Zion*Solutions*, LLC
ZS-2014-0100: Attachment 7 - Zion Station Offsite Dose Calculation Manual

Zion Station ODCM current as of December 31, 2013

Exelon
Nuclear

Offsite

Dose

Calculation

Manual

Docket Numbers:

Dresden	*50-10, 50-237, 50-249*
Quad Cities	*50-254, 50-265*
Zion	*50-295, 50-304*
LaSalle	*50-373, 50-374*
Byron	*50-454, 50-455*
Braidwood	*50-456, 50-457*

OFFSITE DOSE CALCULATION MANUAL

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Part 1: GENERIC SECTIONS

Note: Previous Chapter 6 was deleted and previous Chapter 8 was renumbered as Chapter 6.
Previous Chapter 7 was deleted and replaced by the references section.
Previous Chapter 9 was deleted.
Previous Appendix B and C have been combined into Appendix B.
Previous Appendix D has been revised into Appendix C.
Previous Appendix E has been deleted and is Reference 101.

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CHAPTER 1
INTRODUCTION

1.0 INTRODUCTION

The Offsite Dose Calculation Manual (ODCM) presents a discussion of the following:

- The basic concepts applied in calculating offsite doses from nuclear plant effluents.
- The regulations and requirements for the ODCM and related programs.
- The methodology and parameters for the offsite dose calculations used by the nuclear power stations to assess impact on the environment and compliance with regulations.

The methodology detailed in this manual is intended for the calculation of radiation doses during routine (i.e., non-accident) conditions. The calculations are normally performed using a computer program. Manual calculations may be performed in lieu of the computer program.

The dose effects of airborne radioactivity releases predominately depend on meteorological conditions (wind speed, wind direction, and atmospheric stability). For airborne effluents, the dose calculations prescribed in this manual are based on historical average atmospheric conditions. This methodology is appropriate for estimating annual average dose effects and is stipulated in the Bases Section of the Radiological Effluent Technical Standards (RETS) of all Exelon Nuclear nuclear power stations.

1.1 STRUCTURE OF THIS MANUAL

This manual is the ODCM for the following Exelon Nuclear power stations: Braidwood, Byron, Dresden, LaSalle, Quad Cities and Zion. It is divided into two parts. The material in the first part is generic (applicable to more than one station) and consists of Chapters 1 through 7 and Appendices A through C. The material in the second part is station (or site) specific. Therefore, there are six separate sets of station-specific sections each containing three chapters (chapters 10, 11, 12) and an appendix (App. F).

The chapters of the generic section provide a brief introduction to and overview of Exelon Nuclear's offsite dose calculation methodology and parameters. Appendices A and B provide detailed information on specific aspects of the methodology. Appendix C contains tables of values of the generic parameters used in offsite dose equations.

The station-specific section provides specific requirements for the treatment and monitoring of radioactive effluents, for the contents of the Radiological Environmental Monitoring Program (REMP) and the Radiological Effluent Technical Standards (RETS). These three programs are detailed in ODCM Chapters 10, 11 and 12, respectively. Appendix F contains tables of values for the station-specific parameters used in the offsite dose equations. References are provided as required in each station-specific chapter and appendix.

An ODCM Bases and Reference Document (see Reference 101) provides description of the bases for the methodology and parameters discussed in the generic section of the ODCM. This is a stand-alone document and is not considered to be a part of the ODCM.

CHAPTER 2

REGULATIONS AND GUIDELINES

2.0 INTRODUCTION

This chapter of the ODCM serves to illustrate the regulations and requirements that define and are applicable to the ODCM. Any information provided in the ODCM concerning specific regulations are not a substitute for the regulations as found in the Code of Federal Regulations (CFR) or Technical Specifications.

2.1 CODE OF FEDERAL REGULATIONS

Various sections of the Code of Federal Regulations (CFR) require nuclear power stations to be designed and operated in a manner that limits the radiation exposure to members of the public. These sections specify limits on offsite radiation doses and on effluent radioactivity concentrations and they also require releases of radioactivity to be "As Low As Reasonably Achievable". These requirements are contained in 10CFR20, 10CFR50 and 40CFR190. In addition, 40CFR141 imposes limits on the concentration of radioactivity in drinking water provided by the operators of public water systems.

2.1.1 10CFR20, Standards for Protection Against Radiation

This revision of the ODCM addresses the requirements of 10CFR20. The 10CFR20 dose limits are summarized in Table 2-1.

2.1.2 Design Criteria (Appendix A of 10CFR50)

Section 50.36 of 10CFR50 requires that an application for an operating license include proposed Technical Specifications. Final Technical Specifications for each station are developed through negotiation between the applicant and the NRC. The Technical Specifications are then issued as a part of the operating license, and the licensee is required to operate the facility in accordance with them.

Section 50.34 of 10CFR50 states that an application for a license must state the principal design criteria of the facility. Minimum requirements are contained in Appendix A of 10CFR50.

2.1.3 ALARA Provisions (Appendix I of 10CFR50)

Sections 50.34a and 50.36a of 10CFR50 require that the nuclear plant design and the station RETS have provisions to keep levels of radioactive materials in effluents to unrestricted areas "As Low As Reasonably Achievable" (ALARA). Although 10CFR50 does not impose specific limits on releases, Appendix I of 10CFR50 does provide numerical design objectives and suggested limiting conditions for operation. According to Section I of Appendix I of 10CFR50, design objectives and limiting conditions for operation, conforming to the guidelines of Appendix I "shall be deemed a conclusive showing of compliance with the "As Low As Reasonably Achievable" requirements of 10CFR50.34a and 50.36a."

An applicant must use calculations to demonstrate conformance with the design objective dose limits of Appendix I. The calculations are to be based on models and data such that the actual radiation exposure of an individual is "unlikely to be substantially underestimated" (see 10CFR50 Appendix I, Section III.A.1).

The guidelines in Appendix I call for an investigation, corrective action and a report to the NRC whenever the calculated dose due to the radioactivity released in a calendar quarter exceeds one-half of an annual design objective. The guidelines also require a surveillance program to monitor releases, monitor the environment and identify changes in land use.

2.1.4 40CFR190, Environmental Radiation Protection Standards for Nuclear Power Operations

Under an agreement between the NRC and the EPA, the NRC stipulated to its licensees in Generic Letter 79-041 that "Compliance with Radiological Effluent Technical Specifications (RETS), NUREG-0472 (Rev.2) for PWR's or NUREG-0473 (Rev.2) for BWR's, implements the LWR provisions to meet 40CFR190". (See Reference 103 and 49.)

The regulations of 40CFR190 limit radiation doses received by members of the public as a result of operations that are part of the uranium fuel cycle. Operations must be conducted in such a manner as to provide reasonable assurance that the annual dose equivalent to any member of the public due to radiation and to planned discharges of radioactive materials does not exceed the following limits:

- 25 mrem to the total body
- 75 mrem to the thyroid
- 25 mrem to any other organ

An important difference between the design objectives of 10CFR50 and the limits of 40CFR190 is that 10CFR50 addresses only doses due to radioactive effluents. 40CFR190 limits doses due to effluents and *also to radiation sources maintained on site. See Section 2.4 for further discussion of the differences* between the requirements of 10CFR50 Appendix I and 40CFR190.

2.1.5 40CFR141, National Primary Drinking Water Regulations

The following radioactivity limits for community water systems were established in the July, 1976 Edition of 40CFR141:

- Combined Ra-226 and Ra-228: $\leq$ 5 pCi/L.
- Gross alpha (particle activity including Ra-226 but excluding radon and uranium): $\leq$ 15 pCi/L.
- The average annual concentration of beta particle and photon radioactivity from man-made radionuclides in drinking water shall not produce an annual dose equivalent to the total body or any internal organ greater than 4 mrem/yr.

The regulations specify procedures for determining the values of annual average radionuclide concentration which produce an annual dose equivalent of 4 mrem. Radiochemical analysis methods are also specified. The responsibility for monitoring radioactivity in a community water system falls on the supplier of the water. However, some of the Exelon Nuclear stations have requirements related to 40CFR141 in their specific RETS. For calculation methodology, see Section A.6 of Appendix A.

2.2 RADIOLOGICAL EFFLUENT TECHNICAL STANDARDS

The Radiological Effluent Technical Standards (RETS) were formerly a subset of the Technical Specifications. They implement provisions of the Code of Federal Regulations aimed at limiting offsite radiation dose. The NRC published Standard Radiological Effluent Technical Specifications for PWRs (Reference 2) and for BWRs (Reference 3) as guidance to assist in the development of technical specifications. These documents have undergone frequent minor revisions to reflect changes in plant design and evolving regulatory concerns. The Radiological Effluent Technical Specifications have been removed from the Technical Specifications and placed in the ODCM as the Radiological Effluent Technical Standards (RETS) (see Reference 90). The RETS of each station are similar but not identical to the guidance of the Standard Radiological Effluent Technical Specifications.

2.2.1 Categories

The major categories found in the RETS are the following:

- **Definitions**
  A glossary of terms (not limited to the ODCM).

- **Instrumentation**
  This section states the Operability Requirements (OR) for instrumentation performance as well as the associated Surveillance Requirements. The conservative alarm/trip setpoints ensure regulatory compliance for both liquid and gaseous effluents. Surveillance requirements are listed to ensure ORs are met through testing, calibration, inspection and calculation. Also included are the bases for interpreting the requirements. The Operability Requirement (OR) is the ODCM equivalent of a Limiting Condition for Operation (LCO) as defined in both the NRC published Standard Radiological Effluent Technical Specifications and the stations' Technical Specifications.

- **Liquid Effluents**
  This section addresses the limits, special reports and liquid waste treatment systems required to substantiate the dose due to liquid radioactivity concentrations to unrestricted areas. Surveillance Requirements and Bases are included for liquid effluents.

- **Gaseous Effluents**
  This section addresses the limits, special reports and gaseous radwaste and ventilation exhaust treatment systems necessary for adequate documentation of the instantaneous offsite radiation dose rates and doses to a member of the public. Surveillance Requirements and Bases are included for gaseous effluents.

- **Radiological Environmental Monitoring Program**
  This section details the Radiological Environmental Monitoring Program (REMP) involving sample collection and measurements to verify that the radiation levels released are minimal. This section describes the annual land use census and participation in an interlaboratory comparison program. Surveillance Requirements and Bases are included for environmental monitoring.

- **Reports and Records**
  This section serves as an administrative guide to maintain an appropriate record tracking system. The management of procedures, record retention, review/audit and reporting are discussed.

2.3 OFFSITE DOSE CALCULATION MANUAL

The NRC in Generic Letter 89-01 defines the ODCM as follows (not verbatim) (see Reference 90):

> The Offsite Dose Calculation Manual (ODCM) shall contain the methodology and parameters used in the calculation of offsite doses resulting from radioactive gaseous and liquid effluents, in the calculation of gaseous and liquid effluent monitoring Alarm/Trip Setpoints, and in the *conduct of the Radiological Environmental Monitoring Program. The ODCM shall also contain* (1) the Radioactive Effluent Controls and Radiological Environmental Monitoring Programs and (2) descriptions of the Information that should be included in the Annual Radiological Environmental Operating and Annual Radioactive Effluent Release Reports.

Additional requirements for the content of the ODCM are contained throughout the text of the RETS.

2.4 OVERLAPPING REQUIREMENTS

In 10CFR20, 10CFR50 and 40CFR190, there are overlapping requirements regarding offsite radiation dose and dose commitment to the total body. In 10CFR20.1301 the total effective dose equivalent (or TEDE) to a member of the public is limited to 100 mrem per calendar year. In addition, Appendix I to 10CFR50 establishes design objectives on annual total body dose or dose commitment of 3 mrem per reactor for liquid effluents and 5 mrem per reactor for gaseous effluents (see 10CFR50 Appendix I, Sections II.A and II.B.2(a)). Finally, 40CFR190 limits annual total body dose or dose commitment to a member of the public to 25 mrem due to all uranium fuel cycle operations.

While these dose limits/design objectives appear to overlap, they are different and each is addressed separately by the RETS. Calculations are made and reports are generated to demonstrate compliance to all regulations. Refer to Tables 2-1, 2-2 and 2-3 for additional information regarding instantaneous effluent limits, design objectives and regulatory compliance.

2.5 DOSE RECEIVER METHODOLOGY

Table 2-2 lists the location of the dose recipient and occupancy factors, if applicable. Dose is assessed at the location in the unrestricted area where the combination of existing pathways and receptor age groups indicates the maximum potential exposures. The dose calculation methodology is consistent with the methodology of Regulatory Guide 1.109 (Reference 6) and NUREG 0133 (Reference 14). Dose is therefore calculated to a maximum individual. The maximum individual is characterized as "maximum" with regard to food consumption, occupancy and other usage of the area in the vicinity of the plant site. Such a "maximum individual" represents reasonable deviation from the average for the population in general. In all physiological and metabolic respects the maximum individual is assumed to have those characteristics that represent averages for their corresponding age group. Thus, the dose calculated is very conservative compared to the "average" (or typical) dose recipient who does not go out of the way to maximize radioactivity uptakes and exposure.

Finally Table 2-3 relates the dose component (or pathway) to specific ODCM equations and the appropriate regulation.

Table 2-1

Regulatory Dose Limit Matrix

REGULATION	DOSE TYPE		DOSE LIMIT(s)		ODCM EQUATION
Airborne Releases:			(quarterly)	(annual)	
10CFR50 App. I[3]	Gamma Dose to Air due to Noble Gas Radionuclides (per reactor unit)		5 mrad	10 mrad	A-1
	Beta Dose to Air Due to Noble Gas Radionuclides (per reactor unit)		10 mrad	20 mrad	A-2
	Organ Dose Due to Specified Non-Noble Gas Radionuclides (per reactor unit)		7.5 mrem	15 mrem	A-7
	Total Body and Skin Dose (if air dose is exceeded)	Total Body	2.5 mrem	5 mrem	A-3
		Skin	7.5 mrem	15 mrem	A-4
Technical Specifications	Total Body Dose Rate Due to Noble Gas Radionuclides (instantaneous limit, per site)		500 mrem/yr		A-5
	Skin Dose Rate Due to Noble Gas Radionuclides (instantaneous limit, per site)		3,000 mrem/yr		A-6
	Organ Dose Rate Due to Specified Non-Noble Gas Radionuclides (instantaneous limit, per site)		1,500 mrem/yr		A-16
Liquid Releases:			(quarterly)	(annual)	
10CFR50 App. I[3]	Whole (Total) Body Dose (per reactor unit)		1.5 mrem	3 mrem	A-17
	Organ Dose (per reactor unit)		5 mrem	10 mrem	A-17
Technical Specifications	The concentration of radioactivity in liquid effluents released to unrestricted areas		Ten (10) times the concentration values listed in 10CFR20 Appendix B; Table 2, Column 2, Table C-6 of ODCM Appendix C for Noble Gases		A-21
Total Doses [1]:					
10 CFR 20.1301 (a)(1)	Total Effective Dose Equivalent [4]		100 mrem/yr		A-25
10CFR20.1301 (d) and 40CFR190	Total Body Dose		25 mrem/yr		A-25
	Thyroid Dose		75 mrem/yr		A-25
	Other Organ Dose		25 mrem/yr		A-25
Other Limits [2]:					
40CFR141	Total Body Dose Due to Drinking Water From Public Water Systems		4 mrem/yr		A-17
	Organ Dose Due to Drinking Water From Public Water Systems		4 mrem/yr		A-17

1 These doses are calculated considering all sources of radiation and radioactivity in effluents.

[2] These limits are not directly applicable to nuclear power stations. They are applicable to the owners or operators of public water systems. However, the RETS of some of the Exelon Nuclear nuclear power stations require assessment of compliance with these limits. For additional information, see Section A.6 of Appendix A.

[3] Note that 10CFR50 provides design objectives not limits.

[4] Compliance with 10CFR20.1301(a)(1) is demonstrated by compliance with 40CFR190. Note that it may be necessary to address dose from on-site activity by members of the public as well.

TABLE 2-2

DOSE ASSESSMENT RECEIVERS

Dose Component or Pathway	Location; Occupancy if Different than 100%
"Instantaneous" dose rates from airborne radioactivity	Unrestricted area boundary location that results in the maximum dose rate
"Instantaneous" concentration limits in liquid effluents	Point where liquid effluents enter the unrestricted area
Annual average concentration limits for liquid effluents	Point where liquid effluents enter the unrestricted area
Direct dose from contained sources	Receiver spends part of this time in the controlled area and the remainder at his residence or fishing nearby; *occupancy factor is considered and is site-*specific. See Appendix F, Table F-8 for occupancy factors for N-16 skyshine.
Direct dose from airborne plume	Receiver is at the unrestricted area boundary location that results in the maximum dose.
Dose due to radioiodines, tritium and particulates with half-lives greater than 8 days for inhalation, ingestion of vegetation, milk and meat, and ground plane exposure pathways.	Receiver is at the location in the unrestricted area where the combination of existing pathways and receptor age groups indicates the highest potential exposures.
Ingestion dose from drinking water	The drinking water pathway is considered as an additive dose component in this assessment only if the public water supply serves the community immediately adjacent to the plant.
Ingestion dose from eating fish	The receiver eats fish from the receiving body of water (lake or river)
Total Organ Doses	Summation of ingestion/inhalation doses
Total Dose	Summation of above data (Note it may also be necessary to address dose from on-site activity by members of the public.)

TABLE 2-3

DOSE COMPONENT/REGULATION MATRIX

Dose Component or Pathway	Reference equation; *Comments*	Regulation in which dose component is utilized: 10CFR20	40CFR190	10CFR50 App. *I*
"Instantaneous" dose rates from airborne radioactivity (RETS requirement only)	A-5: Total Body A-6: Skin A-16: Organ			
"Instantaneous" concentration limits in liquid effluents	A-21: Ten times the limits of Table 2, Col. 2,10CFR20, Appendix B to §§20.1001 – 20.2402, Table C-6 of Appendix C for Noble Gases	X(2)		
Annual average concentration limits for liquid effluents	10CFR20, Appendix B to §§20.1001 – 20.2402(2)	X(3)		
Direct dose from contained sources	A-23 and Section A.3.2	X	X	
Direct dose from airborne plume	A-1: Gamma air dose A-2: Beta air dose A-3: Total body dose A-4: Skin dose	X	X	X X X X
Direct dose from radioactivity deposited on the ground	A-7 and A-8	X	X	X
Inhalation dose from airborne effluents	A-7 and A-9 (1)	X	X	X
Ingestion dose from vegetables	A-7, A10 and A-11 (1)	X	X	X
Ingestion dose from milk	A-7, A-12 and A-13 (1)	X	X	X
Ingestion dose from meat	A-7, A-14 and A-15 (1)	X	X	X
Ingestion dose from drinking water	A-17, A-18 and A-19 (1)	X	X	X
Ingestion dose from eating fish	A-17, A-18 and A-20 (1)	X	X	X
Total Organ Doses	A-25		X	X
Total Effective Dose Equivalent	A-25(4)	X		

1 Ingestion/inhalation dose assessment is evaluated for adult/teen/child and infant for 10CFR50 Appendix I compliance and for 10CFR20/40CFR190 compliance. Ingestion/inhalation dose factors are taken from Reg. Guide 1.109 (Reference 6).

2 Technical Specifications for most stations have been revised to allow 10 times the 10CFR20 value or specifically states the maximum instantaneous dose rate limit.

3 Optional for 10CFR20 compliance.

4 Compliance with the Total Effective Dose Equivalent limits of 10CFR20 is demonstrated by compliance with 40CFR190. It may also be necessary to address dose from on-site activity by members of the public.

Figure 2-1

Simplified Chart of Offsite Dose Calculations[2]

Category	Radionuclides	Pathway	Text Section	Receptor	Code and Limits	Frequency of Calculation[1]
Airborne	Releases:					
	Noble Gases:	Plume γ^a	A.1.3.1	Total Body	RETS: 500 mrem/yr Instantaneous	As Required by Station Procedure
	Noble Gases:	Plume γ^a and β^b	A.1.3.2	Skin	RETS: 3000 mrem/yr Instantaneous	
	Noble Gases:	Plume γ^a	A.1.2.1	Air[4]	10CFR50[3]: 5 mrad/qtr, 10 mrad/yr	Monthly
	Noble Gases:	Plume β^b	A.1.2.2	Air[4]	10CFR50[3]: 10 mrad/qtr, 20 mrad/yr	
	Non-Noble Gases:	Inhalation[b]	A.1.5	Child (Any Organ)	RETS: 1500 mrem/yr Instantaneous	As required by Station Procedure
	Non-Noble Gases:	Ground Deposition[c]	A.1.4.1	Total body	10CFR50[3]: 7.5 mrem/qtr, 15 mrem/yr	Monthly and Annually
		Inhalation[c]	A.1.4.2	Four Age groups (All Organs)		
		Vegetation[d]	A.1.4.3.1			
		Milk[d]	A.1.4.3.2			
		Meat[d]	A.1.4.3.3			
Liquid	Releases:					
	All	Water	A.2.2		RETS, 10 times 10CFR20 Appendix B; Table 2; Col. 2, Table C-6 of Appendix C for Noble Gases	As Required by Station Procedure
	Non-Noble Gases	Water[e] and Fish[f]	A.2.1	Total Body	10CFR50[3]: 1.5 mrem/qtr 3 mrem/yr	Monthly
	Non-Noble Gases	Water[e] and Fish[f]	A.2.1	4 Age Groups (All Organs)	10CFR50[3]: 5 mrem/qtr 10 mrem/yr	
	Non-Noble Gases	Water[e]	A.6	Adult (Total Body and all Organs)	40CFR141: 4 mrem/yr	When Required by RETS
Uranium Fuel Cycle:	All	All releases plus direct radiation from contained sources	A.4.2	Total Body	40CFR190: 25 mrem/yr	Annually
				Thyroid (Adult)	40CFR190: 75 mrem/yr	
				All Other Organs (Adult)	40CFR190: 25 mrem/yr	
TEDE:	All	External + Internal	A.5	Total Body + organs (Adult)	10CFR20: 100 mrem/yr	Annually

Figure 2-1 (Cont'd)

Notes for Figure 2-1:

1. Definition: Monthly means at least once per 31 days or once per month. See station RETS for exact requirements.

2. Additional Calculations: In addition to the calculations shown in this figure, monthly projections of doses due to radioactive materials are required for gaseous and liquid effluents from Exelon Nuclear nuclear power stations. See Sections A.1.6 and A.2.5 of Appendix A.

   Also, projections of drinking water doses are required at least once per 92 days for Dresden and Quad Cities. See Section A.7 of Appendix A.

3. 10 CFR 50 prescribes design objectives not limits.

4. If the air dose is exceeded, doses to the total body and skin are calculated. Total body objectives are 2.5 mrem/qtr and 5.0 mrem/year; the skin dose objectives are 7.5 mrem/qtr and 15 mrem/year.

a Evaluated at the unrestricted area boundary.

b Evaluated at the location of maximum offsite X/Q.

c Ground plane and inhalation pathways are considered to be present at all offsite locations.

d Evaluated at the location in the unrestricted area where the combination of existing pathways and receptor age groups indicates the maximum potential exposures. If no real pathway exists then a hypothetical cow-milk producer is evaluated at 5 miles in the highest D/Q sector.

e Evaluated for the nearest downstream community water supply as specified in Table A-3 of Appendix A. The flow and dilution factors specified in Table F-1 of Appendix F are used.

f Evaluated for fish caught in the near-field region downstream of plant using the flow and dilution factors specified in Table F-1 of Appendix F.

CHAPTER 3

EXPOSURE PATHWAYS

3.0 INTRODUCTION

Figure 3-1 illustrates some of the potential radiation exposure pathways to humans due to routine operation of a nuclear power station. These exposure pathways may be grouped into three categories:

- **Airborne Releases**
  Exposures resulting from radioactive materials released with gaseous effluents to the atmosphere.
- **Liquid Releases**
  Exposures resulting from radioactive materials released with liquid discharges to bodies of water.
- **Radiation from Contained Sources**
  Exposures to radiation from contained radioactive sources.

When performing radiation dose calculations, only exposure pathways that significantly contribute (≥ 10%) to the total dose of interest need to be evaluated. The radiation dose from air and water exposure pathways are routinely evaluated. (see Regulatory Guide 1.109, Reference 6.)

3.1 AIRBORNE RELEASES

For airborne releases of radioactivity, the NRC considers the following pathways of radiation exposure of persons:

- External radiation from radioactivity airborne in the effluent plume.
- External radiation from radioactivity deposited by the plume on the ground.
- Ingestion of radioactivity on, or in, edible vegetation (from direct plume deposition).
- Ingestion of radioactivity that entered an animal food product (milk or meat) because the animal ingested contaminated feed, with the contamination due to direct deposition on foliage.
- Inhalation of radioactivity in the plume.

Dose for airborne releases is assessed at the location in the unrestricted area where the combination of existing pathways and receptor age groups indicates the maximum potential exposures.

3.2 LIQUID RELEASES

For liquid releases of radioactivity (Figure 3-1), the NRC considers the following pathways of radiation exposure of persons:

- Ingestion of aquatic food (e.g., fish or inverterbrate) obtained from the body of water to which radioactive station effluents are discharged.
- Ingestion (drinking) of potable water contaminated by radioactive liquid effluents discharged from the station.

For the aquatic food pathway, only fish is considered since it is the only significant locally produced aquatic food consumed by humans.

The stations omit the pathways involving irrigation and animal consumption of contaminated water because these pathways were determined to be insignificant. The stations also omit the pathway of radiation exposure from shoreline sediment because this pathway was also found to be insignificant (see ODCM Bases and Reference Document, Section O.3.2).

The stations have also verified that the dose contribution to people participating in water recreational activities (swimming and boating) is negligible. (See ODCM Bases and Reference Document, Reference 101, Tables O-3 and O-4) This pathway was not addressed explicitly in Regulatory Guide 1.109. Thus, the stations also omit dose assessments for the water recreational activities pathway.

Periodically the Illinois Army Corps of Engineers dredges silt and debris from the river beds near Exelon Nuclear nuclear stations. As a part of the land use census, Exelon Nuclear will determine if the Corps performed dredging within one mile of the discharge point. If so, Exelon Nuclear will obtain spoils samples, through it's REMP vendor, for analysis. The impact to the offsite dose will be evaluated on a case by case basis and added to the station annex of the ODCM when applicable.

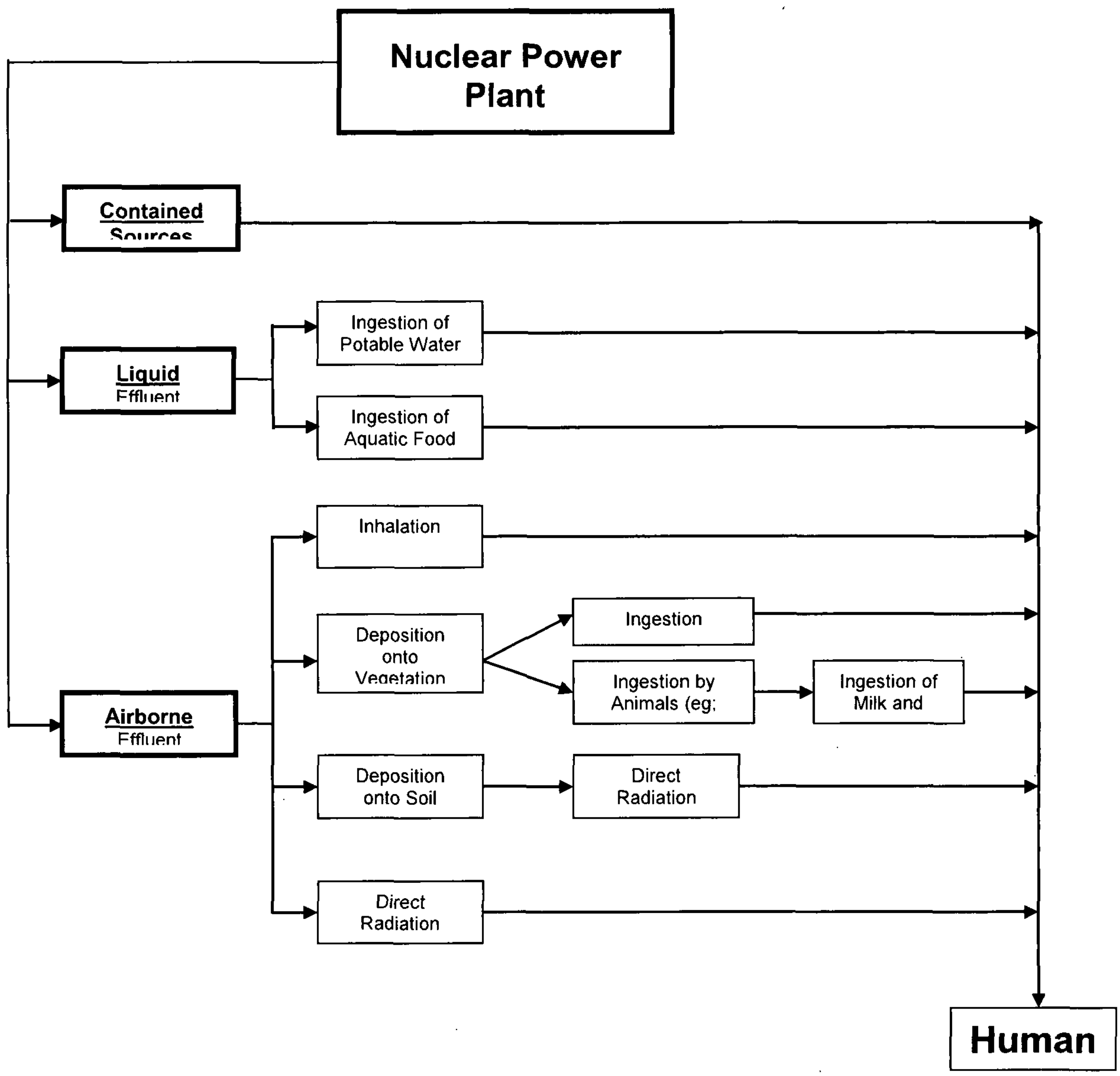
In addition, to assure that doses due to radioactivity in liquid effluents will be ALARA, concentrations will be limited to ten times (10x) the values given in 10CFR20 Appendix B, Table 2; Column 2. Specific limitations for concentrations of entrained noble gases are contained in the stations' Radiological Effluent Technical Standards (RETS).

3.3 RADIATION FROM CONTAINED SOURCES

Radioactivity contained within tanks, pipes or other systems and contained radioactive material or waste stored on site can produce radiation at offsite locations. Annual offsite radiation doses near the stations due to such sources were judged to be negligible in comparison with applicable limits except for doses due to BWR turbine skyshine and potential doses due to radioactive waste storage facilities (excludes radioactive material storage). See ODCM Bases and Reference Document, Reference 101. Changes or modifications to the power station that may impact the offsite dose through increases to the direct radiation levels need to be evaluated on a case by case basis and added to Chapter 12 of the station annex to the ODCM when applicable (e.g.; the Old Steam Generator Storage Facilities).

Figure 3-1

Radiation Exposure Pathways to Humans



CHAPTER 4

METHODOLOGY

4.0 INTRODUCTION

This chapter provides an introduction to the methodology used by Exelon Nuclear to calculate offsite radiation doses resulting from the operation of nuclear power stations. Additional explanation and details of the methodology are provided in Appendices A and B. Appendix A discusses each dose limit in the RETS and provides the associated assessment equations. Appendix B describes methods used to determine values of parameters included in the equations.

4.1 IMPORTANT CONCEPTS AND PARAMETERS

4.1.1 Dose

The dose calculation equations contained in the ODCM are based on two types of exposure to radiation; external and internal exposure. The first type of exposure is that resulting from radioactive sources external to the body (including radiation emanating from an effluent plume, radiation emanating from radioactivity deposited on the ground and radiation emanating from contained sources (also referred to as direct radiation)). Exposure to radiation external to the body only occurs while the source of the radioactivity is present.

Internal exposure occurs when the source of radioactivity is inside the body. Radiation can enter the body by breathing air containing the radioactivity, or by consumption of food or drinking water containing radioactivity. Once radioactivity enters the body and becomes internal radiation, a person will continue to receive radiation dose until the radioactivity has decayed or is eliminated by biological processes. The dose from this type of exposure is also termed dose commitment, meaning that the person will continue to receive dose even-though the plume containing the radioactivity has passed by the individual, or even-though the individual is no longer drinking water containing radioactivity.

The regulations addressed by the ODCM may require assessment of either type of exposure to radiation or of both types in summation.

The term dose is used instead of the term "dose equivalent," as defined by the International Commission on Radiological Units and Measurements (ICRU). When applied to the evaluation of internal deposition of radioactivity, the term "dose," as used in the ODCM, includes the prospective dose component arising from retention in the body beyond the period of environmental exposure, i.e., the dose commitment. The dose commitment is evaluated over a period of 50 years.

4.1.2 Exposure Pathways

All of the exposure pathways are discussed in Chapter 3. This section presents the exposure pathways addressed by Exelon Nuclear nuclear stations in the ODCM and associated software.

For releases of radioactivity in airborne effluents the primary pathways are the following:

- Direct radiation from an effluent plume.
- Direct radiation from radioactivity deposited on the ground by a plume.
- Inhalation of radioactivity in a plume.
- Ingestion of radioactivity that entered the food chain from a plume that deposited radioactivity on vegetation.

For releases of radioactivity in liquid effluents, the exposure pathways considered are human consumption of water and fish.

When determining total doses, as required by 10CFR20 and 40CFR190, the BWR stations also consider direct radiation due to skyshine from nitrogen-16 (^{16}N) in turbines and associated piping. All nuclear power stations will consider exposure to radiation emanating from onsite radwaste storage facilities when they are put into operation.

4.1.3 Categories of Radioactivity

Radionuclide content of effluent releases from nuclear power stations can be categorized according to the characteristics of the radionuclides. In evaluating doses associated with a particular pathway, only those categories of radionuclides that significantly contribute to the dose need to be included in the dose calculations (See Section 3.0). The categories of radionuclides considered by the Exelon Nuclear nuclear power stations for each of the airborne pathways are summarized in Table 4-1. Selection of the significant airborne pathways was based on the following:

- The requirements in the RETS (see discussion in Appendix A)
- Applicable regulatory guidance (References 6 and 14), and
- A study of the potential radiological implications of nuclear facilities in the upper Mississippi River basin (Reference 20).

Calculations were used to determine which radionuclides were significant for a particular pathway. For example, in the case of direct radiation from a plume of airborne radioactivity, it was found that radiation from noble gases is significant and radiation from radioactive iodine was not. The dose rate per unit of airborne radioactivity concentration is about the same for noble gases and radioactive iodine since they emit comparable types and energies of radiation. However, the quantity of noble gas radioactivity released in routine nuclear plant operation typically exceeds the quantity of radioactive iodine by a factor of about 10,000.

As another example, consider the inhalation pathway. Here, the calculations showed that the dose commitment due to radioactive iodine was significant but the dose commitment due to radioactive noble gases was not significant and can be excluded from the compliance calculations for the inhalation pathway. This is true despite the fact that a much larger quantity of noble gas radioactivity is released. The reason for this is that the solubility of noble gas in body tissue is very low, whereas the inhaled radioactive iodine does concentrate in specific body organs such as the thyroid (see the discussion on Pages 228 and 231 to 234 of Reference 38).

4.1.4 Atmospheric Release Point Classifications

The dose impact from airborne release of radioactivity is determined by the height of the release of the effluent plume relative to the ground and by the location of the dose recipient.

The height an effluent plume maintains as it travels above the ground is related to the elevation of the release point and to the height of structures immediately adjacent as follows:

- If the elevation of the release point is sufficiently above the height of any adjacent structures, the plume will remain elevated for considerable distances.

