        nuclide  /yr     /yr     /m3     /m3     /unit   /m3      /L      /L
        --------|------- ------- ------- ------- ------- -------  ------- -------
        H 3      9.7E+05
        C 14     2.0E+04
        FE55     2.0E+04
        CO60     7.7E+04
        NI59     1.2E+03
        NI63     1.3E+05
        SE79     2.4E+03
        KR85     1.4E+07
        SR90     2.6E+08
        Y 90     2.6E+08
        ZR93     1.1E+04
        NB93M    7.1E+03
        TC99     8.1E+04
        RU106    9.5E+02
        PD107    5.8E+02
        AG110M   2.0E-03
        CD113M   1.0E+05
        SN113    5.0E-15
        IN113M   5.0E-15
        SN119M   2.3E-03
        SN121M   2.3E+03
        SN121    1.8E+03
        SN123    6.4E-12
        SN126    4.8E+03
        SB126M   4.8E+03
        SB126    6.7E+02
        TE123M   5.6E-17
        TE127M   8.0E-15
        TE127    7.8E-15
        I 129    1.9E+02
        CS134    2.4E+05
        CS135    2.2E+03
        CS137    3.6E+08
        CE144    2.9E+01
        PR144M   3.5E-01
        PR144    2.9E+01
```

```
PM147    4.0E+06
SM151    3.8E+06
EU152    3.1E+04
EU154    4.2E+06
EU155    3.9E+05
GD153    1.9E-14
U 234    1.4E+04
U 235    4.7E+02
TH231    4.7E+02
U 236    2.6E+03
U 238    1.2E+04
TH234    1.2E+04
PA234    2.0E+01
NP237    1.7E+03
PA233    1.7E+03
PU238    4.9E+06
PU239    6.4E+06
PU240    5.1E+06
PU241    2.5E+08
U 237    6.2E+03
PU242    3.2E+03
AM241    1.6E+07
AM242M   1.4E+04
AM242    1.4E+04
NP238    6.6E+01
AM243    1.0E+04
CM242    1.1E+04
CM244    1.7E+05
```

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

```
TIME #######################################################################

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


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

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


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

             Prior to the beginning of the intake period: (yr)
0               When was the inventory disposed?  (Package degradation starts)
0               When was LOIC?  (Biotic transport starts)
0            Fraction of roots in upper soil (top 15 cm)
0            Fraction of roots in deep soil
0            Manual redistribution: deep soil/surface soil dilution factor
0            Source area for external dose modification factor (m²)
TRANSPORT #################################################################
             ====AIR TRANSPORT===================================SECTION 1=====
                    0-Calculate PM           |0         Release type (0-3)
1            Option: 1-Use chi/Q or PM value |F         Stack release (T/F)
                    2-Select MI dist & dir   |0         Stack height (m)
                    3-Specify MI dist & dir  |0         Stack flow (m3/sec)
2.738E-3     Acute Chi/Q (1y/365.25d)        |0         Stack radius (m)
0            Wind transport direction (3=SW) |0         Effluent temp. (C)
0            Distance to MI (meters)         |0         Building x-section (m²)
F            Use JF data?                    |0         Building height (m)


             ====SURFACE WATER TRANSPORT========================SECTION 2=====
0            Mixing ratio model: 0-use value, 1-river, 2-lake
0            Mixing ratio, dimensionless
0            Average river flow rate for: MIXFLG=0 (m3/s), MIXFLG=1,2 (m/s),
0            Transit time to irrigation withdrawal location (hr)
             If mixing ratio model > 0:
```

```
0              Rate of effluent discharge to receiving water body (m3/s)
0              Longshore distance from release point to usage location (m)
0              Offshore distance to the water intake (m)
0              Average water depth in surface water body (m)
0              Average river width (m), MIXFLG=1 only
0              Depth of effluent discharge point to surface water (m), lake only


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


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


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


               ====EXTERNAL EXPOSURE=================================SECTION 5=====
               Exposure time:                 |  Residential irrigation:
0                 Plume (hr)                   |T         Consider: (T/F)
8766.0            Soil contamination (hr)      |0         Source: 1-ground water
0                 Swimming (hr)                |                  2-surface water
0                 Boating (hr)                 |0         Application rate (in/yr)
0                 Shoreline activities (hr)    |0         Duration (mo/yr)
0              Shoreline type: (1-river, 2-lake, 3-ocean, 4-tidal basin)
0              Transit time for release to reach aquatic recreation (hr)
0              Average fraction of time submersed in acute cloud (hr/person hr)


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


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


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


F              Salt water? (default is fresh)