- If the elevation of the release point is at or below the heights of adjacent structures, the plume is likely to be caught in the turbulence of the wakes created by wind passing over the buildings. The plume elevation would then drop to ground level.

- If the elevation of the release point is not significantly above the heights of adjacent structures, then the plume may be elevated or at ground level.

For the calculations of this manual, each established release point has been designated as belonging to one of three release point classifications:

- Stack (or Elevated) Release Points (denoted by the letter S or subscript s)

  These are release points approximately twice the height of adjacent solid structures. Releases are treated as elevated releases unaffected by the presence of the adjacent structures.

- Ground Level Release Points (denoted by the letter G or subscript g)

  These are release points at ground level or lower than adjacent solid structures. Releases are considered drawn into the downwind wake of these structures and are treated as ground level releases.

- Vent (or Mixed Mode) Release Points (denoted by the letter V or subscript v)

  These are release points as high or higher than adjacent solid structures but lower than twice the structure's heights. These releases are treated as a mixture of elevated and ground level releases. The proportion of the release attributed to either elevated or ground level in a vent release is determined by the ratio of stack exit velocity to the wind speed (see Section B.1.2.4 of Appendix B).

The definitions of these classifications are based on Regulatory Guide 1.111 (Reference 7). A list of the classifications of specific airborne release points for each of the Exelon Nuclear nuclear power stations is contained in Table A-2 in Appendix A.

4.1.5 Historical Average Atmospheric Conditions

The dispersion characteristics of airborne effluents from a nuclear power station are dependent on weather conditions. Meteorological factors that directly affect the concentration of airborne radioactivity in a plume include the following:

- Wind Direction

  The concentration of radioactivity is highest in the direction toward which the wind is blowing.

- Wind Speed

  Greater wind speeds produce more dispersion and consequently lower concentrations of radioactivity.

- Atmospheric Turbulence

  The greater the atmospheric turbulence, the more a plume spreads both vertically and horizontally. For calculations in this manual, the degree of turbulence is classified by use of seven atmospheric stability classes, designated A (extremely unstable) through G (extremely stable). The seven classes and some of their characteristics are listed in Table C-4 of Appendix C.

Meteorological conditions strongly impact the values of various parameters applied in the dose calculations of this manual. These include:

- The Relative Concentration Factors χ/Q and gamma-χ/Q (Section 4.1.6)
- The Relative Deposition Factor D/Q (Section 4.1.7)

The bases sections of the Standard Radiological Effluent Technical Specifications (guidance documents NUREGs 0472, 0473, 1301 and 1302) and the RETS specify that dose calculations be based on "historical average atmospheric conditions". Therefore, this manual provides values for the above parameters that are based on station-specific historical average meteorological conditions. These values were obtained by averaging hourly values of the parameters over a long-term, several-year period of record. The averaging period was based on calendar years in order to avoid any bias from weather conditions associated with any one season. The period of record is identified in each of the tables providing the values (see Appendix F).

4.1.6 Relative Concentration Factors χ/Q and Gamma-χ/Q

A person immersed in a plume of airborne radioactivity is exposed to radiation from the plume and may also inhale some of the radioactivity from the plume. The concentration of radioactivity in air near the exposed person must be calculated to adequately evaluate doses resulting from any inhalation. The relative concentration factor χ/Q (referred to as "chi over Q") is used to simplify these calculations. χ/Q is the concentration of radioactivity in air, at a specified location, divided by the radioactivity release rate. χ/Q has the following units:

Units of $\chi/Q = (\mu Ci/m^3) / (\mu Ci/sec) = sec/m^3$

Station-specific values of χ/Q are provided for each nuclear power station in Table F-5 of Appendix F. These values are based on historical average atmospheric conditions (see Section 4.1.5).
For each of the release point classifications (eg. stack, vent and ground level) and for the 16 compass-direction sectors (N, NNE, etc.), Table F-5 provides the maximum value of χ/Q for locations at or beyond the unrestricted area boundary.

The value of χ/Q for each sector reflects the fraction of time that the wind blew into that sector and the distribution of wind speeds and atmospheric stability classes during that time. Note that the value would be zero if the wind never blew into the sector.

The gamma-χ/Q provides a simplified method of calculating gamma air dose and dose rates for a finite and/or elevated plume. It is used in place of the semi-infinite plume model that tends to underestimate gamma air dose for elevated plumes. Use of the gamma-X/Q also corrects for the tendency of the semi-infinite plume model to overestimate gamma air dose for mixed mode and ground level releases.

The methodologies for determining χ/Q and gamma-χ/Q are discussed in detail in Section B.3 of Appendix B.

4.1.7 Relative Deposition Factor D/Q

As a plume travels away from its release point, portions of the plume may touch the ground and deposit radioactivity on the ground and/or on vegetation. Occurrences of such deposition are important to model since any radioactivity deposited on the ground or on vegetation may directly expose people and/or may be absorbed into food products which can ultimately be ingested by people. The relative deposition factor is used to simplify the dose calculations for these pathways.

The relative deposition factor D/Q is the rate of deposition of radioactivity on the ground divided by the radioactivity release rate. Its value was determined for specific conditions. In this manual it has the following units:

Units of $D/Q = [(pCi/sec)/m^2] / (pCi/sec) = 1/m^2$

The values of D/Q are affected by the same parameters that affect the values of χ/Q: release characteristics, meteorological conditions and location (see Section 4.1.6). Station-specific values of D/Q are provided for each Exelon Nuclear nuclear power station in Appendix F Tables F-5 and F-6. These values are based on historical average atmospheric conditions (see Section 4.1.5).

For each release point classification and for each of the 16 compass-direction sectors (N, NNE, etc.), Table F-5 provides the maximum value of D/Q for locations at or beyond the unrestricted area boundary.

In Table F-6, values of D/Q are given for the locations of the nearest milk and meat producers within 5 miles of the nuclear power station. The methodology for determining D/Q is discussed in Section B.4 of Appendix B.

4.1.8 Dose Factors

Various dose factors are used in this manual to simplify the calculation of radiation doses. These factors are listed in Table 4-2. Definitions of these factors are given in the remainder of this chapter. Methods of determining their values are addressed in Appendix B.

4.2 AIRBORNE RELEASES

4.2.1 Gamma Air Dose

The term 'gamma air dose' refers to the component of dose absorbed by air resulting from the absorption of energy from photons emitted during nuclear and atomic transformations, including gamma rays, x-rays, annihilation radiation, and Bremsstrahlung radiation (see footnote on page 1.109-19 of Regulatory Guide 1.109).

The noble gas dose factors of Reg. Guide 1.109, Table B-1 are based upon assumption of immersion in a semi-infinite cloud. For ground level and mixed mode releases this tends to over estimate the gamma air dose arising from a plume that is actually finite in nature.

For elevated releases, the Reg. Guide 1.109 noble gas dose factors will underestimate exposure as they consider only immersion and not that portion of exposure arising from sky shine. At distances close in to the point of elevated release, the ground level concentration as predicted by **χ/Q** will be essentially zero. In such a case, the sky shine component of the exposure becomes significant and must be considered.

The **gamma-χ/Q** provides a simplified method of calculating gamma air dose and dose rates for a finite and/or elevated plume. The methodology of Reg. Guide 1.109, Section C.2 and Appendix B provide the methodology for calculating finite cloud gamma air dose factors from which the **gamma-χ/Q** values can be derived. Section B.5 addresses the calculation of these dose factors.

Three **gamma-χ/Q** values are defined: $(\chi/Q)_s^\gamma$, $(\chi/Q)_v^\gamma$ **and** $(\chi/Q)_g^\gamma$ for stack, vent and ground level releases, respectively. Section B.3.5 addresses the calculation of the **gamma-χ/Q** values.

4.2.1.1 Finite Cloud Gamma Air Dose Factor

The finite cloud gamma air dose factor is determined by calculating the gamma dose rate to air (at a specific location and corresponding to a given release rate) and dividing that dose rate by the corresponding release rate:

Finite Cloud Gamma Air Dose Factor = [(mrad/yr)/(μCi/sec)]

The methodology for this calculation is discussed in Section B.5 of Appendix B. The calculation is complex because the dose rate at any given point is affected by the radioactivity concentration and distance. Calculation of the finite cloud gamma air dose factor takes into consideration release characteristics, meteorological conditions and location (see Section 4.1.6). Additionally, the value is affected by radiological parameters: the distribution of energies and intensities for gamma emissions from each specific radionuclide and the photon attenuation characteristics of air.

In the ODCM, station-specific values of gamma dose factors are provided for each station in Appendix F, Table F-7. These values are based on historical average atmospheric conditions (see Section 4.1.5). For the release point classification and for each of the 16 compass-direction sectors, Table F-7 provides the maximum value of the gamma air dose factor for noble gas radionuclides at the unrestricted area boundary. The value includes a correction for radioactive decay during transport of the radionuclide from the release point to the dose calculation location.

4.2.1.2 Semi-Infinite Cloud Gamma Air Dose Factor

The semi-infinite cloud gamma dose factor is the gamma air dose rate divided by the concentration of radioactivity in air at the dose calculation location. Values of these gamma dose factors are radionuclide specific and are provided in Appendix C, Table C-9.

The semi-infinite cloud gamma dose factor is used in conjunction with **gamma-χ/Q** to calculate noble gas gamma air dose and dose rate for elevated and finite noble gas plumes. The **gamma-χ/Q** is defined such that for a given finite cloud the semi-infinite cloud methodology will yield the same gamma air dose as the finite cloud methodology.

4.2.2 Beta Air Dose

The term 'beta air dose' refers to the component of dose absorbed by air resulting from the absorption of energy from emissions of beta particles, mono-energetic electrons and positrons during nuclear and atomic transformations (see the footnote on Page 1.109-20 of Regulatory Guide 1.109).

The Beta Air Dose Factor

The beta air dose factor is the beta air dose rate divided by the concentration of radioactivity in air at the dose calculation location. Values of the beta air dose factor are radionuclide specific and are provided in Appendix C Table C-9.

4.2.3 Total Body Dose and Dose Rate

Total Body Dose

Equation A-3 of Appendix A is used to calculate dose to the total body from noble gas radionuclides released in gaseous effluents. The total body dose equation is similar to that used to calculate gamma air dose (Equation A-1 of Appendix A).

Total Body Dose Rate

Equation A-5 of Appendix A is used to calculate dose rate to the total body. The assumptions used for this equation are the same as those used in the calculation of total body dose (Equation A-3 of Appendix A) except that any shielding benefit (dose attenuation) provided by residential structures is not applied. Since the calculation is for the maximum instantaneous dose rate, the dose recipient may be out of doors when exposed and would not be shielded from the exposure by any structural material.

The Total Body Dose Factor

The total body dose factor is the total body dose rate divided by the radioactive release rate. Values for the total body dose factor are site specific and are provided in Table C-9 of Appendix C.

4.2.4 Skin Dose and Dose Rate

Skin Dose

Equation A-4 of Appendix A is used to calculate dose to skin from noble gas radionuclides released in gaseous effluents. The skin dose is the summation of dose to the skin from beta and gamma radiation.

The equation for beta dose to skin is similar to that used to calculate beta dose to air (Equation A-2 of Appendix A) except that beta skin dose factors are used instead of beta air dose factors. The beta skin dose factor differs from the beta air dose factor by accounting for the attenuation of beta radiation by the dead layer of skin. The dead layer of skin is not susceptible to radiation damage and therefore is not of concern. The beta dose to the skin from non-noble gases is insignificant and is not calculated for the reason described in Section 4.1.3. When calculating the beta contribution to skin dose, no reduction is included in the calculations due to shielding provided by occupancy of residential structures.

The equation for gamma dose to skin is similar to that used to calculate gamma dose to air except for the following:

- Equation A-4 of Appendix A includes a units conversion factor 1.11 rem/rad to convert from units of gamma air dose (rad) to units of tissue dose equivalent (rem).

- Equation A-4 of Appendix A includes a dimensionless factor of 0.7 to account for the shielding due to occupancy of residential structures.

Equation A-4 of Appendix A uses gamma air dose factors not gamma total body dose factors. When calculating gamma dose to skin, no reduction is applied for the attenuation of radiation due to passage through body tissue (dead layer of skin).

Skin Dose Rate

Equation A-6 of Appendix A is used to calculate dose rate to skin. The assumptions are the same as those used in the calculation of skin dose (Equation A-4 of Appendix A) except that no credit is taken for shielding of gamma radiation by residential structures. The dose recipient may be outdoors when exposed and the maximum instantaneous dose rate is of concern.

The Skin Dose Factor

Values of the beta air dose factors and skin dose factors are nuclide specific and are provided in Table C-9 of Appendix C for 15 noble gas radionuclides.

4.2.5 *Ground Radiation*

Equations A-7 and A-8 of Appendix A are used to calculate the total body dose due to non-noble gas radionuclides released in gaseous effluents and deposited on the ground.

Comment
Note that if there is no release of radionuclide **i** during a given time period, then the deposition rate is zero, the ground plane concentration is zero and the resulting dose due to ground deposition is zero. If there is a release of radionuclide **i**, the ground concentration is computed as if that release had been occurring at a constant rate for the ground deposition time period.

The Ground Plane Dose Conversion Factor

The ground plane dose conversion factor is the dose rate to the total body per unit of radioactivity concentration on the ground. Values of the ground plane dose conversion factor that are calculated by assuming constant concentration over an infinite plane are provided for various radionuclides in Table C-10 of Appendix C.

4.2.6 Inhalation

Dose

Radioactivity from airborne releases of radioactive iodine, particulate and tritium can enter the body through inhalation. Equations A-7 and A-9 of Appendix A are used to calculate dose commitment to the total body or organs due to inhalation of non-noble gas radionuclides released in gaseous effluents.

The Inhalation Dose Factor

Values for the inhalation dose commitment factor are nuclide specific and are taken from Reg. Guide 1.109 (Reference 6) Tables E-7, 8, 9 and 10. These tables include data for four age groups (adult, teenager, child and infant) and seven body organs.

Dose Rate

The inhalation dose rate is the rate at which dose is accrued by an individual breathing contaminated air. Equation A-16 of Appendix A is used to calculate dose commitment rate to an organ due to inhalation of non-noble gas radionuclides. The assumptions are the same as used in the calculation of inhalation dose. The dose rate is determined for the child age group in accordance with the guidance found in NUREGs 0472, 0473, 1301 and 1302 (References 2, 3, 105 and 106).

4.2.7 Ingestion

Airborne releases of radioactive iodine, particulate and tritium can enter the food chain through deposition on vegetation. The radioactivity can be ingested by humans who consume the vegetation or who consume products (e.g., milk or meat) of animals who have fed on the contaminated vegetation. Each Exelon Nuclear nuclear power station considers the following ingestion pathways:

- Vegetables
- Milk
- Meat.

Equations A-7 and A-10 through A-15 of Appendix A are used to calculate the dose due to ingestion of food containing non-noble gas radionuclides released in gaseous effluents. Dose is assessed at the location in the unrestricted area where the combination of existing pathways and receptor age groups indicates the maximum potential exposures.

Values of the ingestion dose commitment factor are the same for each Exelon Nuclear nuclear power station. The components of this factor are not impacted by station-specific parameters. The station-specific aspects of the calculation of ingestion dose only concern the quantity of radioactivity ingested. Values of the ingestion dose commitment factors are taken from Reg. Guide 1.109 Tables E-11, 12, 13 and 14. These tables include data for four age groups and seven organs.

The equations used for radioactivity concentration on vegetation and in milk, and meat are discussed in Appendix A.

4.3 LIQUID RELEASES

The evaluation of dose due to releases of radioactivity in liquid effluents is required to confirm compliance with the provisions of RETS related to 10CFR50 Appendix I. ODCM Section 3.2 and Figure 3-1 list some of the pathways by which radioactivity in liquid effluents can impact man. The pathways used by Exelon Nuclear to calculate dose from liquid effluents are ingestion by drinking water and by eating fish from the body of water receiving station liquid discharges. The nuclear power stations obtain the dose commitment due to radioactivity in liquid effluent releases by summing the dose commitments from the drinking water and fish pathways depending upon their presence.

Equations A-17 through A-20 of Appendix A are used to calculate dose for the member of the public due to consumption of drinking water and fish.

The radioactivity concentration in water is obtained by dividing the quantity of radioactivity released by the volume of water in which the release is diluted. The result can be modified by a factor to represent any additional dilution that might occur.

The radioactivity concentration in fish is the product of the radioactivity concentration in water and a bioaccumulation factor. The dilution factors for fish may be different from those for water. (The fish may be caught at a location different from where drinking water is drawn.)

The bioaccumulation factor accounts for the fact that the quantity of radioactivity in fish can build up with time to a higher value relative to the concentration of the radioactivity in the water they consume. The bioaccumulation factor is the equilibrium ratio of the concentration of radionuclide **i** in fish to its concentration in water. The same values are used for the bio-accumulation factor at each station. These values are provided in Appendix C, Table C-8.

4.4 CONTAINED SOURCES OF RADIOACTIVITY

In addition to the total body, skin and single organ dose assessments previously described, an additional assessment is required. The additional assessment addresses radiation dose due to radioactivity contained within the nuclear power station and its structures.

There are presently two types of contained sources of radioactivity which are of concern in offsite radiological dose assessments. The first is that due to gamma rays resulting from nitrogen-16 carry- over to the turbine in BWR steam (skyshine). The second is that due to gamma rays associated with radioactive material contained in onsite radwaste and radioactive material storage facilities.

4.4.1 BWR Skyshine

The most significant dose component to members of the public produced by "contained sources" is nitrogen-16 (^{16}N) within the turbine building of BWRs. Although primary side shielding is around the turbine and its piping, ^{16}N gamma rays scattered by air molecules in the overhead air space above the turbine and piping cause a measurable "skyshine" radiation dose in the local power plant environs.

Equation A-23 of Appendix A is used to evaluate skyshine dose. A complicating factor in the calculation is the practice at some stations of adding hydrogen to reactor coolant to improve coolant chemistry. The addition of hydrogen can increase the dose rate due to skyshine up to a factor of 10 times expected levels depending on injection rates and power levels (Reference 39). Increasing the hydrogen injection rate will increase the dose rates even further. (See Reference 102) The skyshine dose determined by Equation A-23 of Appendix A depends on the following factors:

- The distance of the dose recipient location from the turbine.
- The number of hours per year that the location is occupied by a dose recipient.
- The total energy [MWe-hr] generated by the nuclear power station with hydrogen addition.
- The total energy [MWe-hr] generated by the nuclear power station without hydrogen addition.

4.4.2 Onsite Radwaste and Rad Material Storage Facilities

Low-level radioactive waste may be stored at any Exelon Nuclear nuclear power station in the following types of storage facilities:

- Process Waste Storage Facilities
    - Interim Radwaste Storage Facility (IRSF) structure
    - Concrete vaults containing 48 radwaste liners (Also referred to as "48-pack";)
- DAW Storage Facilities
    - Dry Active Waste (DAW) facilities (may include Butler buildings/warehouses)
- Replaced Steam Generator Storage Facilities

Rad Material may be stored in facilities on site

- Rad Material Storage Facilities
    - Contaminated tools and equipment in seavans and/or warehouses

Spent Fuel may be stored in facilities on site:

- ISFSI Facilities
    - Independent spent fuel storage installation facilities

Administrative controls are implemented by each station to ensure compliance to applicable regulations. The impact to the offsite dose will be evaluated on a case by case basis and added to the station annex of the ODCM when applicable. In addition, a 10CFR50.59 analysis may be required for radwaste storage facilities.

4.5 TOTAL DOSE REQUIREMENTS

4.5.1 Total Effective Dose Equivalent Limits; 10CFR20 and 40CFR190

10CFR20 requires compliance to dose limits expressed as "Total Effective Dose Equivalent" (TEDE). Although annual dose limits in 10CFR20 are now expressed in terms of TEDEs, 40CFR190 limits remain stated as organ dose. The NRC continues to require 10CFR50 Appendix I and 40CFR190 doses to be reported in terms of organ dose and not TEDE. Due to the fact that organ dose limits set forth in 40CFR190 are substantially lower than those of 10CFR20 (25 mrem/yr vs 100 mrem/yr), the NRC has stated that demonstration of compliance with the dose limits in 40CFR190 will be deemed as demonstration of compliance with the dose limits of 10CFR20 for most facilities (Reference 104). In addition to compliance with 40CFR190, it may be necessary for a nuclear power plant to address dose from on-site activity by members of the public.

4.5.2 Total Dose For Uranium Fuel Cycle

The nuclear power stations are required to determine the total dose to a member of the public due to all uranium fuel cycle sources in order to assess compliance with 40CFR190 as part of demonstrating compliance with 10CFR20.

The total dose for the uranium fuel cycle is the sum of doses due to radioactivity in airborne and liquid effluents and the doses due to direct radiation from contained sources at the nuclear power station. When evaluation of total dose is required for a station, the following contributions are summed:

- Doses due to airborne and liquid effluents from the station.

- Doses due to liquid effluents from nuclear power stations upstream.
- Doses due to nitrogen-16 (^{16}N) skyshine, if the station is a boiling water reactor.
- Doses due to any onsite radioactive waste storage facilities; if applicable.

Section A.5.2 of Appendix A discusses the details of evaluations.

Table 4-1

Radionuclide Types Considered For Airborne Effluent Exposure Pathways

Category	External Radiation: Plume	External Radiation: Ground	Internal Radiation: Inhalation	Internal Radiation: Ingestion
Noble Gases	X			
Tritium (H-3)			X	X
Iodine[a]		X	X	X
Particulate[a]		X	X	X

[a] The nuclear power stations are not required to consider all iodine radionuclides. Only particulates with half-life greater than 8 days need be considered. For details, see Generic Letter 89-01 and the RETS.

Table 4-2
Radiation Dose Factors

Name and Symbol	Units	Definition	Table
Gamma Air Dose Factor M_i	mrad/yr per $\mu Ci/m^3$	Gamma air dose rate per unit of radioactivity concentration for radionuclide **i**.	RG 1.109 Table B-1, Column 4
Total Body Dose Factor: K_i	mrem/yr per $\mu Ci/m^3$	Total body dose rate per unit of radioactivity concentration for radionuclide **i**.	RG 1.109 Table B-1, Column 5
Beta Air Dose Factor N_i	mrad/yr per $\mu Ci/m^3$	Beta air dose rate per unit of radioactivity concentration for radionuclide **i**.	RG 1.109 Table B-1, Column 2
Beta Skin Dose Factor L_i	mrem/yr per $\mu Ci/m^3$	Beta skin dose rate per unit of radioactivity concentration for radionuclide **i**.	RG 1.109 Table B-1, Column 3
Ground Plane Dose Conversion Factor DFG_i	mrem/hr per pCi/m^2	Dose rate per unit of ground radioactivity concentration for radionuclide **i**.	RG 1.109 Table E-6, Column 2
Inhalation Dose Commitment Factor DFA_{ija}	mrem per pCi	Dose to organ **j** of age group **a** per unit of radioactivity inhaled for radionuclide **i**. (see Note 1)	RG 1.109 Tables; E-7, E-8, E-9, E-10
Ingestion Dose Commitment Factor DFI_{ija}	mrem per pCi	Dose to organ **j** of age group **a** per unit of radioactivity ingested for radionuclide **i**. (see Note 1)	RG 1.109 Tables; E-11, E-12, E-13, E-14

Note 1: Dose assessments for 10CFR20 and 40CFR 190 compliance are made for an adult only.

Dose assessments for 10CFR50 Appendix I are made using dose factors of Regulatory Guide 1.109 (Reference 6) for all age groups.

CHAPTER 5

MEASUREMENT

5.0 INTRODUCTION

Each nuclear station has three measurement programs associated with offsite dose assessment:

- Measurement of releases of radioactivity from the station.
- Measurement of meteorology at the station site.
- Measurement of levels of radiation and radioactivity in the environs surrounding the station.

5.1 EFFLUENT AND PROCESS MONITORING

Radioactivity in liquid and gaseous effluents is measured in order to provide data for calculating radiation doses and radioactivity concentrations in the environment of each nuclear power station. Measurement of effluent radioactivity is required by 10CFR20.1302 and 10CFR50. The RETS of each nuclear power station provide detailed requirements for instrumentation, sampling and analysis. Relevant Regulatory Guides are 1.21 (Reference 4) and 4.15 (Reference 13). Chapter 10 of the ODCM includes brief descriptions of effluent monitoring instruments at each nuclear power station. The RETS of each nuclear power station require submission to the NRC of reports of effluent radioactivity releases and environmental measurements.

5.2 METEOROLOGICAL MONITORING

Meteorological parameters are measured in the vicinity of each nuclear power station in order to provide data for calculating radiation doses due to airborne effluent radioactivity. Some nuclear power stations' Technical Specifications state applicable requirements (typically under the subheading, "Meteorological Instrumentation," in the instrumentation section). Regulatory guidance is given in Regulatory Guide 1.23 (Reference 5). Wind speed, wind direction and the temperature gradient are measured using instruments at two or more elevations on a meteorological tower at each Exelon Nuclear station. The elevations are chosen to provide meteorological data representative of the elevations of the airborne releases from the station. The Annual Radiological Environmental Operating Report includes a summary of meteorological data collected over the reporting year. These data are used to calculate optional isopleths of radiation dose and radioactivity concentration.

5.3 RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM (REMP)

Each nuclear power station has a REMP that provides representative measurements of radiation and radioactive material in the environment. The program provides verification that measurable radiological impacts from the power station on the environment are within expectations derived from effluent measurements and calculations. The REMP is required by 10CFR50 (see Appendix I, Sections IV.B.2 and IV.B.3). General requirements of the program are prescribed in each station's RETS and more precise details (such as specific monitoring locations) are specified in ODCM Chapter 11.

5.3.1 Interlaboratory Comparison Program

The laboratory which performs the REMP analyses is required by the RETS to participate in an interlaboratory comparison program. The purpose is to provide an independent check on the laboratory's analytical procedures and to alert it to potential problems (e.g. accuracy). In order to assess the measurements of radioactivity in environmental media, an independent agency supplies participating laboratories with samples of environmental media containing unspecified amounts of radioactivity. The laboratories measure the radioactivity concentrations and report the results to the agency. At a later time, the agency informs the participating laboratories of the actual concentrations and associated uncertainties. Any significant discrepancies are investigated by the participating laboratories. A similar process is used to assess measurements of environmental radiation by passive thermoluminescent dosimeters.

CHAPTER 6

IMPLEMENTATION OF OFFSITE DOSE ASSESSMENT PROGRAM

6.1 NUCLEAR POWER STATION

The nuclear power station staff is responsible for effluent monitoring. The staff determines effluent radioactivity concentration and flow rate. These data are used to determine the radioactivity release information required for the Radioactive Effluent Release Report and to perform monthly calculations and projections of offsite radiation dose.

The nuclear power station staff is also responsible for control of effluent radioactivity. Procedures are implemented for determining, calculating and implementing setpoints. Liquid and gaseous radwaste treatment systems and ventilation exhaust treatment systems are utilized when appropriate. The nuclear power station staff implements the Process Control Program (PCP) for solid radwaste and measures tank radioactivity and BWR off-gas radioactivity.

The nuclear power station staff maintains instrumentation associated with these activities and demonstrates operability of the instrumentation in accordance with the surveillance requirements of the RETS. In the event that any RETS requirements are violated, the nuclear power station staff is responsible for taking one of the actions allowed by the RETS and issuing any required reports to the NRC.

The nuclear power station staff assembles and distributes the Radioactive Effluent Release Report.

6.2 METEOROLOGICAL CONTRACTOR

The meteorological contractor operates and maintains the meteorological tower instrumentation at each nuclear power station. The contractor collects and analyzes the data and issues periodic reports. The contractor prepares the meteorological data summary required for the Annual Radiological Environmental Operating Report (AREOR) and also computes and plots isopleths included in the AREOR.

6.3 REMP CONTRACTOR

The radiological environmental contractor collects environmental samples and performs radiological analyses as specified in the nuclear power station's REMP (see ODCM Chapters 11 and 12). The contractor issues reports of results to appropriate points of contact and each nuclear station. The contractor participates in an interlaboratory comparison program and reports results in the Annual Radiological Environmental Operating Report. The contractor performs the annual land use census and assembles the Annual Radiological Environmental Operating Report.

CHAPTER 7

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APPENDIX A

COMPLIANCE METHODOLOGY

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APPENDIX A

COMPLIANCE METHODOLOGY

A.0 INTRODUCTION

This appendix reviews the offsite radiological limits applicable to the nuclear power stations and presents in detail the equations and procedures used to assess compliance with these limits. An introduction to the calculational approach used here is given in Chapter 4. The approach incorporates simplifications such as the following:

- Use of pre-calculated atmospheric transport parameters based on historical average atmospheric conditions (see Section 4.1.5). These atmospheric dispersion and deposition factors are defined in Chapter 4.

The equations and parameters of this appendix are for use in calculating offsite radiation doses during routine operating conditions. They are not for use in calculating doses due to non-routine releases (e.g., accident releases).

This section of the ODCM provides the methodological details for demonstrating compliance with the 10CFR20, 10CFR50 Appendix I, 10CFR72.104 and 40CFR190 radiological limits for liquid and gaseous effluents.

An overview of the required compliance is given in Tables 2-1, 2-2, and 2-3. In Table 2-1, the dose components are itemized and referenced, and an indication of their regulatory application is noted. A more detailed compliance matrix is given in Table 2-3. Additionally, the locations of dose receivers for each dose component are given in Table 2-2.

The following sections detail the required radiological dose calculations.

A.1 AIRBORNE RELEASES

A.1.1 Release Point Classifications

The pattern of dispersion of airborne releases is dependent on the height of the release point relative to adjacent structures. For the equations of this appendix, each release point is classified as one of the following three height-dependent types, which are defined in Section 4.1.4:

- Stack (or Elevated) Release Point (denoted by the letter S or subscript s)
- Ground Level Release Point (denoted by the letter G or subscript g)
- Vent (or Mixed Mode) Release Point (denoted by the letter V or subscript v)

The release point classifications of routine release points at the nuclear power stations are stated in Table A-2.

A.1.2 Dose Due to Noble Gas Radionuclides

A.1.2.1 Gamma Air Dose

Requirement

RETS limit the gamma air dose due to noble gas effluents released from each reactor unit to areas at and beyond the unrestricted area boundary to the following:

- Less than or equal to 5 mrad per calendar quarter.

- Less than or equal to 10 mrad per calendar year.

Equation

The gamma air dose due to noble gases released in gaseous effluents is calculated by the following expression:

$$D_\gamma = (3.17E-8)\sum_i M_i \left\{ (\chi/Q)_s^\gamma A_{is} + (\chi/Q)_v^\gamma A_{iv} + (\chi/Q)_g^\gamma A_{ig} \right\} \quad \textbf{(A-1)}$$

The summation is over noble gas radionuclides **i**.

D_γ	Gamma Air Dose Dose to air due to gamma radiation from noble gas radionuclides released in gaseous effluents.	[mrad]
3.17E-8	Conversion Constant (seconds to years)	[yr/sec]
M_i	Gamma Air Dose Conversion Factor Gamma air dose rate factor per unit of radioactivity release rate for radionuclide **i**. From Table B-1 of Reg Guide 1.190.	[(mrad/yr)/(μCi/m³)]
$(\chi/Q)_s^\gamma, (\chi/Q)_v^\gamma, (\chi/Q)_g^\gamma$	Gamma-χ/Q Factor Radioactivity concentration based on finite cloud methodology at a specific location per unit of radioactivity release rate from a stack, vent or ground level release, respectively. See Section B.3.5 and Table F-5b of appendix F.	[sec/m³]
A_{is}, A_{iv}, A_{ig}	Cumulative Radionuclide Release Measured cumulative release of radionuclide **i** over the time period of interest from a stack, vent, or ground level release point, respectively.	[μCi]

Application

RETS require determination of cumulative and projected gamma air dose contributions due to noble gases for the current calendar quarter and the current calendar year at least once per 31 days (see Sections 12.4 of each station's RETS or Technical Specifications).

Gamma air dose is calculated for the sector with the highest offsite $(\chi/Q)^\gamma$ and is compared with the RETS limits on gamma air dose.

For a release attributable to a processing or effluent system shared by more than one reactor unit, the dose due to an individual unit is obtained by proportioning the effluents among the units sharing the system. The allocation procedure is specified in ODCM Chapter 10.

A.1.2.2 Beta Air Dose

Requirement
RETS limit the beta air dose due to noble gases in gaseous effluents released from each reactor unit to areas at and beyond the unrestricted area boundary to the following:

- Less than or equal to 10 mrad per calendar quarter.
- Less than or equal to 20 mrad per calendar year.

Equation
The beta air dose due to noble gases released in gaseous effluents is calculated by the following expression:

$$D_\beta = (3.17E-8)\sum_i \left\{ N_i \left[(\chi/Q)_s A_{is} + (\chi/Q)_v A_{iv} + (\chi/Q)_g A_{ig} \right] \right\} \qquad \textbf{(A-2)}$$

The summation is over noble gas radionuclides **i**.

D_β	Beta Dose	[mrad]
	Dose to air due to beta radiation from noble gas radionuclides released in gaseous effluents.	
3.17E-8	Conversion Constant (seconds to years)	[yr/sec]
N_i	Beta Air Dose Conversion Factor	[(mrad/yr)/(μCi/m^3)]
	Beta air dose rate per unit of radioactivity concentration for radionuclide **i**. Take from Table C-9 of Appendix C.	
$(\chi/Q)_s$ $(\chi/Q)_v$ $(\chi/Q)_g$	Relative Concentration Factor	[sec/m^3]
	Radioactivity concentration based on semi-infinite cloud methodology at a specified location per unit of radioactivity release rate for a stack, vent, or ground level release, respectively. See Section 4.1.6, Section B.3 of Appendix B, and Table F-5 of Appendix F.	
A_{is}, A_{iv}, A_{ig}	Cumulative Radionuclide Release	[μCi]
	Measured cumulative release of radionuclide **i** over the time period of interest from a stack, vent, or ground level release point, respectively.	

Application
RETS require determination of cumulative and projected beta air dose contributions due to noble gases for the current calendar quarter and the current calendar year at least once per 31 days (see Section 12.4 of each station's RETS or Technical Specification).

Beta air dose is calculated for the sector with the highest offsite **(χ/Q)** and is compared with the RETS limit on beta air dose.

For a release attributable to a processing or effluent system shared by more than one reactor unit, the dose due to an individual unit is obtained by proportioning the effluents among the units sharing the system. The allocation procedure is specified in ODCM Chapter 10.

A.1.2.3 *Total Body Dose*

Requirement
The total body dose, to any receiver is due, in part, to gamma radiation emitted from radioactivity in airborne effluents. This component is added to others to demonstrate compliance to the requirements of 40CFR190 and 10CFR20.

Equation

The total body dose component due to gamma radiation from noble gases released in gaseous effluents is calculated by the following expression:

$$D_{TB} = (3.17E-8)\sum_{i} K_i \left\{ (\chi/Q)_s^{\gamma} A_{is} + (\chi/Q)_v^{\gamma} A_{iv} + (\chi/Q)_g^{\gamma} A_{ig} \right\} \quad \text{(A-3)}$$

The summation is over noble gas radionuclides **i**.

D_{TB}	Total Body Dose	[mrem]
	Dose to the total body due to gamma radiation from noble gas radionuclides released in gaseous effluents.	
3.17E-8	Conversion Constant (seconds to years)	[yr/sec]
K_i	Gamma Total Body Dose Conversion Factor	[(mrem/yr)/(uCi/m3)]
	Gamma total body dose factor due to gamma emissions for noble gas radionuclide **i** released from a stack, vent or ground level release point, respectively. Taken from Table C-9 of Appendix C.	
A_{is}, A_{iv}, A_{ig}	Cumulative Radionuclide Release	[μCi]
	Measured cumulative release of radionuclide **i** over the time period of interest from a stack, vent, or ground level release point, respectively.	

Application

The total body dose is also calculated for the 40CFR190 and 10CFR20 compliance assessments. In some cases, the total body dose may be required in 10CFR50 Appendix I assessments (See Table 2-1).

A.1.2.4 Skin Dose

Requirement
There is no regulatory requirement to evaluate skin dose. However, this component is evaluated for reference as there is skin dose design objective contained in 10CFR50 Appendix I. Note that in the unlikely event that if beta air dose guideline is exceeded, then the skin dose will require evaluation.

Equation
The part of skin dose due to noble gases released in gaseous effluents is calculated by the following expression:

$$\begin{aligned} D_{SK} = (3.17E-8)\sum_{i} \Big\{ & L_i \left[(\chi/Q)_s A_{is} + (\chi/Q)_v A_{iv} + (\chi/Q)_g A_{ig} \right] \\ & + (1.11) M_i \left[(\chi/Q)_s^{\gamma} A_{is} + (\chi/Q)_v^{\gamma} A_{iv} + (\chi/Q)_g^{\gamma} A_{ig} \right] \Big\} \end{aligned} \quad \text{(A-4)}$$

The summation is over noble gas radionuclides **i**.

D_{SK}	Skin Dose Dose to the skin due to beta and gamma radiation from noble gas radionuclides released in gaseous effluents.	[mrem]
L_i	Beta Skin Dose Conversion Factor Beta skin dose rate per unit of radioactivity concentration for radionuclide **i**. Taken from Table C-9 of Appendix C.	[(mrem/yr)/(μCi/m³)]
1.11	Conversion Constant (rads in air to rem in tissue)	[mrem/mrad]

All other terms have been previously defined.

Application

The skin dose is calculated for reference only.

A.1.3 Dose Rate Due to Noble Gas Radionuclides

A.1.3.1 Total Body Dose Rate

Requirement
RETS limit the total body dose rate due to noble gases in gaseous effluents released from a site to areas at and beyond the site boundary to less than or equal to 500 mrem/yr at all times. (see Section 12.4 of each station's RETS and Technical Specifications)

Equation
The total body dose rate due to noble gases released in gaseous effluents is calculated by the following expression:

$$\dot{D}_{TB} = \sum_i K_i \left\{ (\chi/Q)_s^\gamma Q_{is} + (\chi/Q)_v^\gamma Q_{iv} + (\chi/Q)_g^\gamma Q_{ig} \right\} \qquad \textbf{(A-5)}$$

The summation is over noble gas radionuclides **i**.

$\dot{D}_{TB}$	Total Body Dose Rate Dose rate to the total body due to gamma radiation from noble gas radionuclides released in gaseous effluents.	[mrem/yr]
Q_{is}, Q_{iv}, Q_{ig}	Release Rate Measured release rate of radionuclide **i** from a stack, vent or ground level release point, respectively.	[μCi/sec]

All other terms have been previously defined.

Application

RETS require the dose rate due to noble gases in gaseous effluents be determined to be within the above limit in accordance with methodology specified in the ODCM (see Section 12.4 of each station's RETS and Technical Specifications).

To comply with this specification, each station uses an effluent radiation monitor setpoint corresponding to an offsite total body dose rate at or below the limit (see Chapter 10). In addition, each station assesses compliance by calculating offsite total body dose rate on the basis of periodic samples obtained in accordance with station procedures.

A.1.3.2 Skin Dose Rate

Requirement
RETS limit the skin dose rate due to noble gases in gaseous effluents released from a site to areas at and beyond the site boundary to less than or equal to a dose rate of 3000 mrem/yr at all times. (See Section 12.4 of each station's RETS and/or Technical Specifications)

Equation
The skin dose rate due to noble gases released in gaseous effluents is calculated by the following expression:

$$\begin{aligned}\dot{D}_{SK} = \sum_i \Big\{ & L_i \left[(\chi/Q)_s Q_{is} + (\chi/Q)_v Q_{iv} + (\chi/Q)_g Q_{ig} \right] \\ & + (1.11)\, M_i \left[(\chi/Q)_s^\gamma Q_{is} + (\chi/Q)_v^\gamma Q_{iv} + (\chi/Q)_g^\gamma Q_{ig} \right] \Big\}\end{aligned} \qquad \textbf{(A-6)}$$

The summation is over noble gas radionuclides **i**.

$\dot{D}_{SK}$	Skin Dose Rate	[mrem/yr]
	Dose rate to skin due to beta and gamma radiation from noble gas radionuclides released in gaseous effluents.	
Q_{is}, Q_{iv}, Q_{ig}	Release Rate	[μCi/sec]
	Measured release rate of radionuclide **i** from a stack, vent or ground level release point, respectively.	

All other terms been previously defined.

Application
RETS require the dose rate due to noble gases in gaseous effluents to be determined to be within the above limit in accordance with methodology specified in the ODCM. (See Section 12.4 of each station's RETS and Technical Specifications.)

To comply with this specification, each station uses an effluent radiation monitor setpoint corresponding to an offsite skin dose rate at or below the limit (see Chapter 10). In addition, each station assesses compliance by calculating offsite skin dose rate on the basis of samples obtained periodically in accordance with station procedures.

A.1.4 Dose Due to Non-Noble Gas Radionuclides

Requirement

RETS provide the following limits, based on 10CFR50 Appendix I, on the dose to a member of the public from specified non-noble gas radionuclides in gaseous effluents released from each reactor unit to areas at and beyond the unrestricted area boundary:

- Less than or equal to 7.5 mrem to any organ during any calendar quarter.
- Less than or equal to 15 mrem to any organ during any calendar year.

The individual dose components are also required as part of the 40CFR190 assessments and combined as part of the 10CFR20 assessment (See Section A.4). The dose due to radionuclides deposited on the ground is considered to be a component of the deep dose equivalent for 10CFR20 compliance and an organ (and total body) dose component for 10CFR50 Appendix I and 40CFR190 compliance.

In accordance with the definition of dose in Regulatory Guide 1.109, the term "dose" in this document when applied to individuals, is used instead of the more precise term "dose equivalent," as defined by the International Commission on Radiological Units and Measurements (ICRU). When applied to the evaluation of internal deposition of radioactivity, the term "dose" as used here, includes the prospective dose component arising from retention in the body beyond the period of environmental exposure, i.e., the dose commitment. The dose commitment is evaluated over a period of 50 years. Assessments for 10CFR50 Appendix I compliance are made for 4 age groups (adult/teenager/child/infant) using Regulatory Guide 1.109 (Reference 6) dose conversion factors.

Equation

The dose is calculated for releases in the time period under consideration.

Specifically, the dose is calculated as follows:

$$\mathbf{D_{aj}^{NNG} = (3.17E-8)\sum_{p}\sum_{i}\left[W_s R_{aipj} A_{is} + W_v R_{aipj} A_{iv} + W_g R_{aipj} A_{ig}\right]} \qquad \textbf{(A-7)}$$

The summation is over pathways **p** and non-noble gas radionuclides **i**.

$\mathbf{D_{aj}^{NNG}}$	Dose Due to Non-Noble Gas Radionuclides Dose due to non-noble gases (radioiodines, tritium and particulates) to age group **a**, and to organ **j**.	[mrem]
3.17E-8	Conversion Constant (seconds to years)	[yr/sec]
$\mathbf{W_s, W_v, W_g}$	Relative Concentration Factor Radioactive concentration at a specific location per unit of radioactivity release rate or concentration for stack, vent or ground level release, respectively. W_s, W_v, or W_g = $(\chi/Q)_s$, $(\chi/Q)_v$ or $(\chi/Q)_g$ for immersion, inhalation and all tritium pathways. W_s, W_v, or W_g = $(D/Q)_s$, $(D/Q)_v$ or $(D/Q)_g$ for ground plain and all ingestion pathways.	
$\mathbf{(\chi/Q)_s, (\chi/Q)_v, (\chi/Q)_g}$	Relative Concentration Factor	[sec/m^3]

Radioactivity concentration based on semi-infinite cloud model at a specified location per unit of radioactivity release rate for a stack, vent, or ground level release, respectively. See Section 4.1.6, Section B.3 of Appendix B, and Table F-5 of Appendix F.

$(D/Q)_s$, $(D/Q)_v$, $(D/Q)_g$ Relative Deposition Factor [$1/m^2$]

Radioactivity concentration at a specified location per unit of radioactivity release concentration for a stack, vent, or ground level release, respectively. See Section 4.1.6, Section B.3 of Appendix B, and Table F-6 of Appendix F.

R_{aipj} Site-Specific Dose Factor [(m^2 mrem/yr)/(μCi/sec)] or [(mrem/yr)/($\mu Ci/m^3$)]

Site-specific dose factor for age group **a**, nuclide **i**, pathway **p** and organ **j**. Pathway included are ground plane exposure, inhalation, vegetation ingestion, milk ingestion and meat ingestion. Values of R_{aipj} are provided in Appendix F.

A_{is}, A_{iv}, A_{ig} Cumulative Radionuclide Release [μCi]

Measured cumulative release of radionuclide **i** over the time period of interest from a stack, vent, or ground level release point, respectively.

Application
RETS require cumulative and projected dose contributions for the current calendar quarter and the current calendar year for the specified non-noble gas radionuclides in airborne effluents to be determined at least once per 31 days (see Section 12.4 of each station's RETS and Technical Specifications).

To comply with this specification, each nuclear power station obtains and analyzes samples in accordance with the radioactive gaseous waste or gaseous effluent sampling and analysis program in its RETS. In accordance with NUREG 0133 (Reference 14), dose due to non-noble gases is assessed at the location in the unrestricted area where the combination of existing pathways and receptor age groups indicates the maximum potential exposure. The inhalation and ground plane exposure pathways are considered to exist at all locations. The food ingestion pathways at a specific location are considered based on their existence as determined by land use census. The values used for (χ/Q) and (D/Q) correspond to the applicable pathway location.

For a release attributable to a processing or effluent system shared by more than one reactor, the dose due to an individual unit is obtained by proportioning the effluents among the units sharing the system. The allocation procedure is specified in ODCM Chapter 10.

The dose evaluated is also included as part of the 10CFR20 and 40CFR190 assessment (See Section A.4).

A.1.4.1 Ground Deposition

The site-specific dose factor for ground deposition of radioactivity is considered to be a total body dose component and is calculated by the following expression:

$$R_{ai(GP)j}[D/Q] = K'K''(0.7)DFG_i\left[\frac{1-e^{-\lambda_i t_b}}{\lambda_i}\right] \qquad \textbf{(A-8)}$$

$R_{ai(GP)j}[D/Q]$	Ground Plane Deposition Dose Factor	[(m^2 mrem/yr)/(μCi/sec)]
	Site-specific ground plane dose factor for age group **a**, nuclide **i** and organ **j**. The ground plane dose is calculated using (D/Q).	
K'	Conversion Constant (1E6 pCi per μCi)	[pCi/μCi]
K"	Conversion Constant (8760 hr/yr)	[hr/yr]
0.7	Shielding Factor; a factor which accounts for shielding due to occupancy of structures.	dimensionless
DFG_i	Ground Plane Dose Conversion Factor	[(mrem/hr)/(pCi/m^2)]
	Dose rate to the total body per unit of surface radioactivity concentration due to standing on ground uniformly contaminated with radionuclide **i**. Taken from Table C-10 of Appendix C.	
	Note that ground plane dose factors are only given for the total body and no age group. Doses to other organs are assumed to be equal to the total body dose. All age groups are assumed to receive the same dose.	
λ_i	Radiological Decay Constant	[hr^{-1}]
	Radiological decay constant for radionuclide **i**. See Table C-7 of Appendix C.	
t_b	Time Period of Ground Deposition	[hr]
	Time period during which the radioactivity on the ground is assumed to have been deposited. See Table C-1 of Appendix C.	

Application
The ground plane exposure pathway is considered to exist at all locations.

A.1.4.2 Inhalation

The site-specific dose factor for inhalation is calculated by the following expression:

$$R_{ai(Inhal)j}[\chi/Q] = K'BR_aDFA_{aij} \qquad \textbf{(A-9)}$$

$R_{ai(Inhal)j}[\chi/Q]$	Inhalation Pathway Dose Factor	[(mrem/yr)/(μCi/m^3)]
	Site-specific inhalation dose factor for age group **a**, nuclide **i** and organ **j**. The inhalation dose is calculated using (χ/Q).	
K'	Conversion Constant (1E6 pCi per μCi)	[pCi/μCi]
BR_a	Individual Air Inhalation Rate	[m^3/yr]
	The air intake rate for individuals in age group **a**. See Table C-2 of Appendix C.	
DFA_{aij}	Inhalation Dose Conversion Factor	[mrem/pCi]

Dose commitment to an individual in age group **a** to organ **j** per unit of activity of radionuclide **i** inhaled. Taken from Tables E-7 through E-10 of Regulatory Guide 1.109. The value for H-3 is taken from NUREG 4013 (Reference 107).

Application
The inhalation exposure pathway is considered to exist at all locations.

A.1.4.3 Food Ingestion Pathway Dose Factors

Application
Food ingestion pathway doses are calculated at locations indicated by the land use census survey. If no real pathway exists within 5 miles of the station, the cow-milk pathway is assumed to be located at 5 miles. Food pathway calculations are not made for sectors in which the offsite regions near the station are over bodies of water.

A.1.4.3.1 Vegetation Ingestion Pathway Dose Factor
The dose factor for consumption of vegetables is calculated by the following expression:

$$R_{ai(Veg)j}[D/Q] = K'\left[\frac{(r)}{Y_v(\lambda_i + \lambda_w)}\right](DFL_{aij})\left[U_a^L f_L e^{-\lambda_i t_L} + U_a^S f_g e^{-\lambda_i t_h}\right] \quad \textbf{(A-10)}$$

$R_{ai(Veg)j}[D/Q]$ — Vegetation Ingestion Pathway Dose Factor [(m^2 mrem/yr)/(μCi/sec)]

Site-specific vegetation ingestion dose factor for age group **a**, nuclide **i** and organ **j**. With the exception of H-3, the vegetation dose is calculated using (D/Q).

K' — Conversion Constant (1E6 pCi per μCi) [pCi/μCi]

r — Vegetation Retention Factor — dimensionless

Y_v — Agricultural Productivity Yield [kg/ m^2]

λ_i — Radiological Decay Constant [1/sec]

Radiological decay constant for radionuclide **i**. See Table C-7 of Appendix C.

λ_w — Weathering Decay Constant [1/sec]

Removal constant for physical loss of activity by weathering. See Table C-1 of Appendix C.

DFL_{aij} — Ingestion Dose Conversion Factor [mrem/pCi]

Ingestion dose conversion factor for age group **a**, nuclide **i** and organ **j**. Converts pCi ingested to mrem. Taken from Tables E-11 though E-14 of Regulatory Guide 1.109. The value for H-3 is taken from NUREG 4013 (Reference 107).

U_a^L — Consumption Rate for Fresh Leafy Vegetation [kg/yr]

Consumption rate for fresh leafy vegetation for age group **a**.

U_a^S	Consumption Rate for Stored Vegetation	[kg/yr]
	Consumption rate for stored vegetation for age group **a**.	
f_L	Local Leafy Vegetation Fraction	dimensionless
	Fraction of the annual intake of fresh leafy vegetation which is grown locally.	
f_g	Local Stored Vegetation Fraction	dimensionless
	Fraction of the annual intake of stored vegetation which is grown locally.	
t_L	Environmental Transport Time - Fresh Vegetation	[sec]
	Average time between harvest of leafy vegetation and its consumption.	
t_h	Environmental Transport Time - Stored Vegetation	[sec]
	Average time between harvest of stored vegetation and its consumption.	

The tritium dose from the vegetation pathway must be considered separately as the transport mechanism is based on airborne concentration rather than ground deposition. The dose factor for the tritium vegetation pathway is:

$$\mathbf{R}_{a(H-3)(Veg)j}[\chi/Q] = \mathbf{K'K'''}\left(\mathbf{U}_a^L\mathbf{f}_L + \mathbf{U}_a^S\mathbf{f}_g\right)\mathbf{DFL}_{a(H-3)j}[0.75(0.5/H)] \qquad \textbf{(A-11)}$$

$R_{a(H-3)(Veg)j}[\chi/Q]$	Tritium Vegetation Ingestion Pathway Dose Factor	[(mrem/yr)/(μCi/m^3)]
	Site-specific tritium vegetation ingestion dose factor for age group **a** and organ **j**. The tritium vegetation dose is calculated using χ/Q.	
K'''	Conversion Constant (1E3 gm per Kg)	[gm/Kg]
H	Absolute Atmospheric Humidity	[gm/m^3]
0.75	Water Fraction	dimensionless
	The fraction of total vegetation that is water.	
0.5	Specific Activity Ratio	dimensionless

A.1.4.3.2 Milk Ingestion Pathway Dose Factor

The dose factor for consumption of milk is calculated by the following expressions:

$$R_{ai(Milk)j}[D/Q] = K' \frac{Q_F(U_{am})}{\lambda_i + \lambda_w} F_m(r)(DFL_{aij}) \left[\frac{f_p f_s}{Y_p} + \frac{(1 - f_p f_s) e^{-\lambda_i t_h}}{Y_s} \right] e^{-\lambda_i t_f} \tag{A-12}$$

$R_{ai(Milk)j}[D/Q]$	Milk Ingestion Pathway Dose Factor	[(m^2 mrem/yr)/(μCi/sec)]
	Site-specific milk ingestion dose factor for age group **a**, nuclide **i** and organ **j**. With the exception of H-3, the milk dose factor is calculated using (D/Q).	
K'	Conversion Constant (1E6 pCi per μCi)	[pCi/μCi]
Q_F	Feed Consumption	[Kg/da]
	Amount of feed consumed by milk animal each day. See Table C-1 of Appendix C.	
U_{am}	Milk Consumption Rate	[l/yr]
	Milk consumption rate for age group **a**.	
F_m	Stable Element Transfer Coefficient for Milk	[da/l]
	Fraction of animal's daily intake of a particular chemical element which appears in each liter of milk (pCi/l in milk per pCi/da ingested by animal). See Table C-3 of Appendix C.	
f_p	Pasture Time Fraction	dimensionless
	Fraction of year that animal is on pasture.	
f_s	Pasture Grass Fraction	dimensionless
	Fraction of animal feed that is pasture grass while animal is on pasture.	
Y_P	Agricultural Productivity Yield - Pasture Grass	[kg/m^2]
	The agricultural productivity by unit area of pasture feed grass.	
Y_S	Agricultural Productivity Yield - Stored Feed	[kg/m^2]
	The agricultural productivity by unit area of stored feed.	
t_h	Environmental Transport Time - Stored Feed	[sec]
	Average time between harvest to consumption of stored feed by milk animal.	
t_f	Environmental Transport Time - Pasture to Consumption	[sec]
	Average time from pasture, to milk animal, to milk, to consumption.	

All other terms have been previously defined.

The tritium dose from the milk pathway must be considered separately as the transport mechanism is based on airborne concentration rather than ground deposition. The dose factor for the tritium milk pathway is:

$$R_{a(H-3)(Milk)j}[\chi/Q] = K'K'''F_m\,Q_F U_{am} DFL_{a(H-3)j}[0.75(0.5/H)] \quad \textbf{(A-13)}$$

$R_{a(H-3)(Milk)j}[\chi/Q]$	Tritium Milk Ingestion Pathway Dose Factor	[(mrem/yr)/(μCi/m^3)]
	Site-specific tritium milk ingestion dose factor for age group **a** and organ **j**. The tritium milk dose is calculated using χ/Q.	
K'''	Conversion Constant (1E3 gm per Kg)	[gm/Kg]
H	Absolute Atmospheric Humidity	[gm/m^3]
0.75	Water Fraction	dimensionless
	The fraction of total vegetation that is water.	
0.5	Specific Activity Ratio	dimensionless

All other terms have been previously defined.

A.1.4.3.3 Meat

The dose factor for consumption of meat is calculated by the following expression:

$$R_{ai(Meat)j}[D/Q] = K'\frac{Q_F(U_{af})}{\lambda_i + \lambda_w}F_f(r)(DFL_{aij})\left[\frac{f_p f_s}{Y_p} + \frac{(1 - f_p f_s)e^{-\lambda_i t_h}}{Y_s}\right]e^{-\lambda_i t_f} \quad \textbf{(A-14)}$$

$R_{ai(Meat)j}[D/Q]$	Meat Ingestion Pathway Dose Factor	[(m^2 mrem/yr)/(μCi/sec)]
	Site-specific meat ingestion dose factor for age group **a**, nuclide **i** and organ **j**. With the exception of H-3, the meat dose factor is calculated using (D/Q).	
U_{af}	Meat Consumption Rate	[l/yr]
	Meat consumption rate for age group **a**.	
F_f	Stable Element Transfer Coefficient for Meat	[da/Kg]
	Fraction of animal's daily intake of a particular chemical element which appears in each liter of meat (pCi/Kg in meat per pCi/da ingested by animal). See Table C-3 of Appendix C.	
t_h	Environmental Transport Time - Stored Feed	[sec]
	Average time between harvest to consumption of stored feed by meat animal.	
t_f	Environmental Transport Time - Pasture to Consumption	[sec]

Average time from pasture, to meat animal, to meat, to consumption.

All other terms have been previously defined.

The tritium dose from the meat pathway must be considered separately as the transport mechanism is based on airborne concentration rather than ground deposition. The dose factor for the tritium meat pathway is:

$$R_{a(H-3)(Meat)j}[\chi/Q] = K'K'''F_f\, Q_F U_{af} DFL_{a(H-3)j}[0.75(0.5/H)] \qquad \textbf{(A-15)}$$

$R_{a(H-3)(Meat)j}[\chi/Q]$	Tritium Meat Ingestion Pathway Dose Factor	[(mrem/yr)/(μCi/m^3)]
	Site-specific tritium meat ingestion dose factor for age group **a** and organ **j**. The tritium meat dose is calculated using χ/Q.	
K'''	Conversion Constant (1E3 gm per Kg)	[gm/Kg]
H	Absolute Atmospheric Humidity	[gm/m^3]
0.75	Water Fraction	dimensionless
	The fraction of total vegetation that is water.	
0.5	Specific Activity Ratio	dimensionless

All other terms have been previously defined.

A.1.5 Dose Rate Due to Non-Noble Gas Radionuclides

Requirement
RETS limit the dose rate to any organ, due to radioactive materials in gaseous effluents released from a site to areas at and beyond the site boundary, to less than or equal to a dose rate of 1500 mrem/yr (see Section 12.4 of each station's RETS and Technical Specifications).

Typically the child is considered to be the limiting receptor in calculating dose rate to organs due to inhalation of non-noble gas radionuclides in gaseous effluents.

Equation
The dose rate to any child organ due to inhalation is calculated by the following expression:

$$\dot{D}^{NNG}_{(Child)i(Inhal)j} = \sum_i R_{(Child)i(Inhal)j}\{(\chi/Q)_s Q_{is} + (\chi/Q)_v Q_{iv} + (\chi/Q)_g Q_{ig}\} \qquad \textbf{(A-16)}$$

The summation is over non-noble gas radionuclides **i**.

$\dot{D}^{NNG}_{(Child)i(Inhal)j}$	Inhalation Dose Rate	[mrem/yr]
	Dose rate to the child age group from radionuclide **i**, via the inhalation pathway to organ **j** due to non-noble gas radionuclides.	
$R_{(Child)i(Inhal)j}$	Inhalation Dose Factor	[(mrem/yr)/(μCi/m^3)]

Inhalation dose factor for child age group for radionuclide **i**, and organ **j**. This dose factor is defined by Equation A-9.

Q_{is}, Q_{iv}, Q_{ig}	Radionuclide Release Rate	[μCi/sec]
	Measured release rate of radionuclide **i** from a stack, vent, or ground level release point, respectively.	

All other terms have been previously defined.

Application
RETS require the dose rate due to non-noble gas radioactive materials in airborne effluents be determined to be within the above limit in accordance with a sampling and analysis program specified in the RETS (see Section 12.4 of each station's RETS and Technical Specifications).

To comply with this specification, each station obtains and analyzes samples in accordance with the sampling and analysis program in its RETS. The child organ dose rate due to inhalation is calculated in each sector at the location of the highest offsite χ/Q. The result for the sector with the highest organ inhalation dose rate is compared to the limit.

A.1.6 Operability and Use of Gaseous Effluent Treatment Systems

Requirement
10CFR50 Appendix I and the station RETS require that the ventilation exhaust treatment system and the waste gas holdup system be used when projected offsite doses in 31 days, due to gaseous effluent releases, from each reactor unit, exceed any of the following limits:

- 0.2 mrad to air from gamma radiation.
- 0.4 mrad to air from beta radiation.
- 0.3 mrem to any organ of a member of the public.

The nuclear power stations are required to project doses due to gaseous releases from the site at least once per 31 days.

Equation
Offsite doses due to projected releases of radioactive materials in gaseous effluents are calculated using Equations A-1, A-2 and A-7. Projected cumulative radionuclide releases are used in place of measured cumulative releases A_{is}, A_{iv} and A_{ig}.

Application

For a release attributable to a processing or effluent system shared by more than one reactor unit, the dose due to an individual unit is obtained by proportioning the effluents among the units sharing the system. The allocation procedure is specified in Chapter 10 of this manual.

A.2 LIQUID RELEASES

A.2.1 Dose

Requirement
The design objectives of 10CFR50, Appendix I and RETS provide the following limits on the dose to a member of the public from radioactive materials in liquid effluents released from each reactor unit to restricted area boundaries:

- During any calendar quarter, less than or equal to 1.5 mrem to the total body and less than or equal to 5 mrem to any organ.
- During any calendar year, less than or equal to 3 mrem to the total body and less than or equal to 10 mrem to any organ.

The organ doses due to radioactivity in liquid effluents are also used as part of the 40CFR190 compliance and are included in the combination of doses to determine the total dose used to demonstrate 10CFR20 compliance. (See Section A.4)

Dose assessments for 10CFR50 Appendix I compliance are made for four age groups (adult/teenager/child/infant) using NUREG 0133 (Reference 14) methodology and Regulatory Guide 1.109 (Reference 6) dose conversion factors.

Equation
The dose from radioactive materials in liquid effluents considers the contributions for consumption of fish and potable water. All of these pathways are considered in the dose assessment unless demonstrated not to be present. While the adult is normally considered the maximum individual, the methodology provides for dose to be calculated for all four age groups. The dose to each organ (and to the total body) is calculated by the following expression:

$$\mathbf{D_{aj}^{Liq} = F\ \Delta t \sum_{p}\sum_{i} A_{aipj} C_i} \qquad \textbf{(A-17)}$$

The summation is over exposure pathways **p** and radionuclides **i**.

$\mathbf{D_{aj}^{Liq}}$	Organ and Total Body Dose Due to Liquid Effluents Dose to organ **j** (including total body) of age group **a** due to radioactivity in liquid effluents.	[mrem]
F	Near Field Average Dilution Factor Dilution in the near field averaged over the period of interest. Defined as:	dimensionless

$$\mathbf{F = \frac{Waste\ Flow}{Dilution\ Flow \times Z}} \qquad \textbf{(A-18)}$$

Waste Flow	Liquid Radioactive Waste Flow The average flow during disposal from the discharge structure release point into the receiving water body.	[gpm]
Dilution Flow	Dilution Water Flow During Period of Interest	[gpm]
Z	Discharge Structure Mixing Factor	dimensionless

Site-specific factor to account for the mixing effect of the discharge structure. The factor addresses the dilution which occurs in the near field between the discharge structure and the body of water containing the fish in the liquid ingestion pathway. From Table F-1, Appendix F.

Δt Duration of Release [hrs]

C_i Average Radionuclide Concentration [μCi/ml]

Average concentration of radionuclide **i**, in the undiluted liquid effluent during time period Δt.

A_{aipj} Site-Specific Liquid Dose Factor [(mrem/hr)/(μCi/ml)]

Site-specific dose factor for age group **a**, nuclide **i**, liquid pathway **p** and organ **j**. The pathways included are potable water and fish ingestion. A_{aipj} is defined for these pathways in the following sections. Values for A_{aipj} are provided in Appendix F.

A 2.1.1 Potable Water Pathway

The site-specific potable water pathway dose factor is calculated by the following expression:

$$A_{ai(PW)j} = k_o \left\{ \frac{U_a^w}{D^w} \right\} DFL_{aij} \qquad \textbf{(A-19)}$$

Where:

$A_{ai(PW)j}$ Site-Specific Dose Factor for Potable Water Pathway [(mrem/hr)/(μCi/ml)]

Site-specific potable water ingestion dose factor for age group **a**, nuclide **i** and organ **j**.

k_o Conversion Constant (1.14E05) [(yr-pCi-ml)/(hr-μCi-l)]

Units constant to convert years to hours, pCi to μCi and liters to ml.

U_a^w Potable Water Consumption Rate [l/yr]

Potable water consumption rate for age group **a**. Taken from Table E-5 of Regulatory Guide 1.109.

D^w Potable Water Dilution Factor dimensionless

Dilution factor from the near field area within one-quarter mile of the release point to the potable water intake. From Table F-1, Appendix F.

DFL_{aij} Ingestion Dose Conversion Factor [mrem/pCi]

Ingestion dose conversion factor for age group **a**, nuclide **i** and organ **j**. Converts pCi ingested to mrem. Taken from Tables E-11 though E-14 of Regulatory Guide 1.109. The value for H-3 is taken from NUREG 4013 (Reference 107).

A.2.1.2 Fish Ingestion Pathway

The site-specific fish ingestion pathway dose factor is calculated by the following expression:

$$A_{ai(Fish)j} = k_o U_a^F BF_i DFL_{aij} \qquad \textbf{(A-20)}$$

Where:

$A_{ai(Fish)j}$	Site-Specific Dose Factor for Potable Water Pathway	[(mrem/hr)/(μCi/ml)]
	Site-specific fish ingestion dose factor for age group **a**, nuclide **i** and organ **j**.	
U_a^F	Fish Consumption Rate	[kg/yr]
	Fish consumption rate for age group **a**. Taken from Table E-5 of Regulatory Guide 1.109.	
BF_i	Bioaccumulation Factor	[(pCi/kg)/(pCi/l)]
	Bioaccumulation factor for nuclide **i** in fresh water fish. Taken from Table C-8 of Appendix C.	

All other terms have been previously defined.

Application
RETS require determination of cumulative and projected dose contributions from liquid effluents for the current calendar quarter and the current calendar year at least once per 31 days. (see Section 12.3 of each station's RETS and/or Technical Specifications).

For a release attributable to a processing or effluent system shared by more than one reactor unit, the dose due to an individual unit is obtained by proportioning the effluents among the units sharing the system. The allocation procedure is specified in ODCM Chapter 10.

A.2.2 Liquid Effluent Concentrations Requirement

Requirement
One method of demonstrating compliance to the requirements of 10CFR20.1301 is to demonstrate that the annual average concentrations of radioactive material released in gaseous and liquid effluents do not exceed the values specified in 10CFR20 Appendix B, Table 2, Column 2. (See 10CFR 20.1302(b)(2).) However, as noted in Section A.5.1, this mode of 10CFR20.1301 compliance has not been elected.

As a means of assuring that annual concentration limits will not be exceeded, and as a matter of policy assuring that doses by the liquid pathway will be ALARA; RETS provides the following restriction:

"The concentration of radioactive material released in liquid effluents to unrestricted areas shall be limited to ten times the concentration values in Appendix B, Table 2, Column 2 to 10CFR20.1001-20.2402."

This also meets the requirement of Station Technical Specifications and RETS.

Equation

According to the footnotes to 10CFR20 Appendix B, Table 2, Column 2, if a radionuclide mix of known composition is released, the concentrations must be such that

$$\sum_i \left(\frac{C_i}{10\,ECL_i} \right) \leq 1 \qquad \textbf{(A-21)}$$

where the summation is over radionuclide **i**.

C_i Radioactivity Concentration in Liquid Effluents to the Unrestricted Area [μCi/ml]

Concentration of radionuclide **i** in liquid released to the unrestricted area.

ECL_i Effluent Concentration Limit in Liquid Effluents Released to the Unrestricted Area [μCi/ml]

The allowable annual average concentration of radionuclide i in liquid effluents released to the unrestricted area. This concentration is specified in 10CFR20 Appendix B, Table 2; Column 2. Concentrations for noble gases are different and are specified in the stations' Technical Specifications/RETS.

10 Multiplier to meet the requirements of Technical Specifications.

If either the identity or concentration of any radionuclide in the mixture is not known, special rules apply. These are given in the footnotes in 10CFR20 Appendix B, Table 2, Column 2.

Application
The RETS and Technical Specifications require a specified sampling and analysis program to assure that liquid radioactivity concentrations at the point of release are maintained within the required limits.

To comply with this provision, each nuclear power station obtains and analyzes samples in accordance with the radioactive liquid waste (or effluent) sampling and analysis program in its RETS. Radioactivity concentrations in tank effluents are determined in accordance with Equation A-22 in the next section. Comparison with the Effluent Concentration Limit is made using Equation A-21.

A.2.3 Tank Discharges

When radioactivity is released to the unrestricted area with liquid discharge from a tank (e.g., a radwaste discharge tank), the concentration of a radionuclide in the effluent is calculated as follows:

$$C_i = C_i^t \, \frac{\textbf{Waste Flow}}{\textbf{Dilution Flow}} \qquad \textbf{(A-22)}$$

C_i *Concentration in Liquid effluent to the unrestricted area.* [μCi/ml]

Concentration of radionuclide **i** in liquid released to the unrestricted area.

C_i^t Concentration in the Discharge Tank [μCi/ml]

Measured concentration of radionuclide **i** in the discharge tank.

All other terms have been previously defined.

A.2.4 Tank Overflow

Requirement
To limit the consequences of tank overflow, the RETS/Technical Specifications may limit the quantity of radioactivity that may be stored in unprotected outdoor tanks. Unprotected tanks are tanks that are not surrounded by liners, dikes, or walls capable of holding the tank contents and that do not have tank overflows and surrounding area drains connected to the liquid radwaste treatment system. The specific objective is to provide assurance that in the event of an uncontrolled release of a tank's contents, the resulting radioactivity concentrations beyond the unrestricted area boundary, at the nearest potable water supply and at the nearest surface water supply, will be less than the limits of 10CFR20 Appendix B, Table 2; Column 2.

The Technical Specifications and RETS may contain a somewhat similar provision. For most nuclear power stations, specific numerical limits are specified on the number of curies allowed in affected tanks.

Application
Table F-1 of Appendix F provides information on the limits applicable to affected stations. The limits are as stated for some stations in the station Technical Specifications.

A.2.5 *Operability and Use of the Liquid Radwaste Treatment System*

Requirement
The design objectives of 10CFR50, Appendix I and RETS/Technical Specifications require that the liquid radwaste treatment system be operable and that appropriate portions be used to reduce releases of radioactivity when projected doses due to the liquid effluent from each reactor unit to restricted area boundaries exceed either of the following (see Section 12.3 of each station's RETS or Technical Specifications);

- 0.06 mrem to the total body in a 31 day period.
- 0.2 mrem to any organ in a 31 day period.

Equation
Offsite doses due to projected releases of radioactive materials in liquid effluents are calculated using Equation A-17. Projected radionuclide release concentrations are used in place of measured concentrations, C_i.