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


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


               USE      GROW   --IRRIGATION--          PROD-   --CONSUMPTION--
               ?  FOOD  TIME  S RATE   TIME   YIELD    UCTION  HOLDUP  RATE
               T/F TYPE days  * in/yr  mo/yr  kg/m²    kg/yr   days    kg/yr
               --- ----- ----- - ----- ----- -----   -------- ------  ------
               T   LEAF V 90.00 0  0.0   0.0   1.5     0.0E+00  0.1     30.0
               T   ROOT V 90.00 0  0.0   0.0   4.0     0.0E+00  0.1    220.0
               T   FRUIT  90.00 0  0.0   0.0   2.0     0.0E+00  0.1    330.0
               F   GRAIN  90.00 0  0.0   0.0   0.8     0.0E+00  0.1     80.0


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


               ---HUMAN---- TOTAL   DRINK   ------------STORED FEED-------------
USE            CONSUMPTION  PROD-   WATER   DIET GROW  -IRRIGATION--       STOR-
```

?	FOOD	RATE	HOLDUP	UCTION	CONTAM	FRAC-	TIME	S	RATE	TIME	YIELD	AGE
T/F	TYPE	kg/yr	days	kg/yr	FRACT.	TION	days	*	in/yr	mo/yr	kg/m3	days
---	------	------	-----	------	-------	----	----	-	-----	-----	-----	-----
F	BEEF	80.0	0.1	0.00	0.00	0.25	90.0	0	0.0	0.00	0.80	0.0
F	POULTR	18.0	0.1	0.00	0.00	1.00	90.0	0	0.0	0.00	0.80	0.0
T	MILK	270.0	0.1	0.00	0.00	0.25	45.0	0	0.0	0.00	2.00	0.0
F	EGG	30.0	0.1	0.00	0.00	1.00	90.0	0	0.0	0.00	0.80	0.0
						------------FRESH FORAGE------------						
	BEEF					0.75	45.0	0	0.0	0.00	2.00	100.0
	MILK					0.75	30.0	0	0.0	0.00	1.50	0.0

##

Input File for GENII -- Vegetable Dose Factors

```
###################### Program GENII Input File ############  8 Jul 88 ####
Title: Veggie Produce
       \GENII\24P.IN                              Created on 01-06-1998 at 07:30
OPTIONS========================= Default =========================================
F    Near-field scenario?       (Far-field)     NEAR-FIELD: narrowly-focused
F    Population dose?           (Individual)                 release, single site
T    Acute release?            (Chronic)        FAR-FIELD:  wide-scale release,
     Maximum Individual data set used                       multiple sites
                              Complete                                   Complete
TRANSPORT OPTIONS============ Section    EXPOSURE PATHWAY OPTIONS===== Section
T    Air Transport              1        F    Finite plume, external      5
F    Surface Water Transport    2        F    Infinite plume, external    5
F    Biotic Transport (near-field) 3,4   F    Ground, external            5
F    Waste Form Degradation (near) 3,4   F    Recreation, external        5
                                         F    Inhalation uptake          5,6
REPORT OPTIONS=======================    F    Drinking water ingestion   7,8
T    Report AEDE only                    F    Aquatic foods ingestion    7,8
F    Report by radionuclide              T    Terrestrial foods ingestion 7,9
T    Report by exposure pathway          F    Animal product ingestion   7,10
F    Debug report on screen              F    Inadvertent soil ingestion

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

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

     --------|----Release Terms------|---------Basic Concentrations--------
     Use when|  transport selected   |  near-field scenario, optionally
     --------|-----------------------|-----------------------------------
     Release |        Surface Buried |        Surface Deep    Ground  Surface
     Radio-  |Air    Water   Waste   |Air    Soil    Soil     Water   Water
     nuclide |/yr    /yr     /m3     |/m3    /unit   /m3      /L      /L
     --------|------- ------- ------- |------- ------- ------- ------- -------
     H 3     |9.7E+05
     C 14    |2.0E+04
     FE55    |2.0E+04
     CO60    |7.7E+04
     NI59    |1.2E+03
     NI63    |1.3E+05
     SE79    |2.4E+03
     KR85    |1.4E+07
     SR90    |2.6E+08
     Y 90    |2.6E+08
     ZR93    |1.1E+04
     NB93M   |7.1E+03
     TC99    |8.1E+04
     RU106   |9.5E+02
     PD107   |5.8E+02
     AG110M  |2.0E-03
     CD113M  |1.0E+05
     SN113   |5.0E-15
     IN113M  |5.0E-15
     SN119M  |2.3E-03
     SN121M  |2.3E+03
     SN121   |1.8E+03
     SN123   |6.4E-12
     SN126   |4.8E+03
     SB126M  |4.8E+03
     SB126   |6.7E+02
     TE123M  |5.6E-17
     TE127M  |8.0E-15
     TE127   |7.8E-15
     I 129   |1.9E+02
     CS134   |2.4E+05
     CS135   |2.2E+03
     CS137   |3.6E+08
     CE144   |2.9E+01
     PR144M  |3.5E-01
     PR144   |2.9E+01
     PM147   |4.0E+06
```