A.2.6 Drinking Water

Five nuclear power stations (Braidwood, Dresden, LaSalle, Quad Cities, and Zion) have requirements for calculation of drinking water dose that are related to 40CFR141, the Environmental Protection Agency National Primary Drinking Water Regulations. These are discussed in Section A.6.

A.2.7 Non-routine Liquid Release Pathways

Cases in which normally non-radioactive liquid streams (such as the Service Water) are found to contain radioactive material are non-routine will be treated on a case specific basis if and when this occurs. Since each station has sufficient capacity to delay a liquid release for reasonable periods of time, it is expected that planned releases will not take place under these circumstances. Therefore, the liquid release setpoint calculations need not and do not contain provisions for treating multiple simultaneous release pathways.

A.3 DOSE DUE TO CONTAINED SOURCES

There are presently two types of contained sources of radioactivity which are of concern in Exelon Nuclear offsite radiological dose assessments. The first source is that due to gamma rays from nitrogen-16 (^{16}N) carried over to the turbine in BWR (boiling water reactor) steam. The second source is that due to gamma rays associated with radioactive material resident in onsite radwaste storage facilities. Gamma radiation from these sources contributes to the total body dose.

A.3.1 BWR Skyshine

The contained onsite radioactivity source which results in the most significant offsite radiation levels at Exelon Nuclear nuclear power stations is skyshine resulting from ^{16}N decay inside turbines and steam piping at boiling water reactor (BWRs).

The ^{16}N that produces the skyshine effect is formulated through neutron activation of the oxygen atoms (oxygen-16, or ^{16}O) in reactor coolant as the coolant passes through the operating reactor core. The ^{16}N travels with the steam produced in the reactor to the steam driven turbine. While the ^{16}N is in transport, it radioactively decays with a half-life of about 7 seconds and produces 6 to 7 MeV gamma rays. Typically, offsite dose points are shielded from a direct view of components containing ^{16}N, but there can be skyshine radiation at offsite locations due to scattering of gamma rays off the mass of air above the steamlines and turbine.

The offsite dose rate due to skyshine has been found to have the following dependencies:

- The dose rate decreases as distance from the station increases.
- The dose rate increases non-linearly as the power production level increases.
- The dose rate increases when hydrogen is added to the reactor coolant, an action taken to improve reactor coolant chemistry characteristics (see Reference 39).

To calculate offsite dose due to skyshine in a given time period, a BWR must track the following parameters:

- The total gross energy E_h produced with hydrogen being added.
- The total gross energy E_o produced without hydrogen being added.

The turbines at BWR sites are sufficiently close to each other that energy generated by the two units at each site may be summed.

An initial estimate of BWR skyshine dose is calculated per the following equation:

$$D^{Sky} = (K)(E_o + M_h E_h)\sum_k \left\{OF_k \, SF_k \, e^{-0.007R_k}\right\} \qquad \textbf{(A-23)}$$

The summation is over all locations **k** occupied by a hypothetical maximally exposed member of the public characterized by the parameters specified in Table F-8 of Appendix F of the Dresden, LaSalle, and Quad Cities ODCMs. The parameters in Equation A-23 are defined as follows:

D^{Sky}	Dose Due to N-16 Skyshine	[mrem]
	External direct gamma dose due to BWR N-16 skyshine for the time period of interest.	
K	Empirical Constant	[mrem/(MWe-hr)]
	A constant determined by fitting data measured at each station.	
E_o	Electrical Energy Generated Without Hydrogen Addition	[MWe-hr]
	Total gross electrical energy generated without hydrogen addition in the time period of interest.	
E_h	Electrical Energy Generated with Hydrogen Addition	[MWe-hr]
	Total gross electrical energy generated with hydrogen addition in the period of interest.	
M_h	Multiplication Factor for Hydrogen Addition	dimensionless
	Factor applied to offsite dose rate when skyshine is present. Hydrogen addition increases main steam line radiation levels typically up to a factor of approximately 5 (see Page 8-1 of Reference 39). M_h is station specific and is given in Table F-8, Appendix F of Dresden, LaSalle and Quad Cities ODCMs.	
OF_k	Occupancy Factor	dimensionless
	The fraction of time that the dose recipient spends at location **k** during the period of interest. See Table F-8, Appendix F of Dresden, LaSalle and Quad Cities ODCMs.	
SF_k	Shielding Factor	dimensionless
	A dimensionless factor that accounts for shielding due to occupancy of structures. SF_k = 0.7 if there is a structure at location **k**; SF_k = 1.0 otherwise. See Table F-8, Appendix F of Dresden, LaSalle and Quad Cities ODCMs.	
0.007	Empirical Constant	[m^{-1}]
	A constant determined by fitting data measured at the Dresden station (see Reference 45).	
R_k	Distance	[m]
	Distance from the turbine to location **k**. See Table F-8, Appendix F of Dresden, LaSalle and Quad Cities ODCMs.	

A.3.2 Dose from Onsite Radwaste Storage Facilities

Low-level radioactive waste may be stored at any, or all Exelon Nuclear nuclear power stations in the following types of storage facilities:

- Interim Radwaste Storage Facility (IRSF)
- Concrete vaults containing 48 radwaste liners (48-Pack)
- Dry Active Waste (DAW) facilities
- Butler buildings/warehouses
- Steam generator storage facilities
- Independent Spent Fuel Storage Installation (ISFSI) facilities

The "48-Pack" is a shielded concrete vault which is designed to hold three tiers of radwaste liners in a four by four array. The outer shell of the "48-Pack" is a three-foot thick concrete wall and a two and one-half foot thick concrete cover slab. The vault is placed on a poured concrete slab. The liners may have an average surface dose rate of fifteen (15) rem per hour (or up to 380 rem/hr if a 50.59 evaluation has been completed).

The DAW facility will contain low-level radioactive waste that would result in dose rates less than the 10CFR20 requirements.

The dose rates resulting from these radwaste and spent fuel storage facilities will be monitored frequently as they are being utilized, and if necessary, a dose calculation model similar to that of Equation A-23 will be developed and placed in the ODCM.

A.4 Total Dose Limits (10CFR20, 10CFR72 and 40CFR190)

The regulatory requirements of 10CFR20, 10CFR72 and 40CFR190 each limit total dose to individual members of the public without regard to specific pathways. The only significant exposure pathways for light water reactors included in 10CFR20, 10CFR72 and 40CFR190 not addressed by 10CFR50 Appendix I are the direct radiation pathway and exposure from on-site activity by members of the public. Sections A.1 and A.2 considered organ doses from the gaseous and liquid effluent streams for purposes of compliance with 10CFR50 Appendix I. Section A.3 addresses the direct radiation component that must be considered for 10CFR20, 10CFR72 and 40CFR190 compliance. The following sections will describe the methodology of assessing direct radiation dose and then the manner in which the various doses are combined to obtain the appropriate "total" for regulatory compliance purposes.

Although annual dose limits in 10CFR20 are now expressed in terms of Total Effective Dose Equivalent (TEDE) 40CFR190 limits are still stated as organ dose. The NRC continues to require 10CFR50 Appendix I, 10CFR72 and 40CFR190 doses to be reported in terms of organ dose. Due to the fact that organ dose limits set forth in 40CFR190 are substantially lower than those of 10CFR20 (25 mrem/yr vs 100 mrem/yr), the NRC has stated that demonstration of compliance with the dose limits in 40CFR190 will be deemed as demonstration of compliance with the dose limits of 10CFR20 for most facilities (Reference 104). In addition to compliance with 40CFR190 it may be necessary for a nuclear power plant to address dose from on-site activity by members of the public.

A.4.1 External Total Body Dose

The external total body dose is comprised of the following parts:

1) Total body dose due to noble gas radionuclides in gaseous effluents (Section A.1.2),
2) Dose due to N-16 skyshine, ISFSI and other contained sources (Sections A.3.1 and A.3.2) and
3) Total body dose due to radioactivity deposited on the ground (Section A.1.4.1).

The external total body dose due to radioactivity deposited on the ground is accounted for in the determination of the non-noble gas dose (See Equations A-7 and A-8) and is not considered here.

The total external total body dose, D^{Ex}, is given by:

$$D^{Ex} = D^{TB} + D^{Sky} + D^{OSF} \quad \textbf{(A-24)}$$

D^{Ex}	Total External Total Body Dose	[mrem]
	Total external total body dose due to irradiation by external sources at the location of interest.	
D^{TB}	Noble Gas Total Body Dose	[mrem]
	External total body dose due to gamma radiation from noble gas radionuclides released in gaseous effluents at the location of interest. See Equation A-3.	
D^{Sky}	N-16 Skyshine Total Body Dose	[mrem]
	External total body dose due to N-16 skyshine for the period and location of interest. See Equation A-23.	
D^{OSF}	Dose From On-Site Storage Facilities	[mrem]
	External total body dose due to gamma radiation from on-site storage facilities at the location of interest. See Section A.3.2.	

A.4.2 Total Dose

The total dose, D^{Tot}, in the unrestricted area to a member of the public due to plant operations is given by:

$$D^{Tot} = D^{Ex} + D_{aj}^{Liq} + D_{aj}^{NNG} \quad \textbf{(A-25)}$$

where:

D^{Tot}	Total Dose To Member of Public	[mrem]
	Total off-site dose to a member of public due to plant operations.	
D^{Ex}	Total External Total Body Dose	[mrem]
	Total body dose due to external exposure to noble gases, N-16 skyshine and on-site storage facilities.	
D_{aj}^{Liq}	Liquid Effluent Dose	[mrem]
	Dose due to liquid effluents to age group **a** and organ **j**. The age group and organ with the highest dose from liquid effluents is used.	
D_{aj}^{NNG}	Non-Noble Gaseous Effluent Dose	[mrem]
	Dose due to non-noble gaseous effluents to age group **a** and organ **j**. The age group and organ with the highest dose from non-noble gas effluents is used.	

A.5 COMPLIANCE TO TOTAL DOSE LIMITS

A.5.1 Total Effective Dose Equivalent Limit - 10CFR20 Compliance

Requirement
Each station's RETS limits the Total Effective Dose Equivalent (TEDE) to an annual limit of 100 mrem, as required by 10CFR20.1301 (a)(1). Demonstration of compliance with the limits of 40CFR190 (per Section 4.5.2) will be considered to demonstrate compliance with the 100 mrem/year limit.

A.5.1.1 Dose to a Member of the Public in the Unrestricted Area

The NRC has stated that demonstration of compliance with the limits of 40CFR190 or with the design objectives of Appendix I to 10CFR50 will be deemed to demonstrate compliance with the limits of 10CFR20.1301(a)(1). Power reactors that comply with Appendix I may also have to demonstrate that they are within the 25 mrem limit of 40CFR190 (See Reference 104). Zion Station ISFSI pad operations are required to demonstrate compliance with 10CFR72.104 limits.

A.5.1.2. Dose to a Member of the Public in the Restricted Area

In August of 1995, a revision to 10CFR20 was implemented that changed the definition of a member of the public. As a result, for each nuclear station, estimated doses were calculated for a member of the public who enters the site boundary, but is not authorized for unescorted access to the protected area of the site and does not enter any radiologically posted areas on the site. Realistic assumptions were made for occupancy times and locations visited while within the site boundary.

These evaluations indicate that the doses estimated for these members of the public are well within the 10CFR20 limits. These dose evaluations will be performed annually and if necessary, a model will be developed and included in the ODCM.

Application
Evaluation of the 40CFR190 dose is used to demonstrate compliance to 10CFR20, 10CFR72 and satisfy station RETS and Technical Specifications (see Chapter 12).

A.5.2 Total Dose due to the Uranium Fuel Cycle (40CFR190)

Requirement

RETS, 40CFR190 and 10CFR72.104 limit the annual (calendar year) dose or dose commitment to any member of the public due to releases of radioactivity and to radiation from uranium fuel cycle sources to the following:

- Less than or equal to 25 mrem to the total body.
- Less than or equal to 25 mrem to any organ except the thyroid.
- Less than or equal to 75 mrem to the thyroid.

Total Dose Components
This requirement includes the total dose from operations at the nuclear power station. This includes doses due to radioactive effluents (airborne and liquid) and dose due to direct radiation from non-effluent sources (e.g., sources contained in systems on site such as the ISFSI). It also includes dose due to plants under consideration, neighboring plants and dose due to other facilities in the uranium fuel cycle.

The operations comprising the uranium fuel cycle are specified in 40CFR190.02(b). The following are included to the extent that they directly support the production of electrical power for public use utilizing nuclear energy:

- Milling of uranium ore.
- Chemical conversion of uranium.
- Isotopic enrichment of uranium.

- Fabrication of uranium fuel.
- Generation of electricity by a light-watered-cooled nuclear power plant using uranium fuel.
- Reprocessing of spent uranium fuel.

Excluded are:

- Mining operations.
- Operations at waste disposal sites.
- Transportation of any radioactive material in support of these operations.
- The re-use of recovered non-uranium special nuclear and by-product materials from the cycle.

When Compliance Assessment is Required
Compliance with the 40CFR190 regulations is now required as part of demonstration of compliance to 10CFR20 regulations per 10CFR20.1301(d), and 10CFR72 regulations per 10CFR72.104.

Equation

The dose due to the uranium fuel cycle is determined by equation A-25.

A.5.3 Summary of Compliance Methodology

The required compliance is given in Tables 2-1, 2-2 and 2-3. In Table 2-1, the dose components are itemized and referenced, and an indication of their regulatory application is noted. A more detailed compliance matrix is given in Table 2-3. The locations of dose receivers for each dose component are given in Table 2-2.

Further, Table 2-2 states the location of the receiver and occupancy factors, if applicable. In general, the receiver spends time in locations that result in maximum direct dose exposure and inhales and ingests radioactivity from sites that yield maximum pathway doses. Thus, the dose calculated is a very conservative one compared to the "average" receiver who does not go out of his way to maximize radioactivity uptakes. Finally, the connection between regulations, the ODCM equations and the station RETS and Technical Specifications is given in Table 12-0.

ISFSI

10CFR72.104 dose limits are the same as those specified by 40CFR190. ISFSI dose contribution is in the form of direct radiation as no liquid or gas releases are expected to occur. The report prepared in accordance with 10CFR72.212 requirements assumes a certain array of vertical concrete casks exists on the ISFSI. The dose contribution from this array of casks was analyzed to be within the 40CFR190 and 10CFR72.104 limits, and is documented in NAC International Calculation 630073-5501 ZION Site Boundary Skyshine Evaluation and Zion Technical Support Document TSD 13-008 "Evaluation of Independent Spent Fuel Storage Installation and Associated processes Dose Rates" and TSD 13-009 "Member of the Public Dose From All Onsite Sources".

If the dose limits of 40CFR190 or 10CFR72.104 are exceeded, a special report to the NRC as well as an appropriate request for exemption/variance is required to be submitted to the NRC.

The requirement that the dose limits of 10CFR72.104 apply to "any real individual" is controlled for ISFSI activities in the ISFSI 72.212 report. Therefore, for the purposes of analyzing dose from the ISFSI, the member of the public as defined in 40CFR190 is the same as the "real individual" identified in the ES&H TSD 13-008 "Evaluation of Independent Spent Fuel Storage Installation and Associated processes Dose Rates" and TSD 13-009 "Member of the Public Dose From All Onsite Sources".

A.6 DOSE DUE TO DRINKING WATER (40CFR141)

The National Primary Drinking Water Regulations, 40CFR141, contain the requirements of the Environmental Protection Agency applicable to public water systems. Included are limits on radioactivity concentration. Although these regulations are directed at the owners and operators of public water systems, several stations have requirements in their Technical Specifications related to 40CFR141.

A.6.1 40CFR141 Restrictions on Manmade Radionuclides

Section 141.16 states the following (not verbatim):

(a) The average annual concentration of beta particle and photon radioactivity from man-made radionuclides in drinking water shall not produce an annual dose equivalent to the total body or any internal organ greater than 4 millirem/year.

(b) Except for the radionuclides listed in Table A-0, the concentration of man-made radionuclides causing 4 mrem total body or organ dose equivalents shall be calculated on the basis of drinking 2 liter of water per day. (Using the 168 hour data listed in "Maximum Permissible Body Burdens and Maximum Permissible Concentration of Radionuclides in Air or Water for Occupational Exposure, "NBSHandbook 69 as amended August 1963, U.S. Department of Commerce.). If two or more radionuclides are present, the sum of their annual dose equivalents to the total body or any organ shall not exceed 4 millirem/year.

TABLE A-0
AVERAGE ANNUAL CONCENTRATIONS ASSUMED TO PRODUCE A TOTAL BODY OR ORGAN DOSE OF 4 MREM/YR

Radionuclide	Critical Organ	pCi / liter
Tritium	Total body	20,000
Strontium-90	Bone marrow	8

A.6.2 Application

The projection or calculation of dose due to the drinking water pathway is made using Equations A-17 and A-19. Projections are made using projected radionuclide releases in place of measured releases A_i. Doses calculated using Equations A-17 and A-19 may differ from doses determined by the methodology prescribed in 40CFR141.16.

When required, a nuclear power station prepares a special report on radiological impact at the nearest community water system. This system is taken as the one listed in Table A-3 of this appendix. The report should include the following:

- The doses calculated by Equations A-17 and A-19.
- A statement identifying the dose calculation methodology (e.g., a reference to this manual).
- A statement that the doses calculated by the ODCM methodology are not necessarily the same as doses calculated by the methodology prescribed in 40CFR141.16.
- The data used to calculate the doses. This information includes the amounts of radioactivity released and the flow rate and dilution values used (see Table F-1). This information is provided to assist the operator of the community water system in performing its own dose assessment.

Table A-1

COMPLIANCE MATRIX

Regulation	Dose to be compared to limit
10CFR50 Appendix I	• Gamma air dose and beta air dose due to airborne radioactivity in effluent plume. • Total body and skin dose due to airborne radioactivity in effluent plume are reported only if certain gamma and beta air dose criteria are exceeded. • Dose for all organs and all four age groups due to iodine and particulate in effluent plume. Existing pathways are considered. • Dose for all organs and all four age groups due to radioactivity in liquid effluents.
10CFR20	• Adherence determined by compliance with dose limits of 40CFR190.
40CFR190 (now, by reference, also part of 10CFR20	• Total body dose due to direct radiation, ground and plume exposure from all sources at a station. • Organ doses to an adult due to all pathways.
RETS/ODCM	• "Instantaneous" noble gas total body and skin dose rates and radioiodine, tritium and particulate inhalation dose rates to a child due to radioactivity in airborne effluents. • "Instantaneous" concentration limits for liquid effluents.
10CFR72.104(a)	• During normal operations and anticipated occurrences.

Table A-2

Release Point Classifications

Station	Release Point	Release Point Classification[a]
Braidwood 1 & 2	Vent Stacks	Vent (Mixed Mode)
Byron 1 & 2	Vent Stacks	Vent (Mixed Mode)
Dresden 1	Plant Chimney Chemical Cleaning	Stack (Elevated) Vent (Mixed Mode)
Dresden 2 & 3	Chimney	Stack (Elevated)
	Reactor Building Ventilation Exhaust Stack	Vent (Mixed Mode)
LaSalle 1 & 2	Main Station Vent Stack	Stack (Elevated)
	Standby Gas Treatment Stack[b]	Stack (Elevated)
Quad Cities 1 & 2	Chimney	Stack (Elevated)
	Reactor Building Ventilation Exhaust Stack	Vent (Mixed Mode)
Zion 1 & 2	Vent Stacks	Ground Level

[a]The definitions of release point classifications (stack, vent and ground level) are given in Section 4.1.4.

[b]The LaSalle standby gas treatment stack is located inside the main station vent stack.

Table A-3

Nearest Downstream Community Water Systems

Station	Exelon Nuclear Facilities Upstream of Station	Characteristics of Nearest Affected Downstream Community Water Supply: Location and Distance[a]	Characteristics of Nearest Affected Downstream Community Water Supply: Other Exelon Nuclear Stations Upstream of Water Supply
Braidwood	None	Wilmington, 5 river miles	None
Byron	None	None within 115 river miles	NA[b]
Dresden	Braidwood	Peoria, 106 river miles	Braidwood LaSalle
LaSalle	Braidwood Dresden	Peoria, 97 river miles	Braidwood Dresden
Quad Cities	None	E. Moline, 16 river miles	None
Zion	None	Lake County Intake, 1.4 miles	None

[a]ODCM Bases and Reference Document (Reference 101) Table O-2 and O-6 provide the bases of the location and distance data.

[b]NA = not applicable. For purposes of the calculations in the ODCM, there are no community water supplies affected by liquid effluents from Byron Station. This is based on the absence of community water supplies between the Byron Station liquid discharge to the Rock River and the confluence of the Rock and Mississippi Rivers, 115 miles downstream.

Table A-4

40CFR190, 10CFR72.104(a) Compliance

40CFR190 Dose 10CFR72.104(a) Dose	Annual Limit (mrem)	ODCM Dose and Equation Number
Total Body	25	Total Body Dose; A-25 evaluated for total body
Thyroid	75	Thyroid Dose; A-25 evaluated for thyroid
Other Organs	25	Organ Dose; A-25 evaluated for all organs except thyroid

Notes:

1. The evaluation is made considering the following sources:
   a. Radioactivity in contained sources within the station;
   b. Radioactivity in station gaseous and liquid effluents;
   c. Dose contributions from neighboring stations and other facilities in the nuclear fuel cycle.

APPENDIX B

MODELS AND PARAMETERS FOR AIRBORNE and LIQUID EFFLUENT CALCULATIONS

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SECTION 1:

MODELS AND PARAMETERS FOR AIRBORNE EFFLUENT CALCULATIONS

B.0 INTRODUCTION

The equations used for calculation of doses due to radioactive airborne effluents are given in Section A.1 of Appendix A. The equations involve the following types of parameters:

- **Meteorological Parameters**
  These include **χ/Q, gamma-χ/Q, D/Q** and wind speed. Their values are based on historical average atmospheric conditions at a site for a selected multi-year historical period (see Section 4.1.5).
- **Dose Factors**
  These parameters are used to provide a simple way to calculate doses and dose rates due to gamma and beta radiation. These parameters are independent of meteorological conditions and therefore generic (i.e., not station-specific).
- **Measured Release Parameters**
  These are measured values of radioactivity releases and release rates.
- **Radiological Decay Constants**
  These are used to account for the radioactive decay between the release of radioactivity to the environment and the exposure of persons to it.
- **Production/Exposure Parameters**
  These are parameters characterizing agricultural production (e.g., length of growing season, transport times) and human exposure patterns (e.g., exposure period, breathing rate, food consumption rates). These parameters affect the quantities of radioactivity to which persons may be exposed.

This appendix discusses the methodology used to determine values of these parameters. Section B.1 addresses how the historical meteorology of a site is characterized by use of a function called the joint frequency distribution. Section B.1 and Sections B.3 through B.5 present equations that use the joint frequency distribution to obtain values for site-specific meteorological parameters. These equations involve a mathematical model of a plume known as the Gaussian plume model. This model is developed in Section B.2. Various generic dose factors are discussed in Sections B.6 through B.10. The other parameters are discussed in the remaining sections.

B.1 METEOROLOGICAL DATA AND PARAMETERS

Predicting where airborne effluent will travel requires information on the following:

- Wind speed
- Wind direction
- Atmospheric turbulence

The greater the atmospheric turbulence, the more an effluent plume will tend to broaden and the more dilute the concentration will be. Atmospheric turbulence is affected by the general condition of the atmosphere (e.g., the vertical temperature distribution) and by local features (e.g., objects that protrude into the wind stream). A commonly used classification scheme for the degree of atmospheric turbulence associated with the general condition of the atmosphere involves seven stability classes:

A Extremely Unstable
B Moderately Unstable
C Slightly Unstable
D Neutral

E Slightly Stable
F Moderately Stable
G Extremely Stable

This classification scheme is based on Reference 5, Table 1. Each class is associated with a particular range of wind direction fluctuations and of vertical temperature gradients in the atmosphere. These are specified in Table C-4 of Appendix C.

B.1.1 Data

Historical atmospheric conditions at each nuclear power station were recorded by an instrumented meteorological tower that measured wind speed, wind direction, and temperature at various heights. Hourly average values of wind speed, wind direction, and stability class were determined. The difference in temperature between two heights was used to assign an atmospheric stability class based on the correlation between temperature gradient and stability class in Table C-4 of Appendix C.

In obtaining the data, quality assurance checks and corrections were made. Also, corrections were applied to compensate for the limitations of wind sensors at low speeds. A calm was said to exist if the wind speed was less than that of the threshold of either the anemometer (wind speed meter) or the wind direction vane. For calm conditions, a wind speed equal to one-half of the higher threshold was assigned. For each stability class, the wind directions during calm conditions were assumed to be distributed in proportion to the observed wind direction distribution of the lowest non-calm wind speed class.

B.1.2 Joint Frequency Distribution

The data for a particular historical period are summarized by developing a joint frequency distribution (JFD). Each such distribution specifies the fraction of time during the historical period that the following jointly occur:

- Wind speed within a particular range (wind speed class).
- Downwind direction in one of the 16 sectors corresponding to the 16 principal compass directions (N, NNE, etc.).
- Atmospheric conditions corresponding to one of the seven atmospheric stability classes discussed in Section B.1. Table B-1 of this appendix displays a portion of an example JFD.

Different JFDs are associated with the different release classifications defined in Section 4.1.4. One JFD is defined for stack releases, and another JFD is defined for ground level releases. Two JFDs are associated with vent (mixed mode) releases, one for the portion of the time the release is treated as elevated and the other for the portion of the time the release is treated as ground level.

B.1.2.1 Downwind Direction Versus Upwind Direction

Unless otherwise noted, any reference to wind direction in this document represents downwind direction, i.e., the direction in which the wind is blowing toward. This is because the parameters developed in this document are used to calculate radioactivity concentration and radiation dose downwind of a release point. In contrast, it is conventional for meteorologists to provide JFDs based on upwind direction, the direction from which the wind is blowing. For example, the JFDs presented in the annual operating reports of the nuclear power stations are obtained from a meteorological contractor and the directions specified in the reports are upwind directions. Users of JFDs should always be careful to ascertain whether the directions specified are upwind or downwind.

B.1.2.2 Stack JFD

For a stack release, the JFD is defined as follows:

$\Sigma f_S(n,\theta,c)$ Joint Frequency Distribution, Stack Release

The fraction of hours during a period of observation that all of the following hold:

- The average wind speed is within wind speed class **n**.
- The downwind direction is within the sector denoted by θ.
- The atmospheric stability class is **c**.

This function is defined for application to a stack release point (see Section 4.1.4). Its value is based on hourly average wind data obtained at a height representative of the release point height.

The stack JFD is normalized to 1:

$$\Sigma f_S(n,\theta,c) = 1 \tag{B-1}$$

The summation is over all wind speed classes **n**, all compass direction sectors θ, and all stability classes **c**.

B.1.2.3 Ground Level JFD

For a ground level release, the JFD **$f_g(n, \theta,c)$** is defined in the same way as for a stack release except *that the wind data are obtained at a height representative of a ground level release point. This height is* taken as about 10 meters.

The ground level JFD is normalized to 1:

$$\Sigma f_g(n,\theta,c) = 1 \tag{B-2}$$

The summation is over all wind speed classes **n**, all compass direction sectors, and all stability classes **c**.

B.1.2.4 Vent JFDs

In accordance with the approach recommended in Regulatory Guide 1.111 (Reference 7), the plume from a vent release is treated as elevated part of the time and as ground level the rest of the time. Two JFDs are determined:

- **$f_{v,elev}(n,\theta,c)$** characterizes the plume during the part of the time that it is considered elevated;
- **$f_{v,gnd}(n,\theta,c)$** characterizes the plume during the part of the time that it is considered ground level.

Their definitions are as follows:

$f_{v,elev}(n,\theta,c)$ Joint Frequency Distribution, Elevated Portion of a Vent Release

The fraction of hours during a period of observation that the plume is considered elevated and that all of the following hold:

- The average wind speed is within wind speed class **n**.
- The downwind direction is within the sector denoted by θ.
- The atmospheric stability class is **c**.

$f_{v,gnd}(n,\theta,c)$ Joint Frequency Distribution,
Ground Level Portion of a Vent Release

The fraction of hours during a period of observation that the plume is considered ground level and that all of the following hold:

- The average wind speed is within wind speed class **n**.
- The downwind direction is within the sector denoted by θ.
- The atmospheric stability class is **c**.

The value of $f_{v,elev}(n, \theta,c)$ is based on hourly average wind data at a height representative of the vent release point. Where the measurement height differed considerably from the release height, wind speed data for the release height was obtained by extrapolation. The value of $f_{v,gnd}(n, \theta,c)$ is based on hourly average wind data obtained at a height representative of a ground level release point. This is taken as about 10 meters.

The sum of these two JFDs is normalized to 1:

$$\Sigma\{ f_{v,elev}(n, \theta,c) + f_{v,gnd}(n, \theta,c) \} = 1 \qquad \textbf{(B-3)}$$

The summation is over all wind speed classes **n**, all compass direction sectors θ, and all stability classes **c**.

The prescription of Regulatory Guide 1.111 is used in determining the fraction of time that the plume is considered elevated and the fraction of time that it is considered ground level. The fractions are obtained from the ratio of stack exit velocity W_o to hourly average wind speed **u** at the height of the vent release point as follows:

· If $W_o/u > 5$, then the plume is considered elevated for the hour.

· If $W_o/u \leq 1$, then the plume is considered ground level for the hour.

· If $1 < W_o/u \leq 5$, the plume is considered to be a ground level release for a fraction G_t of the hour and an elevated release for a fraction $(1 - G_t)$ of the hour where G_t is defined as follows:

$$G_t = 2.58 - 1.58(W_o/u) \quad \text{for } 1.0 < W_o/u \leq 1.5 \qquad \textbf{(B-4)}$$

$$G_t = 0.30 - 0.06(W_o/u) \quad \text{for } 1.5 < W_o/u \leq 5.0 \qquad \textbf{(B-5)}$$

B.1.3 Average Wind Speed

Using the joint frequency distribution, average wind speeds are obtained for each station. Values are obtained for each downwind direction (N, NNE, etc.) and for various release point classifications (stack, vent, and ground level).

B.1.3.1 Stack Release

For a stack release, the following formula is used:

$$u_s(\theta) = \Sigma\{ f_s(n, \theta,c)u_n \} / \Sigma\{ f_s(n, \theta,c) \} \quad \textbf{(B-6)}$$

where the summations are over wind speed classes **n** and stability classes **c**.

$u_s(\theta)$	Average Wind Speed, Stack Release	[m/sec]
	The average wind speed in downwind direction θ for a stack release.	
u_n	Wind Speed for Class **n**	[m/sec]
	A wind speed representative of wind speed class **n**. For each wind speed class except the highest, u_n is the average of the upper and lower limits of the wind speed range for the class. For the highest wind speed class, u_n is the lower limit of the wind speed range for the class.	

The parameter f_s is defined in Section B.1.2.2.

B.1.3.2 Ground Level Release

For a ground level release, the following formula is used:

$$u_g(\theta) = \Sigma\{ f_g(n, \theta,c)u_n \} / \Sigma\{ f_g(n, \theta,c) \} \quad \textbf{(B-7)}$$

where the summations are over wind speed classes n and stability classes **c**.

$u_g(\theta)$	Average Wind Speed, Ground Level Release The average wind speed in downwind direction θ for a ground level release.	[m/sec]

The parameter f_g is defined in Section B.1.2.3.

B.1.3.3 Vent Release

For a vent release, the following formula is used:

$$u_v(\theta) = \Sigma \{ [f_{v,elev}(n, \theta,c) + f_{v,gnd}(n, \theta,c)]u_n \} / \Sigma\{ f_{v,elev}(n,\theta,c) + f_{v,gnd}(n,\theta,c) \} \quad \textbf{(B-8)}$$

where the summations are over wind speed classes **n** *and stability classes* **c**.

$u_v(\theta)$	Average Wind Speed, Vent Release	[m/sec]
	The average wind speed in downwind direction θ for a vent release.	

The parameters $f_{v,elev}$ and $f_{v,gnd}$ are defined in Section B.1.2.4.

B.2 GAUSSIAN PLUME MODELS

As a plume of airborne effluents moves away from an elevated release point, the plume both broadens and meanders. It has been found that the time-averaged distribution of material in an effluent plume can be well represented mathematically by a Gaussian function.

B.2.1 Mathematical Representation

In a widely used form of the Gaussian plume model, the distribution of radioactivity in a plume is represented mathematically by the equation below:

$$\chi(x,y,z) = [Q/(2\pi\, \sigma_y\, \sigma_z u)]\exp(-y^2/2\sigma^2_y) \times \{\exp[-(z-h_e)^2/2\sigma^2_z] + \exp[-(z+h_e)^2/2\sigma^2_z]\} \quad \text{(B-9)}$$

$\chi(x,y,z)$ Radioactivity Concentration [μCi/m^3]

The concentration of radioactivity at point **(x,y,z)**. The **x**, **y**, and **z** axis are defined as follows:

x Downwind Distance [m]

Distance from the stack along an axis parallel to the wind direction.

y Crosswind Distance [m]

Distance from the plume centerline along an axis parallel to the crosswind direction.

z Vertical Distance [m]

Distance from the ground (grade level at the stack) along an axis parallel to the vertical direction.

Q Release Rate [μCi/sec]

Release rate of radioactivity.

σ_y, σ_z Horizontal and Vertical Dispersion Coefficients [m]

Standard deviations of the Gaussian distributions describing the plume cross-sections in the **y** and **z** directions, respectively. The values of σ_y and σ_z depend on several parameters:

- Downwind distance **x**.

  Because a plume broadens and meanders as it travels away from its release point, the values of σ_y and σ_z increase as **x** increases.

- Atmospheric stability class.

  The plume is broadest for extremely unstable atmospheric conditions (Class A) and narrowest for extremely stable conditions (Class G).

- Time period of averaging plume concentration.

The values of σ_y and σ_z increase as the averaging period increases.

u Average Wind Speed [m/sec]

The average wind speed. The average speed of travel of the plume in the **x** direction.

h_e Effective Release Height [m]

The effective height of effluent release above grade elevation.
This may be greater than the actual release height (see Section B.3.1.1.1).

The two exponential functions of **z** in the curly brackets of Equation B-9 represent the emitted and reflected components of the plume. The reflected component (represented by the exponential with **($z + h_e$)** in its argument) arises from the assumption that all material in a portion of the plume that touches ground is reflected upward. This assumption is conservative if one is calculating airborne radioactivity concentration.

B.2.2 Sector-Averaged Concentration

Sometimes, it is desired to determine the average concentration of radioactivity in a sector due to release at a constant rate over an extended period of time (e.g., a year). For such a case, it is reasonable to assume that the wind blows with equal likelihood toward all directions within the sector. From Equation B-9, the following equation for ground level radioactivity concentration can be derived:

$$\chi_{sector} = [2.032\ f\ Q/(\sigma_z\ u\ x)]\exp(-h^2_e/2\sigma^2_z) \qquad \textbf{(B-10)}$$

χ_{sector} Sector-Averaged Ground Level Concentration [μCi/m^3]

The time-averaged concentration of airborne radioactivity in a sector at ground level at a distance **x** from the release point.

2.032 A dimensionless constant.

f Sector Fraction

The fraction of time that the wind blows into the sector.

Q Release rate of radioactivity. [μCi/sec]

The other parameter definitions are the same as for Equation B-9.

B.3 RELATIVE CONCENTRATION FACTOR χ/Q

The relative concentration factor **χ/Q** (called "chi over Q") provides a simplified method of calculating the radioactivity concentration at a given point in an effluent plume when the release rate is known:

$$\chi = Q\ (\chi/Q) \qquad \textbf{(B-11)}$$

χ Concentration of Radioactivity [μCi/m^3]
Concentration of radioactivity at point
(x,y,z) in the atmosphere.

Q Release Rate [μCi/sec]

Release rate of radioactivity.

χ/Q Relative Concentration Factor [sec/m^3]
Relative concentration factor for point **(x,y,z)**. The airborne radioactivity concentration at **(x,y,z)** per unit release rate.

Expressions for χ/**Q** based on Gaussian plume models can be obtained from the equations for concentration χ in Section B.2 simply by dividing both sides of each equation by the release rate **Q**. For example, from Equation B-10, we obtain the following expression for the sector-averaged χ/**Q**:

$$(\chi_{sector}/Q) = [2.032\ f/(\sigma_z\ u\ x)]\exp(-h^2_e/2\sigma^2_z) \tag{B-12}$$

The values of χ/**Q** used in ODCM calculations are both sector-averaged and time-averaged. The time averaging is based on the historical average atmospheric conditions of a specified multi-year time period (see Section 4.1.5) and is accomplished by use of the joint frequency distribution discussed in Section B.1.2. The formulas used to obtain the time- and sector-averaged χ/**Q** are based on Equation B-12, but vary depending on whether the release is a stack, ground level, or vent release. The three cases are discussed below.

B.3.1 Stack Release

For a stack release, the relative concentration factor is designated $(\chi/Q)_S$. Its value is obtained by the following formula:

$$(\chi/Q)_S = (2.032/R)\ \Sigma\{ f_S(n,\theta,c) \times [\exp(-h^2_e/2\sigma^2 z)]/(u_n\ \sigma_z) \} \tag{B-13}$$

The summation is over wind speed classes **n** and atmospheric stability classes **c**.

$(\chi/Q)_S$ *Relative Concentration Factor,* Stack Release [sec/m^3]

The time- and sector-averaged relative concentration factor due to a stack release for a point at ground level at distance **R** in downwind direction θ.

2.032 Constant

A dimensionless constant.

R Downwind Distance [m]

The downwind distance from the release point to the point of interest.

$f_S(n,\theta,c)$ Joint Frequency Distribution, Stack Release

This function is defined in Section B.1.2.2.

h_e Effective Release Height [m]

The effective height of an effluent release above grade elevation. For a stack release, h_e is obtained by correcting the actual height of the release point for plume rise, terrain effects, and downwash as described in Section B.3.1.1, below.

σ_z — Standard Vertical Dispersion Coefficient [m]

A coefficient characterizing vertical plume spread in the Gaussian model for stability class **c** at distance **R** (see Table C-5 of Appendix C).

u_n — Wind Speed [m/sec]

A wind speed representative of wind speed class **n**. For each wind speed class except the highest, u_n is the average of the upper and lower limits of the wind speed range for the class. For the highest wind speed class, u_n is the lower limit of the wind speed range for the class.

This expression is recommended by the NRC in Regulatory Guide 1.111 (Reference 7) and is based on a model designated there as the "constant mean wind direction model." In this model it is assumed that the mean wind speed, the mean wind direction, and the atmospheric stability class determined at the release point also apply at all points within the region in which airborne concentration is being evaluated.

B.3.1.1 Effective Release Height

For a stack release, the effective height of an effluent plume is the height of the release point corrected for plume rise and terrain effects:

If $(h_s + h_{pr} - h_t) < 100$ **meters**, then

$$h_e = h_s + h_{pr} - h_t \quad \textbf{(B-14)}$$

If $(h_s + h_{pr} - h_t) \geq 100$ **meters**, then;

$$h_e = 100 \text{ meters} \quad \textbf{(B-15)}$$

h_e — Effective Release Height [m]

The effective height of an effluent release above grade elevation.

h_s — Actual Release Height [m]

The actual height of the release above grade elevation.

h_{pr} — Plume Rise [m]

The rise of the plume due to its momentum and buoyancy.
(See Section B.3.1.1.1.)

h_t — Terrain Correction Parameter [m]

A parameter to account for the effect of terrain elevation on the effective height of a plume. Taken as zero (see Section B.3.1.1.2).

B.3.1.1.1 Plume Rise

Because nuclear power stations generally have plumes that are not significantly warmer than room temperature, plume rise due to buoyancy is neglected. The formulas used to calculate plume rise due to momentum are given below.

Stability Classes A, B, C, and D

For these stability classes (corresponding to unstable and neutral conditions), $\mathbf{h_{pr}}$ is taken as the lesser of two quantities:

$$h_{pr} = \text{Minimum of } [(h_{pr})_1, (h_{pr})_2] \quad \text{(B-16)}$$
$$(h_{pr})_1 = (1.44)(W_o/u)^{2/3}(R/d)^{1/3}(d) - h_d \quad \text{(B-17)}$$
$$(h_{pr})_2 = (3)(W_o/u)(d) \quad \text{(B-18)}$$

W_o	Stack Exit Velocity The effluent stream velocity at the discharge point.	[m/sec]
u	Wind Speed	[m/sec]
R	Downwind Distance The downwind distance from the release point to the point of interest.	[m]
d	Internal Stack Diameter The internal diameter of the stack from which the effluent is released.	[m]
h_d	Downwash Correction A parameter to account for downwash at low exit velocities.	[m]

The parameter $\mathbf{h_d}$ is calculated by the following equations:

$$h_d = (3)(1.5 - W_o/u)(d) \text{ if } W_o<1.5u \quad \text{(B-19)}$$

$$h_d = 0 \text{ if } W_o \geq 1.5u \quad \text{(B-20)}$$

Note that $\mathbf{(h_{pr})_1}$ can increase without limit as **R** increases; thus, the effect of $\mathbf{(h_{pr})_2}$ is to limit calculated plume rise at large distances from the nuclear power station.

Stability Classes E, F, and G

For these stability classes (corresponding to stable conditions), $\mathbf{h_{pr}}$ is taken as the minimum of four quantities:

$$h_{pr} = \text{Minimum of } [(h_{pr})_1, (h_{pr})_2, (h_{pr})_3, (h_{pr})_4] \quad \text{(B-21)}$$

$$(h_{pr})_3 = (4)(F/S)^{1/4} \quad \text{(B-22)}$$

$$(h_{pr})_4 = (1.5)(F/u)^{1/3}(S)^{-1/6} \quad \text{(B-23)}$$

F Momentum Flux Parameter $[m^4/sec^2]$

A parameter defined as:

$$\mathbf{F = W_o^2(d/2)^2} \quad \textbf{(B-24)}$$

S Stability Parameter $[1/sec^2]$

A parameter defined as follows:

Stability Class	S
E	8.70E-4
F	1.75E-3
G	2.45E-3

The quantities $\mathbf{(h_{pr})_1}$ and $\mathbf{(h_{pr})_2}$ are as defined by Equations B-17 and B-18.

B.3.1.1.2 Terrain Effects

Due to general flatness of the terrain in the vicinity of the stations, the terrain correction parameter $\mathbf{h_t}$ was taken as zero in all calculations of meteorological dispersion and dose parameters for this Manual.

B.3.2 Ground Level Release

For a ground level release, the relative concentration factor is designated $\mathbf{(\chi/Q)_g}$. Its value is obtained by the following formula:

$$\mathbf{(\chi/Q)_g = (2.032/R)\ \Sigma\{\ f_g(n,\theta,c)/(u_n S_z)\ \}} \quad \textbf{(B-25)}$$

The summation is over wind speed classes **n** and atmospheric stability classes **c**.

$\mathbf{(\chi/Q)_g}$ Relative Concentration Factor, Ground Level Release $[sec/m^3]$

The time- and sector-averaged relative concentration factor due to a ground level release for a point at ground level at distance **R** in downwind direction θ.

$\mathbf{f_g(n,\theta,c)}$ Joint Frequency Distribution, Ground Level Release

This function is defined in Section B.1.2.3.

$\mathbf{S_z}$ Wake-Corrected Vertical Dispersion Coefficient [m]

The vertical dispersion coefficient corrected for building wake effects. The correction is made as described below.

The remaining parameters are defined in Section B.3.1.

Wake-Corrected Vertical Dispersion Coefficient

The wake-corrected vertical dispersion coefficient S_z in Equation B-25 is taken as the lesser of two quantities:

$$S_z = \text{Minimum of } [(S_z)_1, (S_z)_2] \qquad \text{(B-26)}$$

$$(S_z)_1 = [\sigma^2_z + D^2/(2\pi)]^{1/2} \qquad \text{(B-27)}$$

$$(S_z)_2 = (\sigma_z)(3^{1/2}) \qquad \text{(B-28)}$$

S_z — Wake-Corrected Vertical Dispersion Coefficient [m]

The vertical dispersion coefficient corrected for building wake effects.

σ_z — Standard Vertical Dispersion Coefficient [m]

The coefficient characterizing vertical plume spread in the Gaussian model for stability class **c** at distance **R** (see Table C-5 of Appendix C).

D — Maximum Height of Neighboring Structure [m]

The maximum height of any neighboring structure causing building wake effects (see Table F-2 of Appendix F).

B.3.3 Vent Release

For a vent release, the relative concentration factor is designated $(\chi/Q)_V$. Its value is obtained by the following formula:

$$(\chi/Q)_V = (2.032/R)\,\Sigma\{ f_{v,elev}(n,\theta,c) \times [\exp(-h^2_e/2\sigma^2_z)]/(u_n\,\sigma_z) + f_{v,gnd}(n,\theta,c)/(u_n S_z) \} \qquad \text{(B-29)}$$

The summation is over wind speed classes **n** and atmospheric stability classes **c**.

$(\chi/Q)_V$ — Relative Concentration Factor, Vent Release [sec/m^3]

The time and sector averaged relative concentration factor due to a vent release for a point at ground level at distance **R** in downwind direction θ.

The parameters $f_{v,elev}(n,\theta,c)$ and $f_{v,gnd}(n,\theta,c)$ are defined in Section B.1.2.4. The parameter S_z is defined in Section B.3.2. The remaining parameters are defined in Section B.3.1.

B.3.4 Removal Mechanisms

In Regulatory Guide 1.111, the NRC allows various removal mechanisms to be considered in evaluating the radiological impact of airborne effluents. These include radioactive decay, dry deposition, wet deposition, and deposition over water. For simplicity, these removal mechanisms cited by the NRC are not accounted for in the evaluation or use of χ/Q in this manual. This represents a conservative approximation as ignoring removal mechanisms increases the value of χ/Q.

B.3.5 Gamma-χ/Q

The noble gas dose factors of Reg. Guide 1.109, Table B-1 are based upon assumption of immersion in a semi-infinite cloud. For ground level and mixed mode releases this tends to overestimate the gamma air dose arising from a plume that is actually finite in nature.

For elevated releases, the Reg. Guide 1.109 noble gas dose factors will underestimate exposure as they consider only immersion and not that portion of exposure arising from sky shine. At distances close in to the point of elevated release, the ground level concentration as predicted by χ/Q will be essentially zero. In such a case, the sky shine component of the exposure becomes significant and must be considered.

The **gamma-χ/Q** provides a simplified method of calculating gamma air dose and dose rates for a finite and/or elevated plume. The methodology of Reg. Guide 1.109, Section C.2 and Appendix B provides the methodology for calculating finite cloud gamma air dose factors from which the **gamma-χ/Q** values can be derived. Section B.5 addresses the calculation of these dose factors.

The **gamma-χ/Q** is defined such that for a given finite cloud the semi-infinite cloud methodology will yield the same gamma air dose as the finite cloud methodology.

Three **gamma-χ/Q** values are defined: $(\chi/Q)_s^\gamma$, $(\chi/Q)_v^\gamma$ **and** $(\chi/Q)_g^\gamma$ for stack, vent and ground level releases, respectively. These **gamma-χ/Q** values are calculated as follows:

For stack releases:

$$(\chi/Q)_s^\gamma = \frac{\sum_i f_i S_i}{\sum_i f_i M_i} \quad \textbf{(B-30)}$$

The summation is over all noble gas radionuclides **i**.

$(\chi/Q)_s^\gamma$	**Gamma-γ/Q** for Stack Releases	[sec/m3]
f_i	Noble Gas Nuclide Fraction	dimensionless
	Fraction of total noble gas release that is due to radionuclide **i**. Values for f_i are listed in Table B-0.	
S_i	Stack Release Gamma Air Dose Factor	[(mrad/yr)/(μCi/sec)]
	Gamma air dose factor for radionuclide **i** for stack releases as defined in Section B.5.1. Taken from Appendix F, Table 7.	
M_i	Semi-Infinite Cloud Dose Factor	[(mrad/yr)/(μCi/m^3)]
	Dose factor for immersion exposure to a semi-infinite cloud of noble gas. Taken from Reg. Guide 1.109, Table B-1, Col 4. (Note that the units in Reg. Guide 1.109 must be multiplied by 1E6 to convert pCi to μCi.)	

For vent releases:

$$(\chi/Q)_v^\gamma = \frac{\sum_i f_i V_i}{\sum_i f_i M_i} \quad \textbf{(B-31)}$$

The summation is over all noble gas radionuclides **i**.

$(\chi/Q)_v^\gamma$	**Gamma-γ/Q** for Vent Releases	[sec/m3]
V_i	Vent Release Gamma Air Dose Factor	[(mrad/yr)/(μCi/sec)]
	Gamma air dose factor for radionuclide **i** for stack releases as defined in Section B.5.3. Taken from Appendix F, Table 7.	

All other terms have been previously defined.

For ground level releases:

$$(\chi/Q)_g^\gamma = \frac{\sum_i f_i G_i}{\sum_i f_i M_i} \qquad \textbf{(B-32)}$$

The summation is over all noble gas radionuclides **i**.

$(\chi/Q)_g^\gamma$	**Gamma-γ/Q** for Ground Releases	[sec/m3]
G_i	Ground Level Release Gamma Air Dose Factor	[(mrad/yr)/(μCi/sec)]
	Gamma air dose factor for radionuclide **i** for ground level releases as defined in Section B.5.2. Taken from Appendix F, Table 7.	

All other terms have been previously defined.

The Noble Gas Nuclide Fraction, f_i is determined from historical release data and defined as:

$$f_i = \frac{A_i}{\sum_i A_i} \qquad \textbf{(B-33)}$$

The summation is over all noble gas radionuclides **i**.

A_i	Cumulative Radionuclide Release	units of activity
	Cumulative release of noble gas radionuclide ***i*** *over a period of time.*	

B.4 RELATIVE DEPOSITION FACTOR D/Q

The quantity **D/Q** (called "D over Q") is defined to provide the following simple way of calculating the rate of deposition of radioactivity at a given point on the ground when the release rate is known.

$$\mathbf{d = Q\ (D/Q)} \qquad \textbf{(B-34)}$$

d	Deposition Rate	[(μCi/m^2)/sec]
	Rate of deposition of radioactivity at a specified point on the ground.	
Q	Release Rate of radioactivity.	[μCi/sec]

D/Q Relative Deposition Factor $[1/m^2]$

Relative deposition factor for a specified point on the ground. The deposition rate per unit release rate.

The values of **D/Q** used in this manual are time-averaged. The time averaging is based on the historical average atmospheric conditions of a specified multi-year time period (see Section 4.1.5) and is accomplished by use of the joint frequency distribution described in Section B.1.2. The formulas used to obtain **D/Q** vary depending on whether the release is a stack, ground level, or vent release. The three cases are discussed below.

B.4.1 Stack Release

For a stack release, the relative deposition factor is designated $(D/Q)_s$. Its value is obtained by the following formula:

$$(D/Q)_s = [1/(2\pi R/16)]\ \Sigma\{f_s(n,\theta,c)\ D_r(c,R,h_e)\} \qquad \textbf{(B-35)}$$

The summation is over wind speed classes **n** and stability classes **c**.

$(D/Q)_s$ Relative Deposition Factor, Stack Release $[1/m^2]$

The time-averaged relative deposition factor due to a stack release for a point at distance **R** in the direction θ.

$2\pi/16$ Sector Width [radians]

The width of a sector over which the plume direction is assumed to be uniformly distributed (as in the model of Section B.2.2). Taken as 1/16 of a circle.

R Downwind Distance [m]

The downwind distance from the release point to the point of interest.

$f_s(n,\theta,c)$ Joint Frequency Distribution, Stack Release

This function is defined in Section B.1.2.2.

$D_r(c,R,h_e)$ Relative Deposition Rate, Stack Release $[m^{-1}]$

The deposition rate per unit downwind distance [μCi/(sec-m)] divided by the source strength [μCi/sec] due to a stack release for stability class **c**, downwind distance **R**, and effective release height h_e.

The value is based on Figures 7 to 9 of Regulatory Guide 1.111, which apply, respectively, to release heights of 30, 60, and 100 m. Linear interpolation is used to obtain values at intermediate release heights. If the effective release height is greater than 100 meters, then the data for 100 meters are used.

h_e Effective Release Height [m]

The effective height of the release above grade elevation. See Section B.3.1.1.

B.4.2 Ground Level Release

For ground level release, the relative deposition factor is designated $(D/Q)_g$. Its value is obtained by the following formula:

$$(D/Q)_g = [1/(2\pi R/16)]\ D_r(R)\ \Sigma\{ f_g(n,\theta,c) \} \qquad \textbf{(B-36)}$$

The summation is over wind speed classes **n** and stability classes **c**.

$(D/Q)_g$	Relative Deposition Factor, Ground Level Release The time-averaged relative deposition factor due to a ground level release for a point at distance **R** in the direction θ.	[$1/m^2$]
$f_g(n,\theta,c)$	Joint Frequency Distribution, Ground Level Release This function is defined in Section B.1.2.3.	
$D_r(R)$	Relative Deposition Rate, Ground Level The deposition rate per unit downwind distance [μCi/(sec-m)] divided by the source strength [μCi/sec] due to a ground level release for downwind distance **R**. The value is taken from Figure 6 of Regulatory Guide 1.111 and is the same for all atmospheric stability classes.	[m^{-1}]

The remaining parameters are defined in Section B.4.1.

B.4.3 Vent Release

For a vent release, the relative deposition factor is designated $(D/Q)_V$. Its value is obtained by the following formula:

$$(D/Q)_V = [1/(2\pi R/16)] \times [\Sigma\{ f_{V,elev}(n,\theta,c)\ D_r(c,R,h_e) \} + D_r(R)\ \Sigma\{ f_{V,gnd}(n,\theta,c) \}] \qquad \textbf{(B-37)}$$

The summation is over wind speed classes **n** and stability classes **c**.

$(D/Q)_V$	Relative Deposition Factor, Vent Release The time-averaged relative deposition factor due to a ground level release for a point at distance **R** in the direction θ.	[$1/m^2$]

The parameters $f_{V,elev}(n,\theta,c)$ and $f_{V,gnd}(n,\theta,c)$ are defined in Section B.1.2.4. The remaining parameters are defined in Sections B.4.1 and B.4.2.

B.5 GAMMA AIR DOSE FACTORS (S_i, V_i, G_i)

The gamma air dose factors provide a simple way of calculating doses and dose rates to air due to gamma radiation. For example, using a dose factor DF_i, gamma air dose rate may be calculated as follows:

$$\dot{D} = \Sigma \dot{D}_i \qquad \textbf{(B-38)}$$

$$\dot{D}_i = \Sigma\{Q_i DF_i\} \qquad \textbf{(B-39)}$$

The summations are over **i** radionuclides.

$\dot{D}$	Gamma Air Dose Rate The gamma air dose rate due to all radionuclides released.	[mrad/yr]
$\dot{D}_i$	Gamma Air Dose Rate Due to Radionuclide **i**	[mrad/yr]
Q_i	Release Rate of Radionuclide **i**	[µCi/sec]
DF_i	Gamma Air Dose Factor for Radionuclide **i** A factor used to calculate gamma air dose or dose rate due to release of radionuclide **i**. Gamma air dose rate at a particular location per unit release rate.	[(mrad/yr)/ (µCi/sec)]

Three gamma air dose factors are defined: S_i, V_i, and G_i. They are used for stack, vent, and ground level releases, respectively. These three release point classifications are defined in Section 4.1.4. The calculation of the three dose factors is discussed below.

B.5.1 Stack Release

For a stack release, the gamma air dose factor S_i is obtained by a model similar to that of Equation 6 of Regulatory Guide 1.109 (Reference 6). A sector-averaged Gaussian plume is assumed and the dose factor is evaluated on the basis of historical average atmospheric conditions. The value of S_i depends on distance **R** from the release point and on downwind sector θ.

The following equation is used:

$$S_i = [260/(2\pi R/16)] \times \Sigma\{f_s(n,\theta,c)[\exp(-\lambda_i R/3600u_n)] \times E_k\ \mu_a(E_k) A_{Ki}\ I(h_e,u_n,c,\sigma_z,E_k)/u_n\} \qquad \textbf{(B-40)}$$

The summation is over wind speed classes **n**, atmospheric stability classes **c**, and photon group indices **k**.

S_i	Gamma Air Dose Factor, Stack Release The gamma air dose factor at ground level for a stack release for radionuclide **i**, downwind sector θ, downwind distance **R** from the release point, and the average atmospheric conditions of a specified historical time period.	[(mrad/yr)/ (µCi/sec)]

260	Conversion factor	[(mrad-radians-m^3-disintegrations)/(sec-MeV-Ci)]
	Reconciles units of Equation B-36.	
$2\pi/16$	Sector Width	[radians]
	The width of a sector over which the plume direction is assumed to be uniformly distributed (as in the model of Section B.2.2). Taken as 1/16 of a circle.	
$f_s(n,\theta,c)$	Joint Frequency Distribution, Stack Release	
	This function is defined in Section B.1.2.2.	
λ_i	Radiological Decay Constant	[hr^{-1}]
	Radiological Decay Constant for radionuclide **i** (see Table C-7 of Appendix C).	
3600	Conversion Factor	[sec/hr]
	The number of seconds per hour. Used to convert wind speed in meters/sec to meters/hr.	
E_k	Photon Group Energy	[MeV/photon]
	An energy representative of photon energy group **k**. The photons emitted by each radionuclide are grouped into energy groups in order to facilitate analysis. All photons with energy in energy group **k** are assumed to have energy $\mathbf{E_k}$.	
$\mu_a(E_k)$	Air Energy Absorption Coefficient	[m^{-1}]
	The linear energy absorption coefficient for air for photon energy group **k**. The fraction of energy absorbed in air per unit of distance traveled for a beam of photons of energy $\mathbf{E_k}$. Distance is measured in units of linear thickness (meters).	
A_{ki}	Effective Photon Yield	[photons/disintegration]
	The effective number of photons emitted with energy in energy group **k** per decay of nuclide **i**. On the basis of Section B.1 of Regulatory Guide 1.109 (Reference 6), the parameter $\mathbf{A_{ki}}$ is calculated as follows:	
	$\mathbf{A_{ki} = [\Sigma\{A_m\ E_m\ \mu_a(E_m)\}]/[E_k\ \mu_a(E_k)]}$	**(B-41)**
	The summation in the numerator is over the index **m**.	
A_m	True Photon Yield	[photons per disintegration]
	The actual number of photons emitted with energy $\mathbf{E_m}$ per decay of nuclide **i**.	

E_m [MeV/photon] — Photon Energy

The energy of the m^{th} photon within photon energy group **k**.

$\mu_a(E_m)$ — Air Energy Absorption Coefficient [m^{-1}]

The linear energy absorption coefficient for air for photon energy E_m.

I(...) — I Function

A dimensionless parameter obtained by numerical evaluation of integrals that arise in the plume gamma dose problem. The value of **I** depends on the arguments **(...)** listed in Equation B-40. A specific definition for **I** is given by Equation F-13 of Regulatory Guide 1.109.

The integrals involved in calculating **I** arise from conceptually dividing up the radioactive plume into small elements of radioactivity and adding up the doses produced at the point of interest by all of the small elements. The distribution of radioactivity in the plume is represented by a sector-averaged Gaussian plume model like that discussed in Section B.2.2.

The parameters **R**, h_e, u_n, and σ_z are defined in Section B.3.1.

B.5.2 Ground Level Release

The gamma air dose factor G_i for a ground level release is defined as follows:

G_i — Gamma Air Dose Factor, Ground Level Release [(mrad/yr)/(µCi/sec)]

The gamma air dose factor at ground level for a ground level release for radionuclide **i**, downwind sector θ, downwind distance **R** from the release point, and the average atmospheric conditions of a specified historical time period.

The value of G_i is obtained by the same equation as used for a stack release, Equation B-36 of Section B.5.1, with the following modifications:

- The joint frequency distribution for a ground level release (f_g of Section B.1.2.3) is used in place of the one for a stack release (f_s).
- In evaluating the **I** function, the effective release height h_e is taken as zero.

This corresponds to use of a finite plume model.

B.5.3 Vent Release

For a vent release, the gamma air dose factor is calculated as follows:

$$V_i = [260/(2\pi R/16)] \times \Sigma\{f_{v,elev}(n,\theta,c)[\exp(-\lambda_i R/3600u_n)] \times A_{ki}E_k\mu_a(E_k)\ I(h_e,u_n,c,\sigma_z,E_k)/u_n + f_{v,gnd}(n,\theta,c)[\exp(-\lambda_i R/3600u_n)] \times A_{ki}E_k\mu_a(E_k)\ I(0,u_n,c,\sigma_z,E_k)/u_n\} \quad \text{(B-42)}$$

The summation is over wind speed classes **n**, atmospheric stability classes **c**, and photon group indices **k**.

V_i	Gamma Air Dose Factor, Vent Release	[(mrad/yr)/(μCi/sec)]

The gamma air dose factor at ground level for a vent release for radionuclide **i**, downwind sector θ, downwind distance **R** from the release point, and the average atmospheric conditions of a specified historical time period.

The parameters $\mathbf{f_{v,elev}(n,\theta,c)}$ and $\mathbf{f_{v,gnd}(n,\theta,c)}$ are defined in Section B.1.2.4. The parameter σ_z is defined in Section B.3.2. The remaining parameters are discussed in Section B.5.1.

B.6 Gamma Total Body Dose Conversion Factor (K_i)

The gamma total body dose conversion factors (K_i) are used to calculate doses and dose rates due to gamma irradiation of the whole body. The gamma total body dose conversion factors are taken from Reg. Guide 1.109, Table B-1, Column 5. The gamma total body dose conversion factors in Table B-1 of Reg. Guide 1.109 are based upon the semi-infinite cloud model.

B.7 BETA AIR AND BETA SKIN DOSE CONVERSION FACTORS (N_i,L_i)

The beta air (N_i) and beta skin (L_i) dose conversion factors are used to calculate doses and dose rates due to noble gas beta exposure. The beta air dose conversion factors are taken from Reg, Guide 1.109, Table B-1, Column 2. The beta skin dose conversion factors are taken from Column 5 of that same table. The values are based on a semi-infinite cloud model.

B.8 GROUND PLANE DOSE CONVERSION FACTOR DFG_i

The ground plane dose conversion factor DFG_i is used to calculate dose due to standing on ground contaminated with radionuclide **i** (see Equation A-8 of Appendix A). The units of DFG_i are (mrem/hr) per (pCi/m^2).

Values are provided (see Table C-10 of Appendix C) for dose to the whole body. The values are taken from Regulatory Guide 1.109 and are based on a model that assumes a uniformly contaminated ground plane.

B.9 INHALATION DOSE COMMITMENT FACTOR DFA_{ija}

The inhalation dose commitment factor DFA_{ija} is used to calculate dose and dose rate to organ **j** of an individual of age group **a** due to inhalation of radionuclide **i** (see Equations A-7 and A-9 of Appendix A).

Values of DFA_{ija} for 10CFR50 compliance are taken from Regulatory Guide 1.109 (Reference 6). The units of DFA_{ija} are mrem per pCi inhaled. Values are provided for seven organs, with the whole body considered as an organ (see Tables E-7, E-8, E-9 and E-10 in Reg. Guide 1.109).

B.10 INGESTION DOSE COMMITMENT FACTOR DFL_{ija}

The ingestion dose commitment factor DFL_{ija} is used to calculate dose to organ **j** of an individual of age group **a** due to ingestion of radionuclide **i** (see Equations A-7 and A10 through A20 of Appendix A).

Values of DFL_{ija} for 10CFR50 compliance are taken from Regulatory Guide 1.109 (Reference 6). The units of DFL_{ija} are mrem per pCi ingested. In Tables E-11, E-12, E-13 and E-14 of Reg. Guide 1.109, values are provided for seven organs, with the whole body considered as an organ.

B.11 MEASURED RELEASE PARAMETERS

Input parameters required for calculations of dose or dose rate due to airborne effluents include measured values of radioactivity release ($\mathbf{A}_{is}$, $\mathbf{A}_{iv}$, and $\mathbf{A}_{ig}$) or release rate ($\mathbf{Q}_{is}$, $\mathbf{Q}_{iv}$, and $\mathbf{Q}_{ig}$) (see Section A.1 of Appendix A). These are obtained per the nuclear power station procedures.

B.12 RADIOLOGICAL DECAY CONSTANTS

Values used for these are obtained from the literature and are specified in Table C-7 of Appendix C.

B.13 PRODUCTION/EXPOSURE PARAMETERS

These parameters characterize various aspects of agricultural production and human exposure. Values used for generic (site-independent) parameters are specified in Appendix C.

Values of site-specific parameters are given in Appendix F. Many of the values are based on Reg. Guide 1.109, while others are based on site-specific considerations.

SECTION 2:

MODELS AND PARAMETERS FOR LIQUID EFFLUENT CALCULATIONS

B.14 INTRODUCTION

Equations for radiation dose and radioactivity concentration due to liquid effluents are given in Section A.2 of Appendix A. The equations involve the following types of parameters:

- Flow and Dilution Parameters.
- Dose Factors.
- Measured Release Parameters.
- Transport/Consumption Parameters.

This section discusses the methodology used to determine these parameters. Section B.15 addresses dose calculations and Section B.16 addresses concentration calculations for tank discharges. For dose calculations, flow and dilution parameters are discussed for two different models; the River Model, which is used for all nuclear power stations except Zion, and the Lake Michigan Model, which is used for Zion.

B.15 DOSE

B.15.1 Drinking Water

The radiation dose due to consumption of drinking water containing released radioactivity is calculated by Equations A-17, A-18 and A-19 of Appendix A:

$$\mathbf{D_{aj}^{Liq} = F\ \Delta t \sum_{p} \sum_{i} A_{aipj} C_i} \qquad \textbf{(A-17)}$$

$$\mathbf{F = \frac{Waste\ Flow}{Dilution\ Flow \times Z}} \qquad \textbf{(A-18)}$$

$$\mathbf{A_{ai(PW)j} = k_o \left\{ \frac{U_a^w}{D^w} \right\} DFL_{aij}} \qquad \textbf{(A-19)}$$

The summation is over index **i** (radionuclides) and **p** (pathways). The parameters are defined in Section A.2.1 of Appendix A.

This methodology addresses the following considerations:

- The duration of the release, Δt.
- The concentration of the activity released, C_i.
- The dilution that takes place in the environment is represented by the parameters **F** and **Z**.
- Receptor consumption rate, U_a^w.
- Dilution which occurs from the near field discharge area to potable water intake as represented by D^w.
- The dose commitment per unit of ingested radioactivity is $\mathbf{DFL_{aij}}$.

B.15.2 Aquatic Foods (Fish)

Near the nuclear power stations, the only aquatic food of significance for human consumption is fish. The liquid dose due to consumption of fish containing released radioactivity is calculated by Equations A-17, A-18 and A-20 of Appendix A.

$$A_{ai(Fish)j} = k_o U_a^F BF_i DFL_{aij} \qquad \textbf{(A-20)}$$

The parameters are defined in Section A.2.1 of Appendix A.

This is similar to the methodolgy used for calculating the dose due to drinking water except for the addition of the bioaccumulation factor, $\mathbf{BF_i}$. This factor is the equilibrium ratio of the concentration of radionuclide **i** in fish (pCi/kg) to its concentration in water (pCi/L). It accounts for the fact that radioactivity ingested by fish can accumulate in their bodies to a higher concentration than in the waters in which the fish live.

B.15.3 Parameters

B.15.3.1 Flow and Dilution

The values of dilution can differ for potable water and fish. The dilution for potable water will depends on where water is drawn, while that for fish will depends on where the fish are caught. Models used to determine these parameters are discussed below. The values used for each station are summarized in Table F-1 of Appendix F.

B.15.3.1.1 River Model

For the purpose of calculating the drinking water dose from liquid effluents discharged into a river, it is assumed that total dilution of the discharge in the river flow occurs prior to consumption. The measure of dilution for the potable water pathway is described by the parameter $\mathbf{D^w}$. A value of $\mathbf{D^w}$ = 1 represents no dilution.

For the fish consumption pathway, the dilution in the near-field is described by the parameter **Z**. This is an estimate of the dilution of released radioactivity in the water consumed by fish caught near the station downstream of its discharge. No additional dilution is assumed to occur.

B.15.3.1.2 Lake Michigan Model

Only (Zion) discharges liquid effluents into Lake Michigan. For this nuclear power station, it is assumed that the dilution in the near-field (**Z**) is dictated by the initial entrainment dilution is a factor of 10. The potable water pathway dilution factor of 6 ($\mathbf{D^w}$) is derived from the plume dilution (a factor of 3 over approximately 1 mile) and the current direction frequency (annual average factor of 2).

B.15.3.2 Dose Factors

Equations A-17 through A-20 of Appendix A determine dose due to ingested radioactivity using the same ingestion dose factor $\mathbf{DFL_{ija}}$ as used in the evaluation of airborne radioactivity which is ingested with foods. The units of $\mathbf{DFL_{ija}}$ are:

(mrem) per (pCi ingested)

For 10CFR50 Appendix I compliance, the data of Tables E-1, E-12, E-13 and E-14 of Reg. Guide 1.109, are used for four age groups and for seven organs, with the whole body considered as an organ.

B.15.3.3 Measured Releases

Calculations of dose due to liquid effluents require measured values of radioactivity concentration release ($\mathbf{C_i}$) for input. These release values are obtained per the nuclear power station procedures.

B.15.3.4 Consumption

Equations A-19 and A-20 of Appendix A involve consumption rates for water and fish ($\mathbf{U_a^w}$ and $\mathbf{U_a^F}$). The values used are specified for each nuclear power station in Table F-1 of Appendix F.

B.16 CONCENTRATION IN TANK DISCHARGES

The concentration of radioactivity in a release to the unrestricted area due to a tank discharge is calculated by Equation A-22 of Appendix A:

$$\mathbf{C_i = C_i^t \frac{Waste\ Flow}{Dilution\ Flow}} \qquad \textbf{(A-22)}$$

The parameters are defined in Section A.2.3 of Appendix A.

The radioactivity concentration released from the tank ($\mathbf{C^t_i}$ at flow rate $\mathbf{F^r}$) is diluted by mixing with the initial dilution stream (with flow rate $\mathbf{F^d}$) to yield a lower concentration ($\mathbf{C_i}$) in the combined streams.