```
SM151    3.8E+06
EU152    3.1E+04
EU154    4.2E+06
EU155    3.9E+05
GD153    1.9E-14
U 234    1.4E+04
U 235    4.7E+02
TH231    4.7E+02
U 236    2.6E+03
U 238    1.2E+04
TH234    1.2E+04
PA234    2.0E+01
NP237    1.7E+03
PA233    1.7E+03
PU238    4.9E+06
PU239    6.4E+06
PU240    5.1E+06
PU241    2.5E+08
U 237    6.2E+03
PU242    3.2E+03
AM241    1.6E+07
AM242M   1.4E+04
AM242    1.4E+04
NP238    6.6E+01
AM243    1.0E+04
CM242    1.1E+04
CM244    1.7E+05
```

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

```
TIME ######################################################################

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


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

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


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

          Prior to the beginning of the intake period: (yr)
0             When was the inventory disposed?  (Package degradation starts)
0             When was LOIC?  (Biotic transport starts)
0         Fraction of roots in upper soil (top 15 cm)
0         Fraction of roots in deep soil
0         Manual redistribution: deep soil/surface soil dilution factor
0         Source area for external dose modification factor (m²)
TRANSPORT ##################################################################
          ====AIR TRANSPORT=====================================SECTION 1=====
                    0-Calculate PM            |0       Release type (0-3)
1         Option: 1-Use chi/Q or PM value     |F       Stack release (T/F)
                  2-Select MI dist & dir       |0       Stack height (m)
                  3-Specify MI dist & dir      |0       Stack flow (m3/sec)
5.556E-3  Acute Chi/Q (1y/365.25d)            |0       Stack radius (m)
0         Wind transport direction (3=SW)      |0       Effluent temp. (C)
0         Distance to MI (meters)              |0       Building x-section (m²)
F         Use JF data?                         |0       Building height (m)


          ====SURFACE WATER TRANSPORT===========================SECTION 2=====
0         Mixing ratio model: 0-use value, 1-river, 2-lake
0         Mixing ratio, dimensionless
0         Average river flow rate for: MIXFLG=0 (m3/s), MIXFLG=1,2 (m/s),
0         Transit time to irrigation withdrawal location (hr)
          If mixing ratio model > 0:
0             Rate of effluent discharge to receiving water body (m3/s)
```

```
0            Longshore distance from release point to usage location (m)
0            Offshore distance to the water intake (m)
0            Average water depth in surface water body (m)
0            Average river width (m), MIXFLG=1 only
0            Depth of effluent discharge point to surface water (m), lake only