Table B-0
Noble Gas Nuclide Fractions

Nuclide	Braidwood[1]	Byron[1]	Dresden[2]	LaSalle[1]	QuadCities[3]	Zion[1]
Ar-41	8.90E-01	8.90E-01	1.46E-02	0.00E+00	1.85E-02	0.00E+00
Kr-83m	0.00E+00	0.00E+00	0.00E+00	4.50E-03	0.00E+00	0.00E+00
Kr-85	2.49E+01	2.49E+01	3.50E-05	2.60E-05	3.11E-02	1.00E+00
Kr-85m	1.80E-01	1.80E-01	3.68E-02	8.00E-03	2.39E-02	0.00E+00
Kr-87	4.00E-02	4.00E-02	3.71E-02	2.60E-02	3.25E-02	0.00E+00
Kr-88	2.80E-01	2.80E-01	4.47E-02	2.60E-02	3.10E-02	0.00E+00
Kr-89	0.00E+00	0.00E+00	0.00E+00	1.70E-01	0.00E+00	0.00E+00
Kr-90	0.00E+00	0.00E+00	0.00E+00	3.70E-01	0.00E+00	0.00E+00
Xe-131m	1.40E+00	1.40E+00	0.00E+00	2.00E-05	1.15E-03	0.00E+00
Xe-133	7.11E+01	7.11E+01	4.88E-02	1.10E-02	6.34E-02	0.00E+00
Xe-133m	5.70E-01	5.70E-01	3.17E-04	3.80E-04	5.00E-05	0.00E+00
Xe-135	5.30E-01	5.30E-01	2.71E-01	2.90E-02	4.95E-02	0.00E+00
Xe-135m	0.00E+00	0.00E+00	1.10E-01	3.40E-02	1.77E-01	0.00E+00
Xe-137	0.00E+00	0.00E+00	0.00E+00	2.00E-01	0.00E+00	0.00E+00
Xe-138	4.00E-02	4.00E-02	4.37E-01	1.20E-01	5.72E-01	0.00E+00

Notes:

(1) From Table 10-1.
(2) From 1998 and 1999 Dresden Station Radiological Environmental Operating Reports.
(3) From 1998 and 1999 Quad Cities Station Radiological Environmental Operating Reports.

Table B-1

Portion of an Example Joint Frequency Distribution

Summary Table of Percent by Direction and Class

Class	N	NNE	NE	ENE	E	ESE	SE	SSE	S
A	.289	.317	.301	.244	.249	.190	.198	.197	.335
B	.190	.187	.178	.158	.125	.065	.079	.130	.193
C	.269	.226	.252	.218	.190	.118	.152	.189	.302
D	3.298	2.327	2.338	2.684	1.992	1.334	1.365	2.172	3.012
E	1.466	1.198	.988	1.331	1.661	1.226	1.472	2.553	3.628
F	.504	.318	.185	.276	.699	.648	.803	1.293	1.732
G	.202	.091	.061	.099	.253	.250	.355	.400	.624
Total	6.217	4.663	4.304	5.011	5.169	3.830	4.424	6.933	9.826

Summary Table of Percent by Direction and Speed

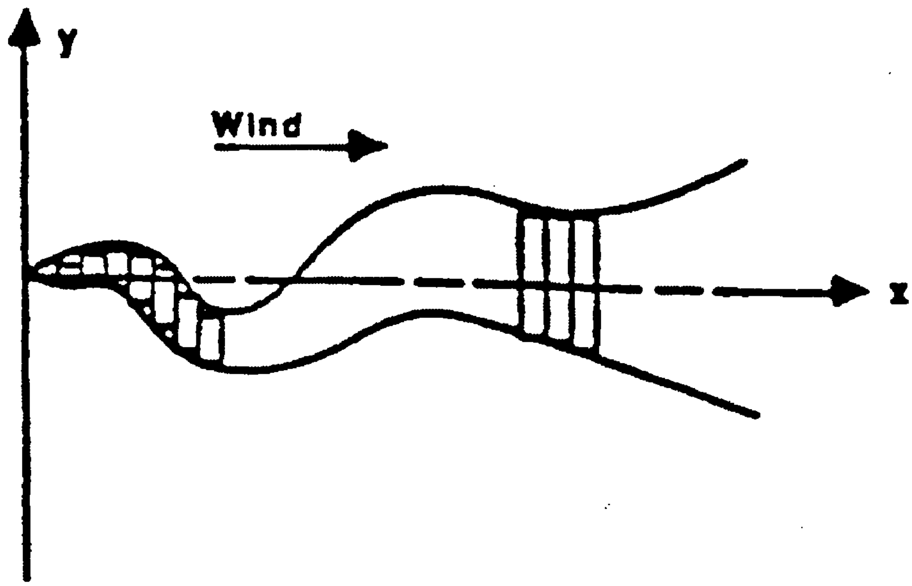
Speed	N	NNE	NE	ENE	E	ESE	SE	SSE	S
.45	.098	.099	.078	.030	.009	.000	.014	.032	.046
1.05	.308	.154	.125	.137	.121	.093	.090	.090	.127
2.05	.939	.602	.458	.594	.843	.606	.598	.605	1.008
3.05	1.164	1.030	.779	.981	1.468	1.075	1.093	1.478	1.982
4.05	1.179	1.024	.878	.995	1.243	.831	1.027	1.727	2.110
5.05	.839	.631	.858	.798	.724	.474	.652	1.254	1.636
6.05	.612	.467	.496	.589	.417	.313	.418	.803	1.153
8.05	.755	.437	.612	.695	.310	.313	.405	.735	1.319
10.05	.253	.157	.183	.165	.032	.093	.103	.180	.374
13.05	.053	.061	.034	.027	.001	.031	.025	.028	.072
18.00	.016	.001	.004	.000	.000	.001	.001	.002	.000
99.00	.000	.000	.000	.000	.000	.000	.000	.000	.000
Total	6.217	4.663	4.304	5.011	5.169	3.830	4.424	6.933	9.826

Summary Table of Percent by Speed and Class

Class Speed	A	B	C	D	E	F	G
.45	.004	.001	.000	.095	.257	.275	.346
1.05	.018	.012	.027	.508	1.035	1.080	.780
2.05	.286	.171	.246	3.256	5.028	3.228	1.419
3.05	.744	.428	.616	6.258	7.173	3.272	.985
4.05	.992	.581	.781	8.165	6.404	1.902	.460
5.05	.909	.506	.808	7.302	4.357	.607	.077
6.05	.712	.388	.613	6.167	2.938	.164	.013
8.05	.819	.500	.755	7.616	2.734	.081	.011
10.05	.230	.150	.196	2.606	.867	.009	.000
13.05	.075	.032	.055	.755	.161	.001	.000
18.00	.004	.000	.018	.117	.012	.000	.000
99.00	.000	.000	.001	.001	.000	.000	.000

Figure B-1

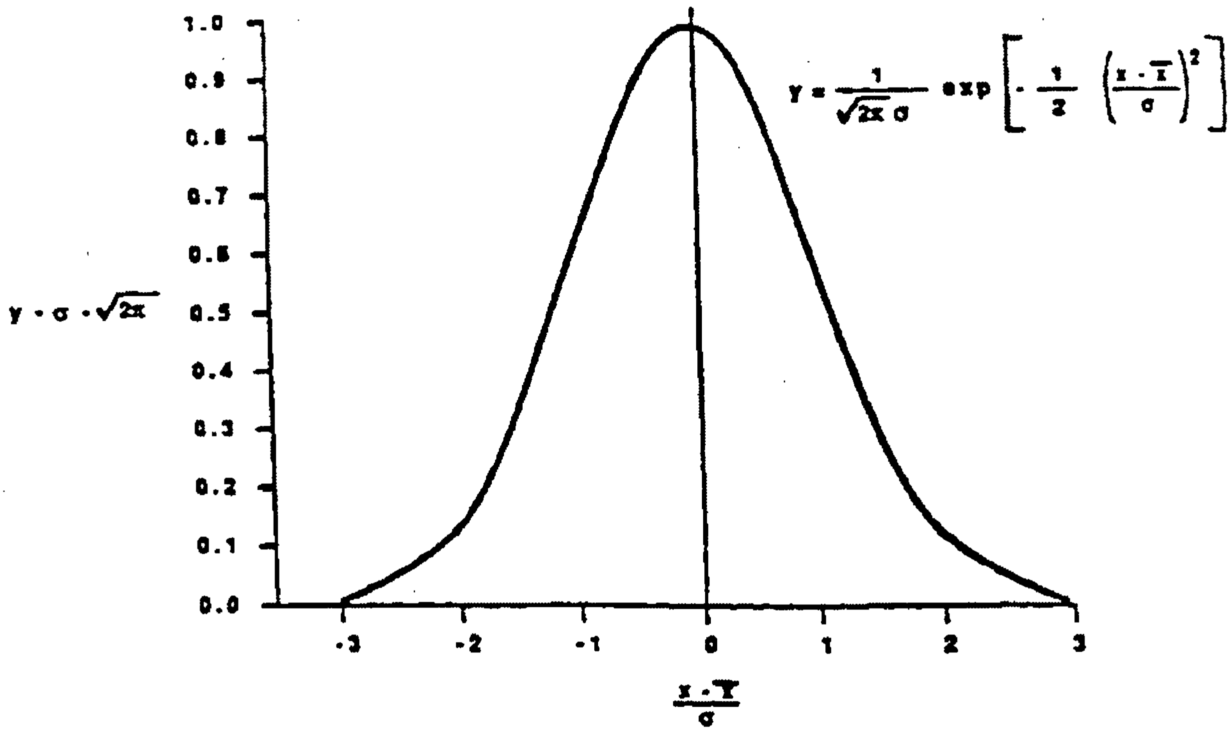
Instantaneous View of Plume



This figure represents a snapshot of a projection of a plume on the horizontal plane. As it moves downwind, the plume meanders about the average wind direction and broadens (adapted from Reference 18).

Figure B-2

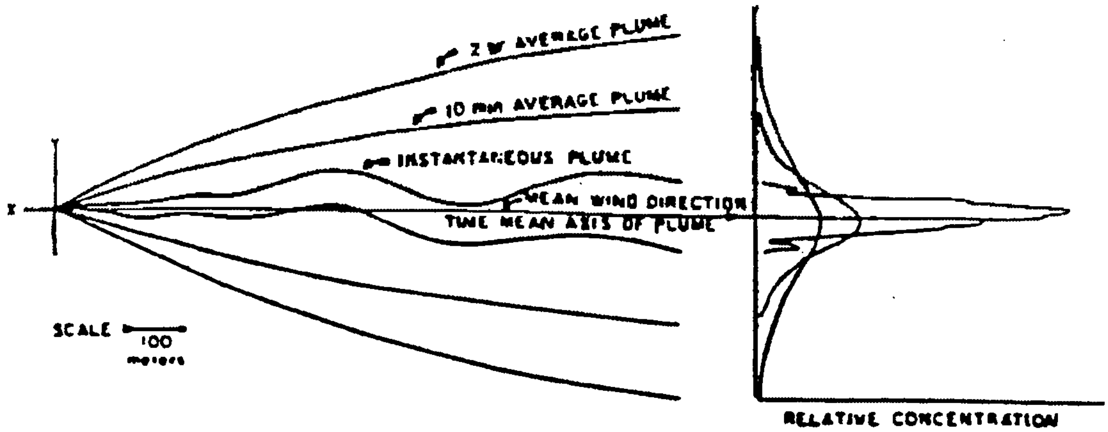
A Gaussian Curve



(Adapted from Reference 24 of Chapter 9, Page 61.)

Figure B-3

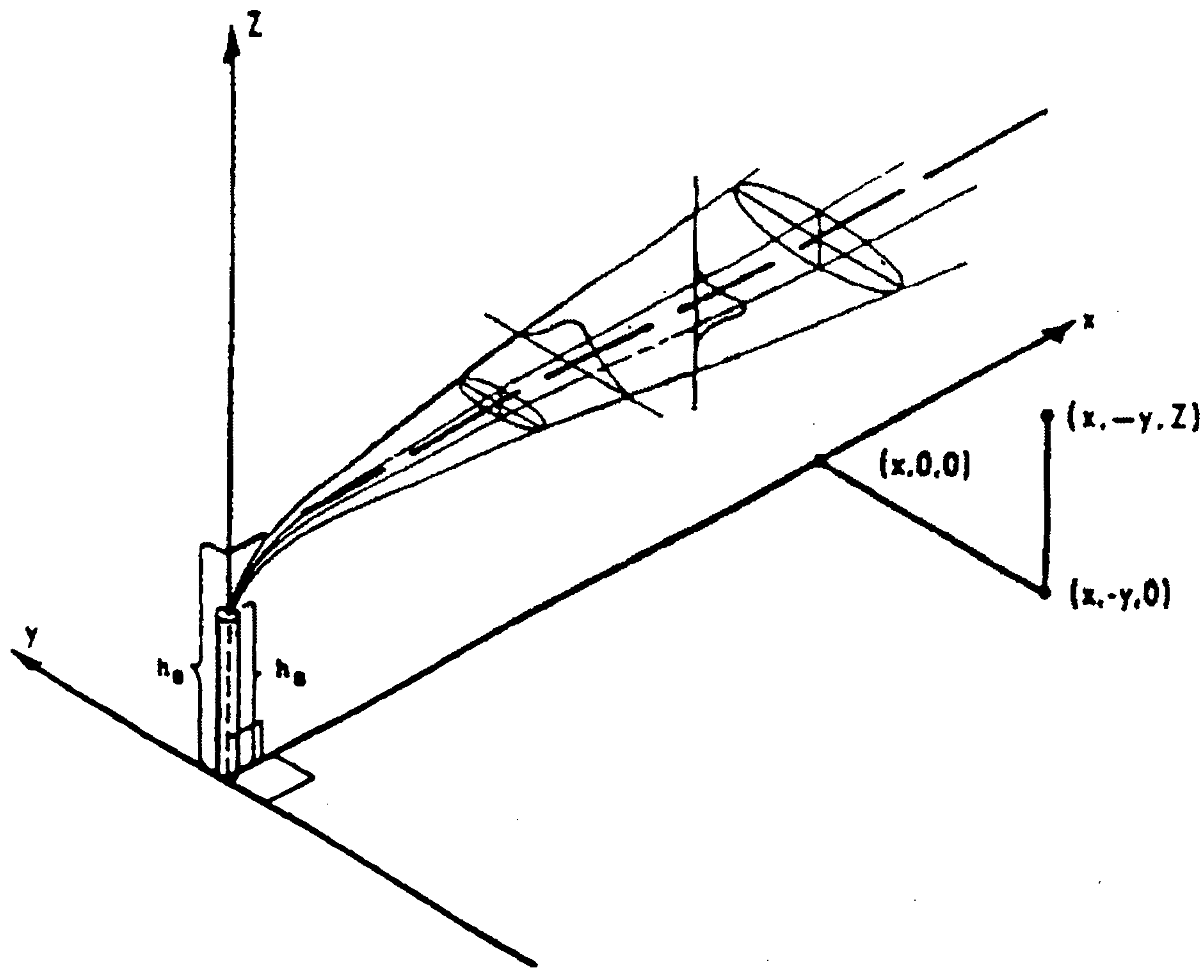
Effect of Observation Period on Plume Shape



This sketch represents the approximate outlines of a smoke plume observed instataneously and averaged over periods of 10 minutes and 2 hours. The diagram on the right shows the corresponding cross plume distribution patterns. The plume width increases as the period of observation increases (from Reference 18).

Figure B-4

A Gaussian Plume



This sketch illsutrates a plume characterized by Equation B-9. The plume is moving downwind in the x direction. Both the horizontal dispersion parameter sz increases as x increases. The reflected component has been omitted in this illustration (adapted from Reference 24).

APPENDIX C

GENERIC DATA

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LIST OF TABLES

APPENDIX C
GENERIC DATA

C.1 INTRODUCTION

This appendix contains generic (common to one or more of the stations) offsite dose calculation parameter factors, or values. Site specific factors are provided in the station annex Appendix F. The factors described in section C.2 are found in the prescribed references and are not repeated in this appendix.

C.2 10CFR50 DOSE COMMITMENT FACTORS

With the exception of H-3, the dose commitment factors for 10CFR50 related calculations are exactly those provided in Regulatory Guide 1.109 (Reference 6). The following table lists the parameters and the corresponding data tables in the RG 1.109:

PATHWAY	ADULT	TEENAGER	CHILD	INFANT
Inhalation	RG 1.109:Table E-7	RG 1.109:Table E-8	RG 1.109:Table E-9	RG 1.109:Table E-10
Ingestion	RG 1.109:Table E-11	RG 1.109:Table E-12	RG 1.109:Table E-13	RG 1.109:Table E-14

These tables are contained in Regulatory Guide 1.109 (Reference 6). Each table (E-7 through E-14) provides dose factors for seven organs for each of 73 radionuclides. For radionuclides not found in these tables, dose factors will be derived from ICRP 2 (Reference 50) or NUREG-0172 (Reference 51). The values for H-3 are taken from NUREG-4013 (Reference 107).

Table C-1
Miscellaneous Dose Assessment Factors -
Environmental Parameters

Parameter	Value	Comment	Equation	Basis[a]
f_g	0.76		A-10, A-11	A
f_L	1.0		A-10, A-11	A
f_p	1.0		A-12, A-14	A
f_s	1.0		A-12, A-14	A
t_b	262,800 hrs	30 years	A-8	C
t_f	48 hrs	Cow Milk Pathway	A-12	A
t_f	480 hrs	Cow Meat Pathway	A-14	A
t_h	1440 hrs	60 days for produce	A-10	A
t_h	2160 hrs	90 days for produce	A-12, A-14	A
t_L	24 hrs	1 day for leafy vegetables	A-10	A
Q_F	50 Kg/da		A-12, A-13, A-14, A-15	B
r	1.0	For Iodines	A-10, A-12, A-14	A
r	0.2	For Particulates	A-10, A-12, A-14	A
Y_p	0.7 Kg/m^2		A-12, A-14	A
Y_s	2.0 Kg/m^2		A-12, A-14	A
Y_v	2.0 Kg/m^2		A-10	A
λ_w	0.0021 hr^{-1}		A-10, A-12, A-14	A
H	8 gm/m^3	Absolute Atmospheric Humidity	A-11, A-13, A-15	D

[a]Basis key:

A: Reference 6, Table E-15.
B: Reference 6, Table E-3.
C: The parameter t_b is taken as the midpoint of plant operating life (based upon an assumed 60 year plant operating lifetime).
D: Reference 14, Section 5.3.1.3.

Table C-2
Miscellaneous Dose Assessment Factors -
Consumption Parameters

Type	Variable	Infant	Child	Teenager	Adult
Air	BR_a (m^3/yr)	1400	3700	8000	8000
Milk	U_{am} (L/yr)	330	330	400	310
Produce	U_a^S (Kg/yr)	0	520	630	520
Leafy Vegetables	U_a^L (Kg/yr)	0	26	42	64
Meat	U_{af} (Kg/yr)	0	41	65	110
Water	U_a^W (L/yr)	330	510	510	730
Fish	U_a^F (Kg/yr)	0	6.9	16	21

From Regulatory Guide 1.109, Table E-5.

Table C-3
Stable Element Transfer Data

Element	F_f Meat (d/kg)	F_M(Cow) Milk (d/L)	Reference
H	1.2E-02	1.0E-02	6
Be	1.5E-03	3.2E-03	Footnote 1
C	3.1E-02	1.2E-02	6
F	2.9E-03	1.4E-02	Footnote 2
Na	3.0E-02	4.0E-02	6
Mg	1.5E-03	3.2E-03	Footnote 1
Al	1.5E-02	1.3E-03	Footnote 3
P	4.6E-02	2.5E-02	6
Cl	2.9E-03	1.4E-02	Footnote 2
Ar	NA	NA	NA
K	1.8E-02	7.2E-03	16
Ca	1.6E-03	1.1E-02	16
Sc	2.4E-03	7.5E-06	Footnote 4
Ti	3.4E-02	5.0E-06	Footnote 5
V	2.8E-01	1.3E-03	Footnote 6
Cr	2.4E-03	2.2E-03	6
Mn	8.0E-04	2.5E-04	6
Fe	4.0E-02	1.2E-03	6
Co	1.3E-02	1.0E-03	6
Ni	5.3E-02	6.7E-03	6
Cu	8.0E-03	1.4E-02	6
Zn	3.0E-02	3.9E-02	6
Ga	1.5E-02	1.3E-03	Footnote 3
Ge	9.1E-04	9.9E-05	Footnote 7
As	1.7E-02	5.0E-04	Footnote 8
Se	7.7E-02	1.0E-03	Footnote 9
Br	2.9E-03	2.2E-02	F_f Footnote 2;F_M from Ref. 16
Kr	NA	NA	NA
Rb	3.1E-02	3.0E-02	6
Sr	6.0E-04	8.0E-04	6
Y	4.6E-03	1.0E-05	6
Zr	3.4E-02	5.0E-06	6
Nb	2.8E-01	2.5E-03	6
Mo	8.0E-03	7.5E-03	6
Tc	4.0E-01	2.5E-02	6
Ru	4.0E-01	1.0E-06	6
Rh	1.5E-03	1.0E-02	6
Pd	5.3E-02	6.7E-03	Footnote 10
Cd	3.0E-02	2.0E-02	Footnote 11
In	1.5E-02	1.3E-03	Footnote 3
Sn	9.1E-04	9.9E-05	Footnote 7
Sb	5.0E-03	2.0E-05	98
Ag	1.7E-02	5.0E-02	6
Te	7.7E-02	1.0E-03	6
I	2.9E-03	6.0E-03	6
Xe	NA	NA	NA
Cs	4.0E-03	1.2E-02	6
Ba	3.2E-03	4.0E-04	6
La	2.0E-04	5.0E-06	6
Ce	1.2E-03	1.0E-04	6
Pr	4.7E-03	5.0E-06	6
Nd	3.3E-03	5.0E-06	6

Table C-3 (Cont'd)
Stable Element Transfer Data

Element	F_f Meat (d/kg)	F_M (Cow) Milk (d/L)	Reference
Pm	2.9E-04	2.0E-05	16
Sm	2.9E-04	2.0E-05	16
Eu	2.9E-04	2.0E-05	16
Gd	2.9E-04	2.0E-05	16
Dy	2.9E-04	2.0E-05	16
Er	2.9E-04	2.0E-05	16
Tm	2.9E-04	2.0E-05	16
Yb	2.9E-04	2.0E-05	16
Lu	2.9E-04	2.0E-05	16
Hf	3.4E-02	5.0E-06	Footnote 5
Ta	2.8E-01	1.3E-03	F_M - Ref.16; F_f -Footnote 6
W	1.3E-03	5.0E-04	6
Re	1.0E-01	1.3E-03	F_M - Ref.16; F_f -Footnote 12
Os	2.2E-01	6.0E-04	Footnote 13
Ir	7.3E-03	5.5E-03	Footnote 14
Pt	5.3E-02	6.7E-03	Footnote 10
Au	1.3E-02	3.2E-02	Footnote 15
Hg	3.0E-02	9.7E-06	F_M - Ref.16; F_f -Footnote 11
Tl	1.5E-02	1.3E-03	F_M - Ref.16; F_f -Footnote 3
Pb	9.1E-04	9.9E-05	98
Bi	1.7E-02	5.0E-04	98
Ra	5.5E-04	5.9E-04	98
Th	1.6E-06	5.0E-06	98
U	1.6E-06	1.2E-04	98
Np	2.0E-04	5.0E-06	6
Am	1.6E-06	2.0E-05	98

Notes:
1. NA = It is assumed that noble gases are not deposited on the ground.
2. Elements listed are those considered for 10CFR20 assessment and compliance.

Footnotes:

There are numerous F_f and F_M values that were not found in published literature. In these cases, the periodic table was used in conjunction with published values. The periodic table was used based on a general assumption that elements have similar characteristics when in the same column of the periodic table. The values of elements in the same column of the periodic table, excluding atomic numbers 58-71 and 90-103, were averaged then assigned to elements missing values located in the same column of the periodic table. This method was used for all columns where there were missing values except column 3A, where there was no data, hence, the average of column 2B and 4A were used.

1. Values obtained by averaging Reference 6 values of Ca, Sr, Ba and Ra.
2. F_f value obtained by assigning the Reference 6 value for I. F_M value obtained by averaging I(Ref. 6) and Br (Ref.16).
3. F_f values obtained by averaging Zn (Ref.6) and Pb (Ref. 98); there were novalues for elements in the same column; an average is taken between values of columns 2B and 4A on the periodic table. F_M values obtained by using the value for Tl from Reference 16.
4. Values obtained by averaging Reference 6 values of Y and La.
5. Values obtained by assigning the Reference 6 value for Zr.
6. F_f values obtained from Ref. 6 value for Nb. F_M values obtained by averaging values for Nb (Ref.6) and Ta (Ref. 16).
7. Values obtained from the Reference 6 values for Pb.
8. Values obtained from the Reference 6 values for Bi.
9. Values obtained from the Reference 6 values for Te.
10. Values obtained from the Reference 6 values for Ni.
11. F_f values obtained from Ref. 6 values for Zn. F_M values obtained by averaging the Reference 6 values for Zn and Hg.
12. Values obtained by averaging Reference 6 values for Mn, Tc, Nd and Reference 98 value for U.
13. Values obtained by averaging Reference 6 values from Fe and Ru.
14. Values obtained by averaging Reference 6 values from Co and Rh.
15. Values obtained by averaging Reference 6 values from Cu and Ag.

Table C-4
Atmospheric Stability Classes

Description	Pasquill Stability Class	$^{a}\sigma_{\theta}$ (degrees)	Temperature Change with Height (°C/100 m)
Extremely Unstable	A	>22.5	<-1.9
Moderately Unstable	B	17.5 to 22.5	-1.9 to -1.7
Slightly Unstable	C	12.5 to 17.5	-1.7 to -1.5
Neutral	D	7.5 to 12.5	-1.5 to -0.5
Slightly Stable	E	3.8 to 7.5	-0.5 to 1.5
Moderately Stable	F	2.1 to 3.8	1.5 to 4.0
Extremely Stable	G	0 to 2.1	>4.0

$^{a}\sigma_{\theta}$ is the standard deviation of horizontal wind direction fluctuation over a period of 15 minutes to 1 hour.

From Regulatory Guide 1.21, Table 4B.

Table C-5
Vertical Dispersion Parameters

Section 1

Vertical Dispersion Parameters σ_z

σ_z (meters) = aR^b+c with σ_z limited to a maximum of 1000 meters
R = downwind range (meters)
a, b and c have the values listed below:

Stability Class	100 < R < 1000 a	b	c	R > 1000 a	b	c
A	*	*	*	0.00024	2.094	-9.6
B	*	*	*	*	*	*
C	0.113	0.911	0.0	*	*	*
D	0.222	0.725	-1.7	1.26	0.516	-13.0
E	0.211	0.678	-1.3	6.73	0.305	-34.0
F	0.086	0.74	-0.35	18.05	0.18	-48.6
G	0.052	0.74	-0.21	10.83	0.18	-29.2

Basis: Reference 53, except for cases denoted by an asterisk. In these cases, the value of σ_z is obtained by a polynomial approximation to the data from Reference 53 (see Section 2 of this table). The functions given in Reference 50 are not used because they are discontinuous at 1000 meters.

Section 2

Polynomial Approximation for σ_z:
σ_z (meters) = $\exp[a_0 + a_1P + a_2P^2 + a_3P^3]$ with σ_z limited to a maximum of 1000 meters
$P = \log_e[R(\text{meters})]$

a_0, a_1, a_2 and a_3 have the values listed below:

Stability Class	Range	Coefficients	
A	100 ≤ R ≤ 1000	a_0 =	-10.50
		a_1 =	6.879
		a_2 =	-1.309
		a_3 =	0.0957
B	100 ≤ R ≤ 1000	a_0 =	-0.449
		a_1 =	0.218
		a_2 =	0.112
		a_3 =	-0.00517
B	R > 1000	a_0 =	319.148
		a_1 =	-127.806
		a_2 =	17.093
		a_3 =	-0.750
C	R > 1000	a_0 =	5.300
		a_1 =	-1.866
		a_2 =	0.3509
		a_3 =	-0.01514

Table C-6
Allowable Concentration of Dissolved or Entrained Noble Gases
Released from the Site to Unrestricted Areas in Liquid Waste

	Allowable Concentration (μCi/mL)[a]	
Nuclide	Braidwood Byron	Dresden LaSalle Quad Cities Zion
Kr 85m	2E-4	2E-4
Kr 85	2E-4	5E-4
Kr 87	2E-4	4E-5
Kr 88	2E-4	9E-5
Ar 41	2E-4	7E-5
Xe 131m	2E-4	7E-4
Xe 133m	2E-4	5E-4
Xe 133	2E-4	6E-4
Xe 135m	2E-4	2E-4
Xe 135	2E-4	2E-4

[a]Computed from Equation 17 of ICRP Publication 2 (Reference 47) adjusted for infinite cloud submersion in water, and R = 0.01 rem/week, ρ_w = 1.0 gm/cm^3, and P_w / P_t = 1.0.

Table C-7
Radiological Decay Constants (λ_i) in hr^{-1}

Isotope	Lambda		Isotope	Lambda		Isotope	Lambda
H-3	6.44E-06		As-73	3.6E-04		Tc-104	2.31E+00
Be-7	5.4E-04		As-74	1.62E-03		Ru-97	9.96E-03
C-14	1.38E-08		As-76	2.63E-02		Ru-103	7.34E-04
F-18	3.78E-01		As-77	1.79E-02		Ru-105	1.56E-01
Na-22	3.04E-05		Se-73	9.69E-02		Ru-106	7.84E-05
Na-24	4.62E-02		Se-75	2.41E-04		Rh-106	8.33E+01
Mg-27	4.39E+00		Br-77	1.21E-02		Pd-109	5.15E-02
Mg-28	3.31E-02		Br-80	2.38E+00		Cd-109	6.22E-05
Al-26	1.10E-10		Br-82	1.96E-02		In-111	1.02E-02
Al-28	1.85E+01		Br-83	2.90E-01		In-115M	1.59E-01
P-32	2.02E-03		Br-84	1.30E+00		In-116	7.66E-01
Cl-38	1.12E+00		Br-85	1.45E+01		Sn-113	2.51E-04
Ar-41	3.79E-01		Kr-79	1.98E-02		Sn-117M	2.12E-03
K-40	6.19E-14		Kr-81	3.77E-10		Sn-119M	9.85E-05
K-42	5.61E-02		Kr-83M	3.79E-01		Sb-117	2.48E-01
K-43	3.07E-02		Kr-85M	1.55E-01		Sb-122	1.07E-02
Ca-47	6.37E-03		Kr-85	7.38E-06		Sb-124	4.80E-04
Sc-44	1.76E-01		Kr-87	5.44E-01		Sb-125	2.86E-05
Sc-46M	1.33E+02		Kr-88	2.44E-01		Sb-126	2.33E-03
Sc-46	3.44E-04		Kr-90	7.71E+00		Ag-108M	6.23E-07
Sc-47	8.44E-03		Rb-84	8.78E-04		Ag-108	1.75E+01
Ti-44	1.67E-06		Rb-86	1.55E-03		Ag-110M	1.16E-04
V-48	1.81E-03		Rb-87	1.67E-15		Ag-111	3.87E-03
Cr-51	1.04E-03		Rb-88	2.33E+00		Te-121M	1.88E-04
Mn-52M	1.94E+00		Rb-89	2.69E+00		Te-121	1.72E-03
Mn-52	5.16E-03		Sr-85	4.45E-04		Te-123M	2.41E-04
Mn-54	9.23E-05		Sr-87M	2.47E-01		Te-125M	4.98E-04
Mn-56	2.69E-01		Sr-89	5.71E-04		Te-125	0.00E+00
Fe-52	8.37E-02		Sr-90	2.77E-06		Te-127M	2.65E-04
Fe-55	2.93E-05		Sr-91	7.29E-02		Te-127	7.41E-02
Fe-59	6.47E-04		Sr-92	2.56E-01		Te-129M	8.59E-04
Co-57	1.07E-04		Y-86	4.70E-02		Te-129	5.96E-01
Co-58	4.08E-04		Y-87	8.63E-03		Te-131M	2.31E-02
Co-60	1.50E-05		Y-88	2.71E-04		Te-131	1.66E+00
Ni-63	7.90E-07		Y-90	1.08E-02		Te-132	8.86E-03
Ni-65	2.75E-01		Y-91M	8.35E-01		Te-134	9.93E-01
Cu-64	5.46E-02		Y-91	4.94E-04		I-123	5.28E-02
Cu-67	4.67E-04		Y-92	1.96E-01		I-124	6.91E-03
Cu-68	8.31E+01		Y-93	6.86E-02		I-125	4.80E-04
Zn-65	1.18E-04		Zr-95	4.51E-04		I-130	5.61E-02
Zn-69M	5.04E-02		Zr-97	4.10E-02		I-131	3.59E-03
Zn-69	7.46E-01		Nb-94	3.90E-09		I-132	3.01E-01
Ga-66	7.37E-02		Nb-95	8.00E-03		I-133	3.33E-02
Ga-67	8.85E-03		Nb-97M	4.15E+01		I-134	7.89E-01
Ga-68	6.10E-01		Nb-97	5.76E-01		I-135	1.05E-01
Ga-72	4.91E-02		Mo-99	1.05E-02		Xe-127	7.93E-04
Ge-77	6.13E-02		Tc-99M	1.15E-01		Xe-129M	3.25E-03
As-72	2.67E-02		Tc-101	2.92E+00		Xe-131M	2.44E-03

Table C-7 (Cont'd)
Radiological Decay Constants (λ_i) in hr^{-1}

Isotope	Lambda		Isotope	Lambda
Xe-133M	1.32E-02		Yb-175	6.89E-03
Xe-133	5.51E-03		Lu-177	4.30E-03
Xe-135M	2.70E+00		Hf-181	6.81E-04
Xe-135	7.61E-02		Ta-182	2.52E-04
Xe-137	1.08E+01		Ta-183	5.78E-03
Xe-138	2.94E+00		W-187	2.91E-02
Cs-129	2.16E-02		Re-188	4.08E-02
Cs-132	4.46E-03		Os-191	1.88E-03
Cs-134	3.84E-05		Ir-194	3.62E-02
Cs-136	2.19E-03		Pt-195M	7.18E-03
Cs-137	2.62E-06		Pt-197	3.79E-02
Cs-138	1.29E+00		Au-195M	8.15E+01
Cs-139	4.41E+00		Au-195	1.58E-04
Ba-131	2.45E-03		Au-198	1.07E-02
Ba-133M	1.78E-02		Au-199	9.20E-03
Ba-133	7.53E-06		Hg-197	2.91E-02
Ba-135M	2.41E-02		Hg-203	6.20E-04
Ba-137M	1.63E+01		Tl-201	9.49E-03
Ba-137	0.00E+00		Tl-206	9.90E+00
Ba-139	4.99E-01		Tl-208	1.36E+01
Ba-140	2.26E-03		Pb-203	1.33E-02
Ba-141	2.27E+00		Pb-210	3.55E-06
Ba-142	3.88E+00		Pb-212	6.51E-02
La-140	1.72E-02		Pb-214	1.55E+00
La-142	4.35E-01		Bi-206	4.63E-03
Ce-139	2.10E-04		Bi-207	2.37E-06
Ce-141	8.88E-04		Bi-214	2.09E+00
Ce-143	2.10E-02		Ra-226	4.94E-08
Ce-144	1.02E-04		Th-232	5.63E-15
Pr-142	3.62E-02		U-238	1.77E-14
Pr-143	2.13E-03		Np-239	1.23E-02
Pr-144	2.40E+00		Am-241	1.83E-07
Nd-147	2.63E-03			
Nd-149	4.01E-01			
Pm-145	4.47E-06			
Pm-148M	6.99E-04			
Pm-148	5.38E-03			
Pm-149	1.31E-02			
Sm-153	1.48E-02			
Eu-152	5.82E-06			
Eu-154	8.99E-06			
Eu-155	1.59E-05			
Gd-153	1.20E-04			
Dy-157	8.60E-02			
Er-169	3.07E-03			
Er-171	9.22E-02			
Tm-170	2.25E-04			
Yb-169	9.03E-04			

(λ_i) =Radiological Decay Constant
= $0.693/T_i$

T_i = Radiological Half-Life in hours
(from Reference 70).
Except for Cu-68, Tc-104, Ba-137, Ta-183, TL-206, Bi-206 which are from References 100.

Table C-8
Bioaccumulation Factors (BF_i) to be Used
in the Absence of Site-Specific Data

Element	BF_i for Freshwater Fish (pCi/kg per pCi/L)	Reference
H	9.0E-01	6
Be	2.8E+01	Footnote 2
C	4.6E+03	6
F	2.2E+02	Footnote 16
Na	1.0E+02	6
Mg	2.8E+01	Footnote 2
Al	2.2E+03	Footnote 13
P	1.0E+05	6
Cl	2.2E+02	Footnote 16
Ar	NA	NA
K	1.0E+03	Footnote 1
Ca	2.8E+01	Footnote 2
Sc	2.5E+01	Footnote 3
Ti	3.3E+00	Footnote 4
V	3.0E+04	Footnote 5
Cr	2.0E+02	6
Mn	4.0E+02	6
Fe	1.0E+02	6
Co	5.0E+01	6
Ni	1.0E+02	6
Cu	5.0E+01	6
Zn	2.0E+03	6
Ga	2.2E+03	Footnote 13
Ge	2.4E+03	Footnote 12
As	3.3E+04	Footnote 14
Se	4.0E+02	Footnote 15
Br	4.2E+02	6
Kr	NA	NA
Rb	2.0E+03	6
Sr	3.0E+01	6
Y	2.5E+01	6
Zr	3.3E+00	6
Nb	3.0E+04	6
Mo	1.0E+01	6
Tc	1.5E+01	6
Ru	1.0E+01	6
Rh	1.0E+01	6
Pd	1.0E+02	Footnote 9
Cd	2.0E+03	Footnote 11
In	2.2E+03	Footnote 13
Sn	2.4E+03	Footnote 12
Sb	1.0E+00	98
Ag	2.3E+00	56
Te	4.0E+02	6
I	1.5E+01	6
Xe	NA	NA
Cs	2.0E+03	6
Ba	4.0E+00	6
La	2.5E+01	6
Ce	1.0E+00	6
Pr	2.5E+01	6
Nd	2.5E+01	6
Pm	3.0E+01	98
Sm	3.0E+01	Footnote 3

Table C-8 (Cont'd)
Bioaccumulation Factors (BF_i) to be Used in the Absence of Site-Specific Data

Element	BF_i for Freshwater Fish (pCi/kg per pCi/L)	Reference
Eu	1.0E+02	Footnote 3
Gd	2.6E+01	Footnote 3
Dy	2.2E+03	Footnote 3
Er	3.3E+04	Footnote 3
Tm	4.0E+02	Footnote 3
Yb	2.2E+02	Footnote 3
Lu	2.5E+01	Footnote 3
Hf	3.3E+00	Footnote 4
Ta	3.0E+04	Footnote 5
W	1.2E+03	6
Re	2.1E+02	Footnote 6
Os	5.5E+01	Footnote 7
Ir	3.0E+01	Footnote 8
Pt	1.0E+02	Footnote 9
Au	2.6E+01	Footnote 10
Hg	2.0E+03	Footnote 11
Tl	2.2E+03	Footnote 13
Pb	3.0E+02	98
Bi	2.0E+01	98
Ra	5.0E+01	98
Th	3.0E+01	98
U	1.0E+01	98
Np	1.0E+01	6
Am	3.0E+01	98

Footnotes:
NA = It is assumed that noble gases are not accumulated.

In Reference 6, see Table A-1.

A number of bioaccumulation factors could not be found in literature. In this case, the periodic table was used in conjunction with published element values. This method was used for periodic table columns except where there were no values for column 3A so the average of columns 2B and 4A was assigned.

1. Value is the average of Reference 6 values in literature for H, Na, Rb and Cs.
2. Value is the average of Ref. 6 values in literature for Sr, Ba and Ref. 98 values for Ra.
3. Value is the same as the Reference 6 value used for Y.
4. Value is the same as the Reference 6 value used for Zr.
5. Value is the same as the Reference 6 value used for Nb.
6. Value is the average of Reference 6 values in literature for Mn and Tc.
7. Value is the average of Reference 6 values in literature for Fe and Ru.
8. Value is the average of Reference 6 values in literature for Co and Rh.
9. Value is the same as the Reference 6 value used for Ni.
10. Value is the average of Reference 6 values in literature for Cu and Reference 56 value for Ag.
11. Value used is the same as the Reference 6 value used for Zn.
12. Value is the average of Reference 6 value in literature for C and Reference 98 value for Pb.
13. Value is the average of columns 2B and 4A, where column 2B is the "Reference 6 value for Zn" and column 4A is the average of "Reference 6 value for C and Reference 98 value for Pb".
14. Value is the average of Ref. 6 value found in literature for P and the Ref. 98 values for Bi and Sb.
15. Value is the same as the Reference 6 value used for Te.
16. Value is the average of Reference 6 values found in literature for Br and I.

Table C-9
Dose Factors for Noble Gases

Nuclide	Beta Air Dose Factor N_i (mrad/yr per uCi/m^3)	Beta Skin Dose Factor L_i (mrem/yr per uCi/m^3)	Gamma Air Dose Factor M_i (mrad/yr per uCi/m^3)	Gamma Total Body Dose Factor K_i (mrem/yr per uCi/m^3)
Kr-83m	2.88E+02	---	1.93E+01	7.56E-02
Kr-85m	1.97E+03	1.46E+03	1.23E+03	1.17E+03
Kr-85	1.95E+03	1.34E+03	1.72E+01	1.61E+01
Kr-87	1.03E+04	9.73E+03	6.17E+03	5.92E+03
Kr-88	2.93E+03	2.37E+03	1.52E+04	1.47E+04
Kr-89	1.06E+04	1.01E+04	1.73E+04	1.66E+04
Kr-90	7.83E+03	7.29E+03	1.63E+04	1.56E+04
Xe-131m	1.11E+03	4.76E+02	1.56E+02	9.15E+01
Xe-133m	1.48E+03	9.94E+02	3.27E+02	2.51E+02
Xe-133	1.05E+03	3.06E+02	3.53E+02	2.94E+02
Xe-135m	7.39E+02	7.11E+02	3.36E+03	3.12E+03
Xe-135	2.46E+03	1.86E+03	1.92E+03	1.81E+03
Xe-137	1.27E+04	1.22E+04	1.51E+03	1.42E+03
Xe-138	4.75E+03	4.13E+03	9.21E+03	8.83E+03
Ar-41	3.28E+03	2.69E+03	9.30E+03	8.84E+03

Source: Table B-1 of Reference 6.

Table C-10
External Dose Factors for Standing on Contaminated Ground
DFG_{ij} (mrem/hr per pCi/ m^2)

Element	Whole Body Dose Factor	Reference	Element	Dose Factor	Reference
H-3	0.00E+00	6	Be-7	5.95E-10	99
C-14	0.00E+00	6	F-18	1.19E-08	99
Na-22	2.42E-08	99	Na-24	2.50E-08	6
Mg-27	1.14E-08	99	Mg-28	1.48E-08	99
Al-26	2.95E-08	99	Al-28	2.00E-08	99
P-32	0.00E+00	6	Cl-38	1.70E-08	99
Ar-41	1.39E-08	99	K-40	2.22E-09	99
K-42	4.64E-09	99	K-43	1.19E-08	99
Ca-47	1.14E-08	99	Sc-44	2.50E-08	99
Sc-46m	1.21E-09	99	Sc-46	2.24E-08	99
Sc-47	1.46E-09	99	Ti-44	1.95E-09	99
V-48	3.21E-08	99	Cr-51	2.20E-10	6
Mn-52m	2.79E-08	99	Mn-52	3.80E-08	99
Mn-54	5.80E-09	6	Mn-56	1.10E-08	6
Fe-52	9.12E-09	99	Fe-55	0.00E+00	6
Fe-59	8.00E-09	6	Co-57	1.65E-09	99
Co-58	7.00E-09	6	Co-60	1.70E-08	6
Ni-63	0.00E+00	6	Ni-65	3.70E-09	6
Cu-64	1.50E-09	6	Cu-67	1.52E-09	99
Cu-68	8.60E-09[1]	--	Zn-65	4.00E-09	6
Zn-69m	5.06E-09	99	Zn-69	0.00E+00	6
Ga-66	2.70E-08	99	Ga-67	1.89E-09	99
Ga-68	1.24E-08	99	Ga-72	3.00E-08	99
Ge-77	1.34E-08	99	As-72	2.23E-08	99
As-73	1.16E-10	99	As-74	9.41E-09	99
As-76	6.46E-09	99	As-77	1.79E-10	99
Se-73	1.38E-08	99	Se-75	4.98E-09	99
Br-77	3.84E-09	99	Br-80	2.01E-09	99
Br-82	3.00E-08	99	Br-83	6.40E-11	6
Br-84	1.20E-08	6	Br-85	0.00E+00	6
Kr-79	3.07E-09	99	Kr-81	1.59E-10	99
Kr-83m	1.42E-11	99	Kr-85m	2.24E-09	99
Kr-85	1.35E-10	99	Kr-87	1.03E-08	99
Kr-88	2.07E-08	99	Kr-90	1.56E-08	99
Rb-84	1.07E-08	99	Rb-86	6.30E-10	6
Rb-87	0.00E+00	99	Rb-88	3.50E-09	6
Rb-89	1.50E-08	6	Sr-85	6.16E-09	99
Sr-87m	3.92E-09	99	Sr-89	5.60E-13	6
Sr-90	1.84E-11	99	Sr-91	7.10E-09	6
Sr-92	9.00E-09	6	Y-86	4.00E-08	99
Y-87	5.53E-09	99	Y-88	2.88E-08	99
Y-90	2.20E-12	6	Y-91m	3.80E-09	6
Y-91	2.40E-11	6	Y-92	1.60E-09	6
Y-93	5.70E-10	6	Zr-95	5.00E-09	6
Zr-97	5.50E-09	6	Nb-94	1.84E-08	99
Nb-95	5.10E-09	6	Nb-97m	8.57E-09	99
Nb-97	8.48E-09	99	Mo-99	1.90E-09	6
Tc-99m	9.60E-10	6	Tc-101	2.70E-09	6
Tc-104	1.83E-08[1]	--	Ru-97	2.99E-09	99
Ru-103	3.60E-09	6	Ru-105	4.50E-09	6
Ru/Rh-106	5.76E-09[3]	6, 99	Pc-109	3.80E-10	99
Cc-109	1.12E-10	99	In-111	5.11E-09	99
In-115m	2.01E-09	99	In-116	0.00E+00[2]	--
Sn-113	1.15E-09	99	Sn-117m	1.96E-08	99
Sn-119m	7.05E-11	99	Sb-117	0.00E+00[2]	--
Sb-122	2.71E-09[1]	--	Sb-124	1.16E-08[1]	--
Sb-125	4.56E-09	99	Sb-126	7.13E-10	99
Ag-108m	1.92E-08	99	Ag-108	1.14E-09	99
Ag-110m	1.80E-08	6	Ag-111	6.75E-10	99
Te-121m	2.65E-09	99	Te-121	6.75E-09	99
Te-123m	1.88E-09	99	Te-125m	3.50E-11	6
Te-125	0.00E+00[2]	--	Te-127m	1.10E-12	6
Te-127	1.00E-11	6	Te-129m	7.70E-10	6
Te-129	7.10E-10	6	Te-131m	8.40E-09	6

Table C-10 (cont.)
External Dose Factors for Standing on Contaminated Ground
DFG_{ij} (mrem/hr per pCi/ m^2)

Element	Whole Body Dose Factor	Reference	Element	Dose Factor	Reference
Te-131	2.20E-09	6	Te-I-132	3.40E-09[5]	6
Te-134	1.05E-08	99	I-123	2.12E-09	99
I-124	1.23E-08	99	I-125	2.89E-10	99
I-130	1.40E-08	6	I-131	2.80E-09	6
I-133	3.70E-09	6	I-134	1.60E-08	6
I-135	1.20E-08	6	Xe-127	3.44E-09	99
Xe-129m	5.57E-10	99	Xe-131m	2.13E-10	99
Xe-133m	4.81E-10	99	Xe-133	5.91E-10	99
Xe-135m	5.23E-09	99	Xe-135	3.36E-09	99
Xe-137	4.26E-09	99	Xe-138	1.30E-08	99
Cs-129	3.39E-09	99	Cs-132	8.40E-09	99
Cs-134	1.20E-08	6	Cs-136	1.50E-08	6
Cs-137/Ba-137m	1.14E-08[4]	6, 99	Cs-138	2.10E-08	6
Cs-139	5.15E-09	99	Ba-131	5.74E-09	99
Ba-133m	8.10E-10	99	Ba-133	4.85E-09	99
Ba-135m	7.26E-10	99	Ba-137m	7.17E-09	99
Ba-137	0.00E+00[2]	--	Ba-139	2.40E-09	6
Ba-La-140	1.71E-08[6]	6	Ba-141	4.30E-09	6
Ba-142	7.90E-09	6	La-142	1.50E-08	6
Ce-139	2.04E-09	99	Ce-141	5.50E-10	6
Ce-143	2.20E-09	6	Ce-Pr-144	5.20E-10[7]	6
Pr-142	1.84E-09	99	Pr-143	0.00E+00	6
Nc-147	1.00E-09	6	Nc-149	5.32E-09	99
Pm-145	3.38E-10	99	Pm-148m	2.35E-08	99
Pm-148	7.22E-09	99	Pm-149	5.32E-10	99
Sm-153	8.95E-10	99	Eu-152	1.30E-08	99
Eu-154	1.41E-08	99	Eu-155	8.27E-10	99
Gc-153	1.46E-09	99	Dy-157	4.39E-09	99
Er-169	6.12E-14	99	Er-171	5.11E-09	99
Tm-170	3.41E-10	99	Yb-169	4.12E-09	99
Yb-175	4.94E-10	99	Lu-177	4.60E-10	99
Hf-181	6.67E-09	99	Ta-182	1.42E-08	99
Ta-183	2.93E-09[1]	--	W-187	3.10E-09	6
Re-188	1.89E-09	99	Os-191	9.83E-10	99
Ir-194	2.31E-09	99	Pt-195m	9.79E-10	99
Pt-197	3.57E-10	99	Au-195m	2.54E-09	99
Au-195	1.14E-09	99	Au-198	5.19E-09	99
Au-199	1.18E-09	99	Hg-197	9.33E-10	99
Hg-203	2.89E-09	99	Tl-201	1.24E-09	99
Tl-206	0.00E+00[2]	--	Tl-208	3.58E-08	99
Pb-203	3.88E-09	99	Pb-210	3.57E-11	99
Pb-212	1.91E-09	99	Pb-214	3.18E-09	99
Bi-206	3.74E-08	99	Bi-207	1.77E-08	99
Bi-214	1.71E-08	99	Ra-226	8.78E-11	99
Th-232	8.14E-12	99	U-238	7.98E-12	99
Np-239	9.50E-10	6	Am-241	3.48E-10	99

1 Valued derived by comparing the percentage and MeV of the nuclide's gammas and then comparing to Cesium-137, as a value was not available in the literature.

2 0.0 due to low yield and short half life. A value was not available in the literature.

3 Value is the sum of Ru-106 (1.50E-9) and Rh-106 (4.26E-9). The Rh-106 value is from Reference 99 and the Ru-106 value is from Reference 6.

4 Value is the sum of Cs-137 (4.20E-9) and Ba-137m (7.17E-9). The values are from references 6 and 99, respectively.

5 Value is the sum of Te-132 (1.70E-9) and I-132 (1.70E-9).

6 Value is the sum of Ba-140 (2.10E-9) and La-140 (1.50E-8) from reference 6. In Reference 6, see Table E-6.

7 Value is the sum of Ce-144 (3.20E-10) and Pr-144 (2.00E-10) from reference 6.

Note: Dose assessments for 10CFR20 and 40CFR190 compliance are made for an adult only.

Dose assessments for 10CFR50 Appendix are made using dose factors of Regulatory Guide 1.109 (Reference 6) for all age groups.

Table C-11

Sector Code Definitions

Sector Code	Sector Direction	Angle from North (Degrees)
A	N	$348.75 < \theta \leq 11.25$
B	NNE	$11.25 < \theta \leq 33.75$
C	NE	$33.75 < \theta \leq 56.25$
D	ENE	$56.25 < \theta \leq 78.75$
E	E	$78.75 < \theta \leq 101.25$
F	ESE	$101.25 < \theta \leq 123.75$
G	SE	$123.75 < \theta \leq 146.25$
H	SSE	$146.25 < \theta \leq 168.75$
J	S	$168.75 < \theta \leq 191.25$
K	SSW	$191.25 < \theta \leq 213.75$
L	SW	$213.75 < \theta \leq 236.25$
M	WSW	$236.25 < \theta \leq 258.75$
N	W	$258.75 < \theta \leq 281.25$
P	WNW	$281.25 < \theta \leq 303.75$
Q	NW	$303.75 < \theta \leq 326.25$
R	NNW	$326.25 < \theta \leq 348.75$

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RADIOACTIVE EFFLUENT TREATMENT AND MONITORING

10.1 AIRBORNE RELEASES

10.1.1 System Description

During operation of the ventilation systems, the principal release points for potentially radioactive airborne effluents are the two auxiliary building ventilation stacks (Unit 1 and Unit 2). Each is classified as a ground level release.

These ventilation systems maintain acceptable ambient air temperatures for equipment operation and personnel habitability, they provide air flow as needed for contamination control purposes, from lesser contamination potential to areas of greater contamination potential, and they provide bulk exhaust flow for ease of effluent control, sampling, and quantification.

The Unit 2 Aux Bldg (AB) ventilation stack provides the release point for airborne effluent from the Aux Bldg, Fuel Building, and the Containments (when the Containment Purge Fans are not in operation). Operation of the AB ventilation system is administratively controlled to ensure that at least one (of 3) exhaust fan is operating when a supply fan is running.

During times when the Containment Purge Fans are operating; the Unit 1 AB ventilation stack provides the release point for airborne effluent from the Unit 1 Containment, and the Unit 2 AB ventilation stack provides the release point for airborne effluent from the Unit 2 Containment.

The Containment Purge Exhaust Fans provide the necessary forced exhaust ventilation for the containment building during times when the construction doors are open. The Containment Purge Exhaust fans discharge to the AB ventilation stacks upstream of the vent stack radiological effluent release monitors. When the containment construction doors are closed, either the containment purge system or the AB ventilation is adequate to maintain forced exhaust ventilation of the containment building. The operation of the construction doors and the containment purge system will be controlled administratively.

Gaseous effluent flow paths via the ventilation systems are described in the Defueled Safety Analysis Report (DSAR).

10.1.1.1 Ventilation Exhaust Treatment System

Ventilation exhaust treatment systems are designed and installed to reduce radioactive material in particulate form in gaseous effluents by passing ventilation through HEPA and/or pre-filters prior to release to the environment. Such a system is not considered to have any effect on noble gas effluents.

10.1.2 Radiation Monitors

Pertinent information and available diagram(s) are provided in the DSAR.

10.1.2.1 Auxiliary Building Ventilation Stack Effluent Monitors

2RIA-PR49 (Unit 2) continuously monitors the final effluent from the Aux Bldg and Fuel Bldg, and the containments when the associated Purge Fans are not in operation, for beta, particulate and noble gas.

The monitor outputs data and alarms to the central control console in the control room and Guard-It Alarm system. The monitor also outputs flow and instrument fail indications.

10.1.2.2 Fuel Building Effluent Air Monitors

DELETED

10.1.2.3 Containment Purge Effluent Monitors

1RIA-PR49 (Unit 1) continuously monitors the final effluent from the Unit 1 containment when the associated Purge Fan is in operation for beta particulate. The monitor outputs its alarms to the Guard-It Alarm system.

2RIA-PR49A (Unit 2) continuously monitors the final effluent from the Unit 2 containment when the associated Purge Fan is in operation for beta particulate. The monitor outputs data and alarms to the central control console in the control room and Guard-It Alarm system.

10.1.3 Alarm and Trip Setpoints

10.1.3.1 Setpoint Calculation

Airborne effluent radiation monitor alarm setpoints should be established as follows:

$$P_{MP} \leq Q_{tv} \times 1/F^{P} \times K^{P} \times C^{M} \quad (10\text{-}1)$$

P_{MP} = Setpoint for monitor, M, on release path, P. [cpm]

Q_{tv} = Total Allowed Release Rate, Vent Release [μCi/sec]

F^{P} = Flow rate through Release Path, P. [cc/sec]

K^{P} = Factor to apportion a fraction of the total release rate, Q_{tv}, to release path, P.

C^{M} = Conversion Factor for monitor, M [cpm per μCi/cc]

10.1.3.2 Release Limits

Alarm and trip setpoints for noble gas effluent monitors are established to indicate serious radiological events that coincide with Defueled Station Emergency Plan (DSEP) EALs and associated emergency classification.

10.1.3.3 Release Mixture

In the determination of alarm and trip setpoints, the noble gas mixture in the station gaseous effluent is assumed to be 100% Kr85. Zion Station has not operated since February of 1997 and is permanently defueled. Subsequent, decay and lack of production results in the presence of only the longer lived Kr85 in the spent fuel rods.

10.1.3.4 Conversion Factors

Calibration factors/monitor response variables for noble gas monitors are based on the energy characteristics of 100% Kr85.

10.1.3.5 HVAC Flow Rates

Flow rates for aux vent stack release are provided by flow measuring instrumentation. However, flow rates out the vent stack can be calculated based on the number of operating fans in the monitored flow path.

F_M	=	$\Sigma F_{ip} \times N_i$	(10-4)
F_M	=	Total Flow In Monitored Flow Path	[cc/sec]
F_{ip}	=	Flow from fan i in path p.	[cc/sec]
N_i	=	Number of fans, in operation	

The maximum flow for each fan is used for setpoint calculations because this maximizes the flow, establishing a conservative, "worst case" release rate/concentration for setpoint determination.

Pertinent data for the fans is provided in Table 10-2.

HVAC flows for the remaining monitors are conservatively fixed at upper bound values.

10.1.4 Allocation of Fuel Building Effluents to Common Release Points

Radioactive gaseous effluents released from the Fuel Building (FB) are routed to the Unit 2 vent stack via the AB Ventilation System. *The Unit 1 Vent stack is isolated from the AB* Ventilation System and therefore is not a release point for the Fuel Building. During operation of the Unit 1 Purge fans, slight communication between the FB and the Unit 1 Containment may exist due to building and ventilation ductwork leakage. Subsequently, during operation of the Unit 1 Purge fans, noble gas effluent releases from the Fuel Building are estimated for the Unit 1 Stack based on a percentage of the measured gas concentration by the Unit 2 Stack monitor (or samples, as required).

10.2 LIQUID RELEASES

10.2.1 System Description

The liquid waste system diagrams are provided in the DSAR.

The liquid radwaste treatment system is designed and installed to allow for a reduction if needed, in the concentration of radioactive liquid effluents by filtration, providing for retention or holdup and/or providing for treatment by demineralizers. The overall purpose is to ensure releases to the lake do not exceed any concentration release limit, and liquid effluent releases to the public are ALARA.

10.2.1.1 Lake Release Tanks (Boric Acid Tanks)

There are two Boric Acid Tanks (35,000 gallon capacity each) which receive processed liquid waste before discharge to Lake Michigan.

10.2.1.2 Holdup Tanks

There are three Holdup Tanks (120,000-gallon capacity each) which receive and store liquid waste from the Containments, AB and FB. The Holdup Tanks (HUTS) will store the liquid waste water until it can be processed for release to Lake Michigan or removed from the site.

10.2.1.3 Turbine Building Fire Sump

The turbine building floor and equipment drain tanks, the service water return tank, miscellaneous auxiliary building HVAC condensate drains, and the fuel pool cooling tower blowdown are discharged to the fire sump for processing by the waste water treatment facility and ultimate discharge into Lake Michigan. The discharge constitutes a potential for very low level radioactive release.

10.2.2 Radiation Monitors

10.2.2.1 Lake Release Tank Monitors

0RT-PR04 monitors releases from the Lake Release Tanks (Boric Acid Tanks). On high alarm, the monitor automatically initiates closure of a valve to prevent further releases. The monitor and valve are located inside the AB in an arrangement that allows closure prior to exceeding release limits. The monitor setpoints are found by solving Equation 10-5 for release setpoint P.

Available information is provided in the DSAR.

10.2.2.2 Turbine Building Fire Sump Monitor

0RT-PR25 continuously monitors the discharge line from the fire sump pumps to the waste water treatment facility. On high alarm, the monitor automatically trips all of the fire sump pumps, thereby containing the liquid in the turbine building. The monitor setpoints are found by solving Equation 10-5 for release setpoint P.

Available information on the monitor is provided in the DSAR.

10.2.3 Alarm and Trip Setpoints

10.2.3.1 Setpoint Calculation

Alarm and trip setpoints of liquid effluent monitors at the principal release points are established to ensure that the concentration limits of the Technical Specifications and 10 CFR 20 are not exceeded in the unrestricted area. The monitor setpoints are found by solving Equation 10-5 for a conservative mixture of radionuclides found in liquid effluents.

$$P \leq K \times (C_{mpc})(F^d/F^r) \qquad (10\text{-}5)$$

P	Release Setpoint The alarm setpoint for radioactivity to be released in liquid effluents.	[μCi/mL]
C_{mpc}	Maximum Permissible Concentration	[μCi/mL]
F^d	Dilution Flow Rate The flow rate of the radwaste dilution stream (service water).	[gpm]
F^r	Discharge Flow Rate The flow rate from the Lake Release Tank (Boric Acid Tank) or fire sump as appropriate.	[gpm]
K	Factor of conservatism. K = 0.5 for Lake Release Tank (Boric Acid Tank) K = 1.0 for sump	

10.2.3.2 Discharge Flow Rates

10.2.3.2.1 Lake Release Tank (Boric Acid Tank) Discharge Flow Rate

Prior to each batch release, the water is recirculated, sampled, and analyzed.

(1)The results of the analysis of the waste sample determine the discharge rate of each batch as follows:

$$F^r_{max} = (C_{mpc})(F^d_{act}/C) \qquad (10\text{-}6)$$

F^r_{max} Maximum Permitted Discharge Flow Rate [gpm]

The maximum permitted flow rate from the Lake Release Tank (Boric Acid Tank). [gpm]

F^d_{act} Actual Dilution Flow Rate [gpm]

The actual flow rate of the radwaste dilution stream.

(1)C Sample Radioactivity Concentration [μCi/mL]

The concentration of radioactivity in The Lake Release Tank (Boric Acid Tank) based on measurements of a sample drawn from the tank.

C_{mpc} has the same definition as in Equation 10-5.

10.2.3.2.2 Turbine Building Fire Sump Discharge Flow Rate

This release path is a continuous discharge. Consequently, the release rate F^r in Equation 10-6 is set equal to maximum design capacity for the pumps on the effluent of the waste water treatment facility.

10.2.3.3 Release Limits

Release limits are determined from 10 CFR 20.

10.2.3.4 Release Mixture

The release mixture used for setpoint determination is based on a composition of 100% of a nuclide with a conservative concentration discharge limit to the lake (e.g., Sr90)

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(1) A more conservative discharge rate may be calculated based on concentration limits for NPDES constituents (e.g., boron concentration). In either case, discharge procedures verify that all discharge limits to the lake are below applicable limits.

10.2.3.5 Conversion Factors

The conversion factor for 0RT-PR25 *(fire sump monitor) is based on detector response to* Cs-137. The conversion factors for monitor 0RT-PR04 are based on detector response curves for Cs-137.

10.2.4 Allocation of Effluents from Common Release Points

Radioactive liquid effluents released from the Lake Release Tanks (Boric Acid Tanks) and turbine building fire sump are comprised of contributions from both units. Under normal operating conditions, it is difficult to apportion the radioactivity between the units. Consequently, allocation is based on the unit discharge canal used for dilution.

10.3 SOLIDIFICATION OF WASTE/PROCESS CONTROL PROGRAM

The process control program (PCP) contains the sampling, analysis, and formulation determination by which solidification of radioactive wastes from liquid systems is ensured.

Table 10-1

Assumed Composition of the Zion Station
Noble Gas Effluent

Isotope	Percent of Effluent
Kr85	100%

Note: Based on time since last unit operation and permanently defueled condition.

TABLE 10-2
HVAC EXHAUST FAN CAPACITIES

FAN	CC/SEC	CFM	CFH
#2 Aux. Bldg.			
0D Exh. Fan	3.16×10^7	6.70×10^4	4,020,000
0E Exh. Fan	3.16×10^7	6.70×10^4	4,020,000
0F Exh. Fan	3.16×10^7	6.70×10^4	4,020,000
#1 Purge Exh.			
1A Purge Fan	2.12×10^7	4.50×10^4	2,700,000
1B Purge Fan	2.12×10^7	4.50×10^4	2,700,000
U1 Mini-Purge Fan	1.42×10^6	3.00×10^3	180,000
H^2 Purge Fan 1A	1.70×10^5	3.60×10^2	21,600
H_2 Purge Fan 1B	1.75×10^5	3.40×10^2	22,200
#2 Purge Exh.			
2A Purge Fan	1.65×10^7	3.50×10^4	2,102,400
2B Purge Fan	1.72×10^7	3.65×10^4	2,188,800
U2 Mini-Purge Fan	1.42×10^6	3.00×10^3	180,000
H_2 Purge Fan 2A	1.82×10^5	3.85×10^2	23,100
H_2 Purge Fan 2B	1.75×10^5	3.71×10^2	22,260
Hot Lab Exh. 0A	1.50×10^6	3.18×10^3	191,000
Hot Lab Exh. 0B	1.18×10^6	2.51×10^3	150,600

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RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

The parameters of the radiological environmental monitoring program for the environs around Zion Station are given in Table 11-1.

Figures 11-1a, 11-1b and 11-2 show sampling and monitoring locations.

Table 11-1
Radiological Environmental Monitoring Program

Exposure Pathway And/or Sample	Sampling or Monitoring Locations	Sampling or Collection Frequency	Type and Frequency of Analysis
1. Airborne	a. Indicators – Near Field Z-01 Onsite No. 1 South side, 0.2 mi S (0.3 km J) Z-02 Onsite No. 2 West side, 0.2 mi W (0.3 km N) Z-03 Onsite No. 3 North side, 0.25 mi NNW (0.4 km R) b. Control– Far Field Z-13 Pleasant Prairie Wisconsin 10 mi NW (15 km Q)	Continuous sampler operation with particulate filter collection weekly, or more frequently if required by dust loading.	Particulate Sampler: Gross beta analysis following weekly filter change[2] and gamma isotopic analysis[3] quarterly on composite filters by location.

Table 11-1
Radiological Environmental Monitoring Program – Cont.

Exposure Pathway And/or Sample	Sampling or Monitoring Locations	Sampling or Collection Frequency	Type and Frequency of Analysis
2. Direct Radiation	a. Indicators – Inner Ring[5] Z-101-1 and 2 0.2 mi N (0.3 km A) Z-102-1 and 2 0.2 mi NNE (0.3 km B) Z-103-1 and 2 0.15 mi NE (0.25 km C) Z-104-1 and 2 0.13 mi ENE (0.2 km D) Z-105-1 and 2 0.1 mi E (0.15 km E) Z-106-1 and 2 0.1 mi ESE (0.15 km F) Z-107-1 and 2 0.1 mi SE (0.15 km G) Z-108-1 and 2 0.13 mi SSE (0.2 km H) Z-110-1 and 2 0.2 mi SSW (0.3 km K) Z-111-1 and 2 0.25 mi SW (0.4 km L) Z-112-1 and 2 0.7 mi WSW (1.1 km M) Z-113-1 and 2 0.6 mi W (1.0 km N) Z-114-1 and 2 0.6 mi WNW (1.0 km P) Z-115-1 and 2 0.4 mi NW (0.6 km Q)	Quarterly	Gamma dose on each TLD quarterly
	b. Other One at each airborne location given in 1.a. Z01-1 and 2 0.2 mi S (0.3 km J) Z02-1 and 2 0.2 mi E (0.3 km N) Z03-1 and 2 0.25 mi NNW (.4 km R) One control at control airborne location Z13-1 and 2 10 mi NW (15 km Q)	Quarterly	Gamma dose on each TLD quarterly

Table 11-1
Radiological Environmental Monitoring Program – Cont.

Exposure Pathway And/or Sample	Sampling or Monitoring Locations	Sampling or Collection Frequency	Type and Frequency of Analysis
2. Direct Radiation – Cont.	c. ISFSI Indicators – Inner Ring Z-121-1 and 2 0.2 mi NNW (0.3 km R) Z-122-1 and 2 0.2 mi W (0.3 km N) Z-123-1 and 2 0.1 mi WSW (0.2 km M) Z-124-1 and 2 0.5 mi SW (0.8 km L) Z-125-1 and 2 0.4 mi SSW (0.6 km K)	Quarterly	Gamma dose on each TLD quarterly
	d. Indicators – Outer Ring Z-209-1 and 2 5.1 mi S (8.2 km K) Z-211-1 and 2 4.7 mi SW (7.6 km L) Z-212-1 and 2 5.1 mi WSW (8.2 km M) Z-213-1 and 2 5.1 mi W (8.2 km N) Z-214-1 and 2 4.6 mi WNW (7.4 km P) Z-215-1 and 2 4.0 mi NW (6.4 km Q) Z-216-1 and 2 3.0 mi NNW (4.8 km R)	Quarterly	Gamma dose on each TLD quarterly

Table 11-1
Radiological Environmental Monitoring Program – Cont.

Exposure Pathway And/or Sample	Sampling or Monitoring Locations	Sampling or Collection Frequency	Type and Frequency of Analysis
3. Waterborne			
	a. Drinking Water Indicator[6]		
	Z-15 Lake County Water Works, 1.4 mi NNW (2.2 km R) Z-16 Waukegan Water Works, 6.1 mi S (9.8 km J)	Weekly grab samples.	Gross beta and gamma isotopic[3] analysis on monthly composite; tritium analysis on quarterly composite.
	b. Control[6]		
	Z-14 Kenosha Water Works, 10.0 mi N (1.60 km A) Z-18 Lake Forest Water Works, 12.9 mi S (20.8 km J)	Weekly grab samples.	Gross beta and gamma isotopic[3] analysis on monthly composite; tritium analysis on quarterly composite.
	c. Sediments		
	Z-25 Lake Michigan, Illinois Beach State Park, 2.0 mi S (3.2 km J)	Semiannually	Gamma isotopic[3] analysis semiannually.

Table 11-1
Radiological Environmental Monitoring Program – Cont.

Exposure Pathway And/or Sample	Sampling or Monitoring Locations	Sampling or Collection Frequency	Type and Frequency of Analysis
4. Ingestion			
	a. Fish Indicator		
	Z-26, Lake Michigan in vicinity of station Discharge	Semiannually	Gamma isotopic[3] analysis on edible portions.
	b. Control		
	Z-27, Lake Michigan, 10.0 mi N (16.0 km A)	Semiannually	Gamma isotopic[3] analysis on edible portions.

Table 11-1
Radiological Environmental Monitoring Program – Cont.

1. Deleted – No longer applicable.

2. Airborne particulate sample filters shall be analyzed for gross beta radioactivity 24 hours or more after sampling to allow for radon and thoron daughter decay. If gross beta activity in any individual air particulate sample is greater than 10 times the 1999 mean of control samples, then, a gamma isotopic analysis shall be performed on that elevated individual sample.

3. Gamma isotopic analysis means the identification and quantification of gamma-emitting radionuclides that may be attributable to the effluents from the station.