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


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

EXPOSURE ##

```
             ====EXTERNAL EXPOSURE==================================SECTION 5=====
             Exposure time:               |  Residential irrigation:
0              Plume (hr)                  |T   Consider: (T/F)
8766.0         Soil contamination (hr)    |0   Source: 1-ground water
0              Swimming (hr)              |            2-surface water
0              Boating (hr)               |0   Application rate (in/yr)
0              Shoreline activities (hr)  |0   Duration (mo/yr)
0            Shoreline type: (1-river, 2-lake, 3-ocean, 4-tidal basin)
0            Transit time for release to reach aquatic recreation (hr)
0            Average fraction of time submersed in acute cloud (hr/person hr)


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


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


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


F            Salt water? (default is fresh)


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


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


             USE    GROW  --IRRIGATION--          PROD-   --CONSUMPTION--
             ?  FOOD TIME  S RATE TIME  YIELD  UCTION  HOLDUP   RATE
             T/F TYPE days * in/yr mo/yr kg/m²  kg/yr   days     kg/yr
             --- ----- ----- - ----- ----- -----  -------- ------   ------
             T   LEAF V 90.00 0  0.0   0.0   1.5   0.0E+00  0.1      30.0
             T   ROOT V 90.00 0  0.0   0.0   4.0   0.0E+00  0.1      220.0
             T   FRUIT  90.00 0  0.0   0.0   2.0   0.0E+00  0.1      330.0
             F   GRAIN  90.00 0  0.0   0.0   0.8   0.0E+00  0.1      80.0


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


             ---HUMAN---- TOTAL  DRINK  -----------STORED FEED------------
      USE    CONSUMPTION  PROD-  WATER  DIET GROW -IRRIGATION--      STOR-
      ?  FOOD RATE HOLDUP UCTION CONTAM FRAC-TIME S RATE TIME  YIELD AGE
```

```
T/F TYPE   kg/yr  days  kg/yr  FRACT.  TION  days  *  in/yr mo/yr  kg/m3  days
--- ------ ------ ----- ------ ------- ----  ----  -  ----- -----  -----  -----
F   BEEF    80.0   0.1   0.00    0.00  0.25  90.0  0    0.0  0.00   0.80    0.0
F   POULTR  18.0   0.1   0.00    0.00  1.00  90.0  0    0.0  0.00   0.80    0.0
T   MILK   270.0   0.1   0.00    0.00  0.25  45.0  0    0.0  0.00   2.00    0.0
F   EGG     30.0   0.1   0.00    0.00  1.00  90.0  0    0.0  0.00   0.80    0.0
                                      -------------FRESH FORAGE------------
    BEEF                              0.75  45.0  0    0.0  0.00   2.00  100.0
    MILK                              0.75  30.0  0    0.0  0.00   1.50    0.0

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

APPENDIX H

CHECKLISTS FOR PEER REVIEW AND APPROVAL

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H-2

CHECKLIST FOR TECHNICAL PEER REVIEW

Document Reviewed: HNF - SD - SNF -TI - 059 Rev 2
 Title:
 Author: P. U Rittmann
 Date: 5/12/99
Scope of Review: Revised X/Qs + Onsum Dose Calculations

Yes No* NA

[X] [ ] [ ]**			Previous reviews complete and cover analysis, up to scope of this review, with no gaps.
[X] [ ] [ ]			Problem completely defined.
[ ] [ ] [X]			Accident scenarios developed in a clear and logical manner.
[X] [ ] [ ]			Necessary assumptions explicitly stated and supported.
[X] [ ] [ ]			Computer codes and data files documented.
[X] [ ] [ ]			Data used in calculations explicitly stated in document.
[X] [ ] [ ]			Data checked for consistency with original source information as applicable.
[ ] [ ] [X]			Mathematical derivations checked including dimensional consistency of results.
[X] [ ] [ ]			Models appropriate and used within range of validity or use outside range of established validity justified.
[X] [ ] [ ]			Hand calculations checked for errors. Spreadsheet results should be treated exactly the same as hand calculations.
[X] [ ] [ ]			Software input correct and consistent with document reviewed.
[X] [ ] [ ]			Software output consistent with input and with results reported in document reviewed.
[X] [ ] [ ]			Limits/criteria/guidelines applied to analysis results are appropriate and referenced. Limits/criteria/guidelines checked against references.
[X] [ ] [ ]			Safety margins consistent with good engineering practices.
[X] [ ] [ ]			Conclusions consistent with analytical results and applicable limits.
[X] [ ] [ ]			Results and conclusions address all points required in the problem statement.
[X] [ ] [ ]			Format consistent with applicable guides or other standards.
[ ] [X]**			Review calculations, comments, and/or notes are attached.
[X] [ ] [ ]			Traceability
[X] [ ] [ ]			Document approved (for example, the reviewer affirms the technical accuracy of the document).

John C Van Keuren   5/12/99
Reviewer (printed name and signature)   Date

* All "no" responses must be explained below or on an additional sheet.

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

HEDOP REVIEW CHECKLIST

Document Reviewed: HNF-SD-SNF-059 Rev 2
Title:
Author: P. D. Rittmann
Date: 5/12/99
Scope of Review: Revised X/Qs + Organ Dose Calculations

Yes No* NA

[✓][ ][ ] 1. A detailed technical review and approval of the environmental transport and dose calculation portion of the analysis has been performed and documented.

[ ][ ][✓] 2. Detailed technical review(s) and approval(s) of scenario and release determinations have been performed and documented.

[ ][ ][✓] 3. HEDOP-approved code(s) were used.

[ ][ ][✓] 4. Receptor locations were selected according to HEDOP recommendations.

[✓][ ][ ] 5. All applicable environmental pathways and code options were included and are appropriate for the calculations.

[✓][ ][ ] 6. Hanford site data were used.

[✓][ ][ ] 7. Model adjustments external to the computer program were justified and performed correctly.

[ ][ ][✓] 8. The analysis is consistent with HEDOP recommendations.

[ ][ ][✓] 9. Supporting notes, calculations, comments, comment resolutions, or other information is attached. (Use the "Page 1 of X" page numbering format and sign and date each added page.)

[✓][ ][ ] 10. Approval is granted on behalf of the Hanford Environmental Dose Overview Panel.

* All "no" responses must be explained below or on an additional sheet.
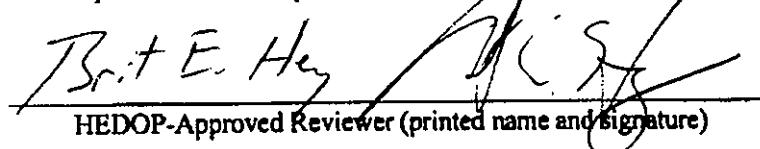
Brit E. Hey
_____   5/12/99
HEDOP-Approved Reviewer (printed name and signature)   Date

COMMENTS (add additional signed and dated page if necessary):