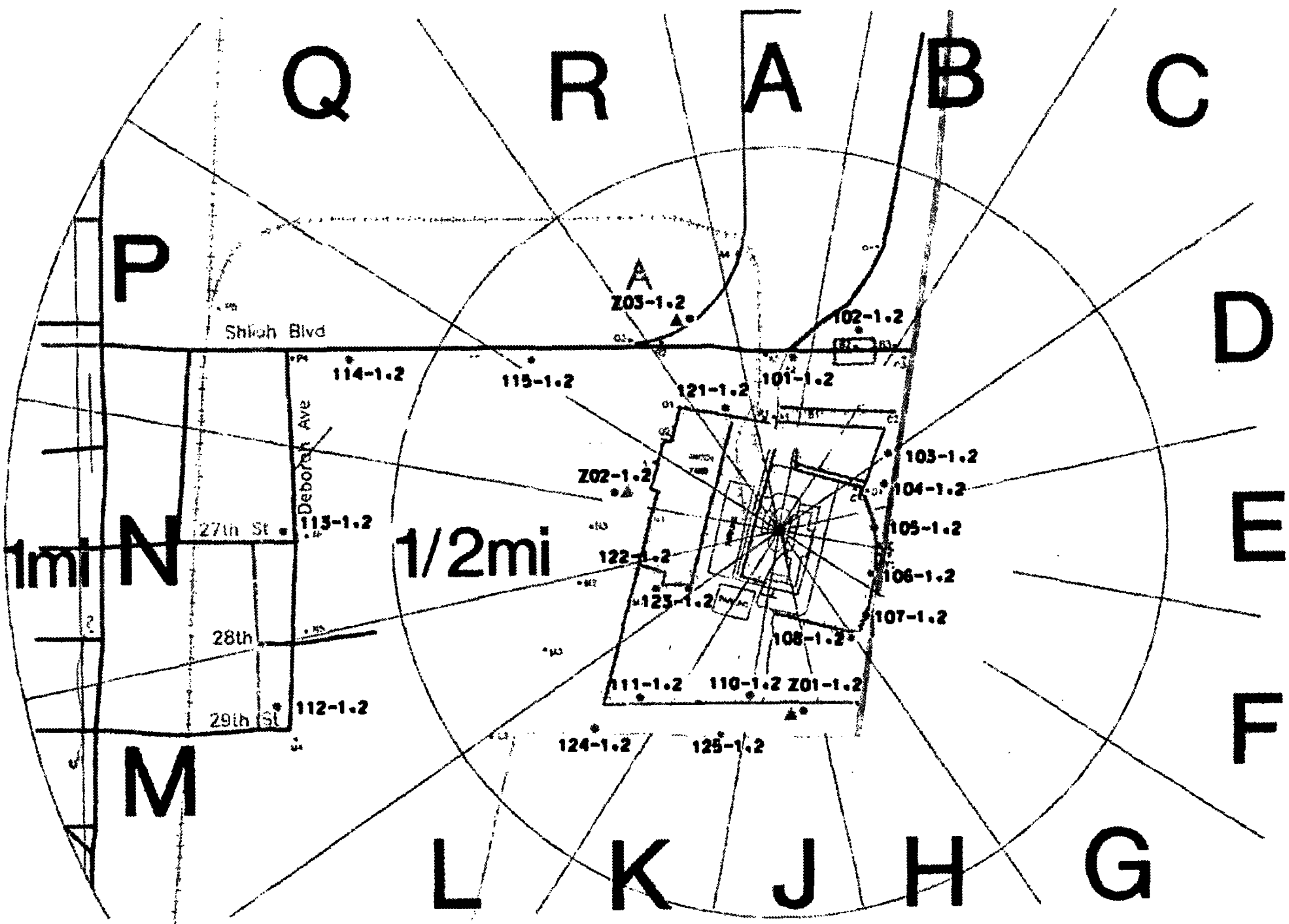
4. Deleted – No longer applicable.

5. Limited TLD placements due to Lake Michigan and location of air samplers.

6. The closest drinking water locations (North/South) chosen for drinking water indicators; two other locations beyond 6.2 miles (north/South) chosen for control samples.

Figure 11-1a

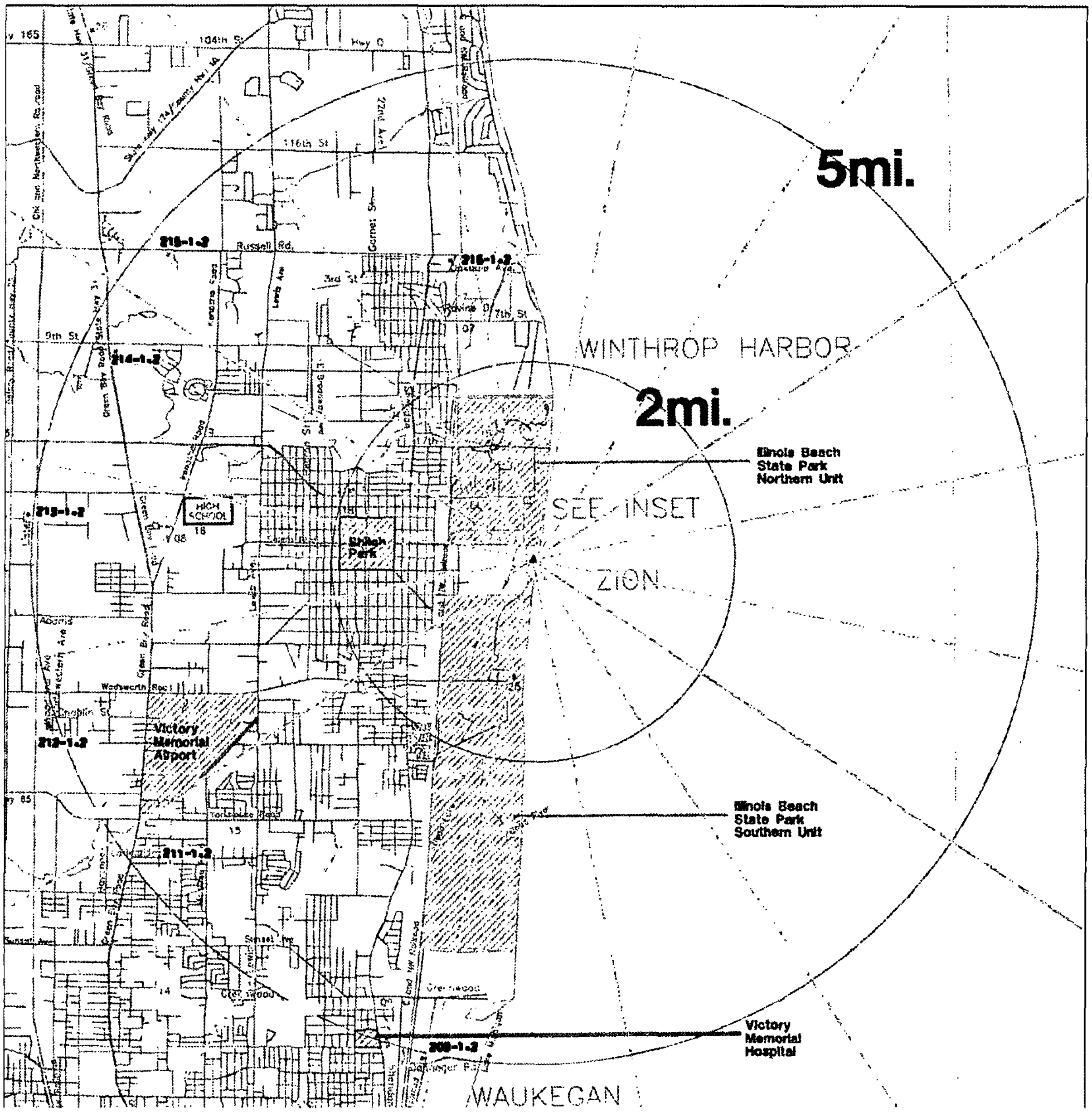
Airborne and Direct Radiation Sample Locations – Inner Ring



- ● TLD Monitoring Location
- ▲ Air Sampling Location

Figure 11-1b

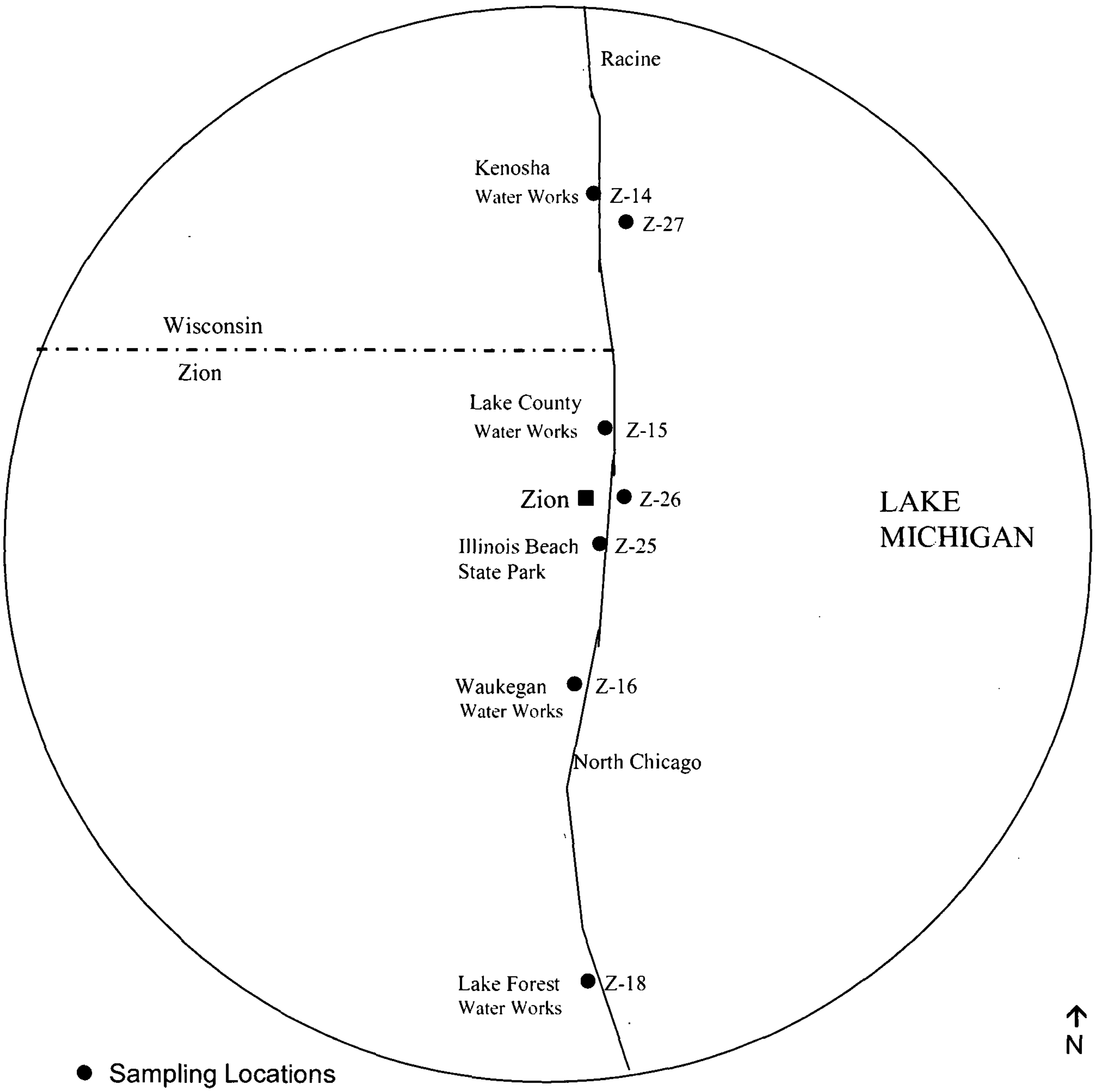
Airborne and Direct Radiation Sample Locations – Outer Ring



- ● TLD Monitoring Location
- ▲ Air Sampling Location

Figure 11-2

Location of Waterborne and Ingestion Sampling Sites



SPECIAL NOTE

The requirements of Permanently Defueled Technical Specifications shall take precedence over this chapter, should any differences occur.

CHAPTER 12

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CHAPTER 12

RADIOLOGICAL EFFLUENT TECHNICAL STANDARDS (RETS) TABLE OF CONTENTS

CHAPTER 12

RADIOACTIVE EFFLUENT TECHNICAL STANDARDS (RETS) LIST OF TABLES

12.1 **DEFINITIONS**

12.1.1 A BATCH RELEASE is the discharge of liquid wastes of a discrete volume. Prior to sampling for analyses, each batch shall be isolated and then thoroughly mixed to assure representative sampling.

12.1.2 A CHANNEL CALIBRATION shall be the adjustment, as necessary, of the channel such that it responds with the necessary range and accuracy to known values of input. The CHANNEL CALIBRATION shall encompass the entire channel including the sensors (where possible), alarm interlock and/or trip functions and shall include the CHANNEL FUNCTIONAL TEST. The CHANNEL CALIBRATION may be performed by any series of sequential, overlapping, or total channel steps such that the entire channel is calibrated.

12.1.3 A CHANNEL CHECK shall be the qualitative assessment of channel behavior during operation by observation. This determination shall include, where possible, comparison of the channel indication and/or status with other indications and/or status derived from independent INSTRUMENT CHANNELS measuring the same parameter.

12.1.4 A CHANNEL FUNCTIONAL CHECK shall be:

a. Instruments-The injection of a simulated signal(s) into the channel as close to the primary sensor(s) as practicable to verify OPERABILITY, including all channel outputs, as appropriate.

b. Logics-The application of input signals, or the operation of relays or switch contacts, in all the combinations required to produce the required decision outputs including the operation of all ACTUATION DEVICES. Where practicable, the test shall include the operation of the ACTUATED EQUIPMENT as well (i.e. pumps will be started, valves operated, etc.).

12.1.5 A COMPOSITE SAMPLE is one in which the quantity of liquid sample is proportional to the quantity of liquid waste discharged and in which the method of sampling employed results in a specimen which is representative of the liquids released.

12.1.6 A CONTINUOUS RELEASE is the discharge of liquid or gaseous wastes of a nondiscrete volume (e.g. from a volume or system that has an input flow during the release).

12.1.7 CONTINUOUS SAMPLING is uninterrupted sampling with the exception of sampling interruptions of short duration for routine activities (e.g. filter replacements).

12.1.8 DOSE EQUIVALENT I-131 shall be that concentration of I-131 (microcurie/gram) which alone would produce the same thyroid dose as the quantity and isotopic mixture of I-131, I-132, I-133, I-134, and I-135 actually present. The Thyroid Dose Conversion factors used for this calculation shall be those listed in Table III of TID-14844, "Calculation of Distance Factors for Power and Test Reactor Sites" or Table E-7 of NRC Regulatory Guide 1.109 Rev. 1, dated October, 1977. This definition is not used in the defueled condition. Decay has eliminated all concerns related to radioactive iodine.

12.1.9 MEMBER OF THE PUBLIC means any individual except when that individual is receiving an occupational dose.

12.1.10 OCCUPATIONAL DOSE means the dose received by an individual in the course of employment in which the individual's assigned duties involve exposure to radiation and/or radioactive material from licensed and unlicensed sources of radiation, whether in the possession of the licensee or other person. Occupational dose does not include dose from background radiation, as a patient from medical practices, from voluntary participation in medical research programs, or as a member of the public.

12.1.11 OPERABLE - A system, subsystem, train, component or device shall be OPERABLE or have OPERABILITY when it is capable of performing its specified function(s), and when all necessary attendant instrumentation, controls, electrical power, cooling or seal water, lubrication or other auxiliary equipment that are required for the system, subsystem, train, component, or device to perform its function(s) are also capable of performing their related support function(s).

12.1.12 OPERATING is defined as performing the intended function in the intended manner.

12.1.13 The OPERATING CYCLE: DELETED

12.1.14 An OPERATIONAL MODE: DELETED

12.1.15 The PROCESS CONTROL PROGRAM (PCP) shall contain the current formulas, sampling, analyses, test, and determinations to be made to ensure that processing and packaging of solid radioactive wastes based on demonstrated processing of actual or simulated wet solid wastes will be accomplished in such a way as to assure compliance with 10CFR Parts 20, 61, and 71, State regulations, burial ground requirements, and other requirements governing the disposal of solid radioactive waste.

12.1.16 PURGE OR PURGING is the controlled process of discharging air or gas from a confinement to maintain temperature, pressure, humidity, concentration or other operating condition, in such a manner, that replacement air or gas is required to purify the confinement.

12.1.17 RATED THERMAL POWER: DELETED

12.1.18 The REACTOR PRESSURE: DELETED

12.1.19 The SITE BOUNDARY shall be that line beyond which the land is not owned, leased or otherwise controlled by the licensee.

12.1.20 SOLIDIFICATION shall be the conversion of radioactive liquid, resin and sludge wastes from liquid systems into a form that meets shipping and burial site requirements.

12.1.21 A SOURCE CHECK shall be the qualitative assessment of channel response when the channel sensor is exposed to a radioactive source.

12.1.22 SURVEILLANCE shall be those parts of the sections which prescribe remedial measures required under designated conditions, activities required to demonstrate instrument operability, and activities performed to ensure applicable offsite dose limits are not exceeded.

12.1.23 The SURVEILLANCE FREQUENCY NOTATION specified for the performance of Surveillance Requirements shall correspond to the intervals defined in Table 12.1-1.

12.1.24 THERMAL POWER: DELETED

12.1.25 UNRESTRICTED AREA means an area, access to which is neither limited nor controlled by the licensee.

12.1.26 GASEOUS EFFLUENT TREATMENT SYSTEM shall be any system designed and installed to reduce radioactive material in particulate form in effluents by passing ventilation through HEPA filters for the purpose of removing particulates from the gaseous exhaust stream prior to the release to the environment. Such a system is not considered to have any affect on noble gas effluents. The iodine removal function is no longer used in the defueled condition.

12.1.27 VENTING is the controlled process of discharging air or gas from a confinement to maintain temperature, pressure, humidity, concentration or other operating condition, in such a manner that replacement air or gas is not provided or required during venting. Vent, used in system names, does not imply a venting process.

12.1.28 WASTE GAS HOLDUP SYSTEM: DELETED

TABLE 12.1-1

SURVEILLANCE FREQUENCY NOTATIONS

NOTATION		FREQUENCY *
S	(Shiftly)	At least once per 12 hours
D	(Daily)	At least once per 24 hours
W	(Weekly)	At least once per 7 days
M	(Monthly)	At least once per 31 days
Q	(Quarterly)	At least once per 92 days
SA	(Semiannually)	At least once per 184 days
A	(Annually)	At least once per 366 days
R		At least once per 18 months
P	(Prior)	Complete prior to start of release
N/A		Not Applicable

* Each Surveillance Requirement shall be performed within the specified time interval with a maximum allowable extension not to exceed 25% of the surveillance interval. These frequency notations do not apply to the Radiological Environmental Monitoring Program as described in Section 12.5.

12.2 **INSTRUMENTATION**

12.2.1 Radioactive Liquid Plant Monitoring Instrumentation

Operability Requirements

12.2.1.A The radioactive liquid plant monitoring instrumentation channels shown in Table 12.2-1 shall be OPERABLE AND, the radioactive liquid effluent monitoring instrumentation channels shall have their alarm/trip setpoints set to ensure that the limits of Section 12.3.1.A are met.

Applicability: As indicated in Table 12.2-3.

Action

1. With a radioactive liquid effluent monitoring instrument channel trip setpoint less conservative than the value necessary to prevent violating the limits of Section 12.3.1.A, immediately suspend the release of radioactive liquid effluents monitored by the affected channel or declare the channel inoperable.

2. With one or more radioactive liquid plant monitoring instrumentation channels inoperable, initiate the SURVEILLANCE requirement delineated in Table 12.2-1.

Surveillance Requirements

12.2.1.B.1 The liquid effluent monitor setpoints shall be determined in accordance with procedures as described in the ODCM.

12.2.1.B.2 Each radioactive liquid plant monitoring instrumentation channel shall be demonstrated OPERABLE by performance of a CHANNEL CHECK, SOURCE CHECK, CHANNEL CALIBRATION and CHANNEL FUNCTIONAL TEST at the frequencies shown in Table 12.2-2.

Bases

12.2.1.C The radioactive liquid plant monitoring instrumentation is provided to indicate abnormal radiological conditions within the plant, AND,

The radioactive liquid effluent instrumentation is provided to monitor and control, as applicable, the release of radioactive materials in liquid effluents. The alarm/trip setpoints for these instruments shall be calculated in accordance with the procedures in the ODCM to ensure that the alarm/trip will occur prior to exceeding the limits of RETS. The OPERABILITY and use of this instrumentation is consistent with the requirements of General Design Criteria 60, 63 and 64 of Appendix A to 10CFR Part 50.

TABLE 12.2-1

RADIOACTIVE LIQUID PLANT MONITORING INSTRUMENTATION

INSTRUMENT	MINIMUM CHANNELS OPERABLE	SURVEILLANCE #	APPLICABLE CONDITION
1. Liquid Effluent Monitors Providing Automatic Termination of Release			
A. Lake Release Tanks (Boric Acid Tanks (BAT))			Liquid Release through this Pathway
1. 0R-PR04	1	1	Liquid Release through this Pathway
B. Turbine Bldg.			
1. 0R-PR25	1	2	
2. Effluent Continuous Composite Sampler			
A. Turbine Building Fire Sump	1	4	All Times
3. Effluent Flow Rate Monitor			
A. Lake Release Tank #1 (U1 Boric Acid Tank)			
1. 0FI-WD005	1	3	Liquid Release through this Pathway
B. Lake Release Tank #2 (U2 Boric Acid Tank)			
1. 0FI-WD006	1	3	Liquid Release through this Pathway
4. Plant System Monitors			
A. SW Dilution Flow			
1. 0FIT-SW54	1	3	Batch Release Through U2 Discharge Canal

TABLE 12.2-1

RADIOACTIVE LIQUID PLANT MONITORING INSTRUMENTATION
(Cont'd)

SURVEILLANCE 1

If the monitor is inoperable, effluent releases from the tank may continue for up to 14 days, provided that prior to initiating the release:

1. At least two independent samples of the tank's contents are analyzed, in accordance with Section 12.3.1.B.1, and

2. At least two technically qualified members of the facility staff independently verify the release-rate calculations and discharge flow path valving; and

3. Approval by the Plant Manager.

Otherwise, suspend release of radioactive effluents via this pathway.

SURVEILLANCE 2

With the number of channels OPERABLE less the minimum number required, effluent releases via this pathway may continue, provided that at least once per day grab samples are analyzed for gross radioactivity (beta /gamma or isotopic) at a lower limit of detection (LLD) as specified in Table 12.3-2. Restore the channel to operable status within 30 days or conduct a station review to determine a plan of action to restore the channel to operable status.

SURVEILLANCE 3

With the number of channels OPERABLE less than the minimum number required, effluent releases via this pathway may continue, for up to 30 days provided the flow rate is estimated at least once per 4 hours during actual releases. Pump curves may be used to estimate flow.

SURVEILLANCE 4

If the composite sampler is inoperable, effluent releases via this pathway may continue, provided that at least once per day grab samples are taken. The samples shall be analyzed in accordance with Section 12.3.1.B.3.

TABLE 12.2-2

RADIOACTIVE LIQUID PLANT MONITORING INSTRUMENTATION SURVEILLANCE

INSTRUMENT	CHANNEL CHECK	SOURCE CHECK	CHANNEL CALIBRATION(1)	CHANNEL FUNCTIONAL TEST (2)
1. Liquid Effluent Monitors Providing Automatic Termination Of Release				
A. Lake Release Tanks (Boric Acid Tanks (BAT))				
1. 0R-PR04	P	P	R	Q
B. Turbine Bldg.				
1. 0R-PR25	D	M	R	Q
2. Effluent Continuous Composite Sampler				
A. Turbine Building Fire Sump	D	N/A	N/A	N/A
3. Effluent Flow Rate Monitor				
A. Lake Release Tank #1 (U1 Boric Acid Tank (BAT))				
1. 0FI-WD005	D(3)	N/A	R	N/A
B. Lake Release Tank #2 (U2 Boric Acid Tank (BAT))				
1. 0FI-WD006	D(3)	N/A	R	N/A
4. Plant System Monitors				
A. SW Dilution Flow				
1. 0FIT-SW54	D(3)	N/A	R(4)	N/A

(1) CHANNEL CALIBRATION shall include performance of a CHANNEL FUNCTIONAL TEST.

(2) The CHANNEL FUNCTIONAL TEST shall also demonstrate that any automatic isolation of this pathway occurs and that control room alarm annunciation occurs if any of the following conditions exist. (if the capability is installed):
a) Instrument indicates levels above the alarm setpoints.
b) Circuit failure.
c) Instrument indicates a downscale failure.
d) Instrument controls not set in operate mode.

(3) CHANNEL CHECK shall consist of verifying indications of flow during periods of release. CHANNEL CHECK shall be made at least once daily on any day on which continuous, periodic, or BATCH RELEASES are made.

(4) Does not include flow sensor.

12.2.2 Radioactive Plant Monitoring Instrumentation

Operability Requirements

12.2.2.A The radioactive plant monitoring instrumentation channels shown in Table 12.2-3 shall be OPERABLE, AND, the radioactive gaseous effluent monitoring instrumentation shall have their alarm/trip setpoints set in accordance with the method prescribed in the ODCM to ensure that the limits of Section 12.4.1.A are met.

Applicability: As indicated in Table 12.2-3.

Action

1. With a radioactive gaseous effluent monitoring instrumentation channel alarm/trip setpoint less conservative than required by the above Section, immediately suspend the release of radioactive gaseous effluents monitored by the affected channel or declare the channel inoperable.

2. With one or more radioactive plant monitoring instrumentation channels inoperable, initiate the SURVEILLANCE requirement as delineated in Table 12.2-3.

Surveillance Requirements

12.2.2.B.1 The effluent monitor setpoints shall be determined in accordance with procedures as described in the ODCM.

12.2.2.B.2 Each radioactive plant monitoring instrumentation channel shall be demonstrated OPERABLE, when in its APPLICABLE CONDITION, by performance of a CHANNEL CHECK, SOURCE CHECK, CHANNEL CALIBRATION and CHANNEL FUNCTIONAL TEST at the frequencies shown in Table 12.2-4.

Bases

12.2.2.C The radioactive plant monitoring instrumentation is provided to indicate abnormal radiological conditions within the plant.

The radioactive gaseous effluent instrumentation is provided to monitor, record and control, as applicable, the release of radioactive materials in gaseous effluents during actual or potential releases. The alarm/trip setpoints for these instruments shall be calculated in accordance with the ODCM to ensure that the alarm/trip will occur prior to exceeding the limits of 10CFR Part 20.

The Unit 2 Auxiliary Building (AB) ventilation stack is considered available as a release path from radiologically controlled areas of the Auxiliary Building, the Containments (when the associated Purge exhaust ducts are isolated), and the Fuel Building via the AB ventilation system, when any AB exhaust fan is discharging to that stack, or any one of the AB exhaust fan dampers is open on that stack. The AB ventilation stacks are also considered available as a release path from the associated Containment when any Containment Purge exhaust fan is discharging to that stack or a Containment vent path is aligned to that stack, regardless of AB exhaust fan or damper status. The Unit 2 Auxiliary Building ventilation stack is unavailable as a release path from the radiologically controlled areas of the Auxiliary Building, the Containments and Fuel Building when all AB exhaust fan dampers for that stack are mechanically blocked closed. The Unit 1 Ventilation stack is permanently isolated from the AB Ventilation system.

The Auxiliary Building ventilation stacks are unavailable as a release path from their associated Containment when all Containment Purge exhaust fans and their associated discharge dampers for that containment are secured.

TABLE 12.2-3

RADIOACTIVE PLANT MONITORING INSTRUMENTATION

INSTRUMENT	MINIMUM CHANNELS OPERABLE	SURVEILLANCE	APPLICABLE CONDITION
1. Effluent Containment Purge or Vent			
A. Particulate Monitor			
1. 1R-PR49	1	11	U1 Venting or Purging
2. 2R-PR49A (Channel 1)	1	11	U2 Venting or Purging
B. Flow Rate Monitor			
1. 1LP-084	1	8	U1 Venting or Purging
2. 2LP-084	1	8	U2 Venting or Purging
2. Aux Building Effluent Monitoring			
A. Gas Activity Monitor			
1. 2R-PR49E (Channel 5)	1	10	**
B. Particulate Monitor			
1. 2R-PR49A (Channel 1)	1	11	**
C. Flow Rate Monitor			
1. 2LP-084	1	8	**

** Whenever the Unit 2 stack is available as a release path from the Auxiliary Building.

INSTRUMENT	MINIMUM CHANNELS OPERABLE	SURVEILLANCE	APPLICABLE CONDITION
3. Fuel Building Monitoring			
A. Area Monitoring			
1. 0RT-AR21	1	12	When fuel is present
2. 0RT-AR22	1	12	When fuel is present
3. 0RT-AR13	1	13	When fuel building crane hooks are used to lift loads located in the spent fuel pool.
4. 0RT-AR24	1	13	When 0RT-AR13 is inoperable AND fuel building crane hooks are used to lift loads located in the spent fuel pool.

TABLE 12.2-3

RADIOACTIVE PLANT MONITORING INSTRUMENTATION
(Cont'd)

TABLE NOTATIONS

SURVEILLANCE 6 - DELETED

SURVEILLANCE 7 - DELETED

SURVEILLANCE 8 - Effluent releases via this pathway may continue provided:
1. The effluent flow rate is estimated at least once per day while a release is in progress.
2. Continuous sampling is maintained with a pump
3. Operations performs a Channel Check daily
4. Restore the inoperable panel to OPERABLE status within 30 days OR conduct a station review to determine a plan of action to restore the panel to OPERABLE status.

SURVEILLANCE 9 - DELETED

SURVEILLANCE 10 - With the number of OPERABLE channels less than the minimum number required:
1. Effluent releases via this pathway may continue provided grab samples are obtained and analyzed for gross activity at least once per day
2. Restore the channel to OPERABLE status within 30 days or conduct a station review to determine a plan of action to restore the channel to OPERABLE status.
3. If _LP084 is inoperable perform actions required per Table 12.2-3. (See Surveillance 8)

Compensatory sampling does not return the monitor to an OPERABLE status.

SURVEILLANCE 11 - With the number of OPERABLE channels less than the minimum number required:
1. Effluent releases via this pathway may continue provided samples are continuously collected as required in Table 12.4-1.
2. Restore the channel to OPERABLE status within 30 days or conduct a station review to determine a plan of action to restore the channel to OPERABLE status.
3. If _LP084 is inoperable perform actions required per Table 12.2-3. (See Surveillance 8)

Compensatory sampling does not return the monitor to an OPERABLE status.

SURVEILLANCE 12- With the number of channels OPERABLE less than the minimum required, stop all movement of fuel within the spent fuel pool and crane operation with loads over the spent fuel pool AND perform area surveys of the monitored area at least once per day.

SURVEILLANCE 13 With the number of channels OPERABLE less than the minimum required in BOTH 0RT-AR13 AND 0RT-AR24, suspend all movement of loads in the spent fuel pool with the crane hooks.

SURVEILLANCE 14 Perform area surveys of the monitored area at least once per day.

TABLE 12.2-4

RADIOACTIVE PLANT MONITORING INSTRUMENTATION SURVEILLANCE

	CHANNEL CHECK	SOURCE CHECK	CHANNEL CALIBRATION (1)	CHANNEL FUNCTIONAL TEST (2)
1. Effluent Containment Purge or Vent				
A. Particulate Monitor				
1. 1R-PR49	D	M	R	Q
2. 2R-PR49A (Channel 1)	D	M	R	Q
B. Flow Rate Monitor				
1. 1LP-084	D	N/A	R	Q
2. 2LP-084	D	N/A	R	Q
2. Aux Building Effluent Monitoring				
A. Gas Activity Monitor				
1. 2R-PR49E (Channel 5)	D	M	R	Q
B. Particulate Monitor				
1. 2R-PR49A (Channel 1)	D	M	R	Q
C. Flow Rate Monitor				
1. 2LP-084	D	N/A	R	Q
3. Fuel Building Monitoring				
A. Area Monitoring				
1. 0RT-AR21	D	M(4)	R	N/A
2. 0RT-AR22	D	M(4)	R	N/A
3. 0RT-AR13	NA	D(3)	R	Q
4. 0RT-AR24	NA	D(3)	R	Q

Table 12.2-4

RADIOACTIVE PLANT MONITORING INSTRUMENTATION SURVEILLANCE
(Cont'd)

TABLE NOTATIONS

(1) CHANNEL CALIBRATION shall include performance of a CHANNEL FUNCTIONAL TEST.

(2) The CHANNEL FUNCTIONAL TEST shall also demonstrate that any automatic isolation occurs; and that Control Room alarm annunciation occurs if any of the following conditions exist (if the capability is installed):

a) Instrument indicates measured levels above the alarm setpoint.
b) Circuit failure.
c) Instrument indicates a downscale failure.
d) Instrument controls not set in "operate" mode.

(3) For the rad monitor in service (i.e. either 0RT-AR13 or 0RT-AR24): When the fuel building crane hooks are used to lift loads located in the spent fuel pool.

(4) Daily during fuel handling operations or load handling operations in or above the spent fuel pool.

12.3 LIQUID EFFLUENTS

12.3.1 Concentration

Operability Requirements

12.3.1.A.1 The concentration of radioactive material released from the site to UNRESTRICTED AREAS (see Zion Station ODCM Annex, Appendix F, Figure F-1) shall be limited to 10 times the concentrations specified in Appendix B, Table 2, Column 2 to 10CFR20.1001-20.2402, for radionuclides other than dissolved or entrained noble gases. For dissolved or entrained noble gases, the concentrations shall be limited to the values listed in Table 12.3-1.

12.3.1.A.2 During the release of radioactive liquid wastes, the combination of dilution water flow and waste water discharge flow shall be established to ensure the discharge concentration limits of 12.3.1.A.1. are not exceeded.

Applicability: At all times.

Action

1. With the concentration of radioactive materials released from the site to UNRESTRICTED AREAS exceeding the limits specified in Section 12.3.1.A.1. immediately decrease the release rate of radioactive materials and/or increase the dilution flow rate to restore the concentration to within the above limits.

Surveillance Requirements

12.3.1.B.1 The radioactivity content of each batch of radioactive liquid waste shall be determined prior to release by sampling and analysis in accordance with Table 12.3-2. The results of pre-release analyses shall be used with the calculational methods in the ODCM to assure that the concentration at the point of release is maintained within the limits of Section 12.3.1.A.1.

12.3.1.B.2 Post-release analyses of samples composited from BATCH RELEASES shall be performed in accordance with Table 12.3-2. The results of the previous post-release analyses shall be used with the calculational methods in the ODCM to assure that the concentrations at the point of release were maintained within the limits of Section 12.3.1.A.1.

12.3.1.B.3 The radioactivity concentration of liquids discharged from continuous release points shall be determined by collection and analysis of samples in accordance with Table 12.3-2. The results of the analysis shall be used with the calculational methods in the ODCM to assure that the concentrations at the point of release were maintained within the limits of Section 12.3.1.A.1.

12.3.1.B.4 Appropriate discharge and dilutions flows for each batch radioactive liquid release shall be determined with the calculational methods in the ODCM to assure that the concentration at the point of release is maintained within the limits of Section 12.3.1.A.1.

Bases

12.3.1.C This Section is provided to ensure that the concentration of radioactive materials released in liquid waste effluents from the site to UNRESTRICTED AREAS will be less than ten (10) times the concentration levels specified in Appendix B, Table 2, Column 2 to 10CFR 20.1001-20.2402. This limitation provides additional assurance that the levels of radioactive materials in bodies of water outside the site will result in exposures within (1) the Section II.A design objectives of Appendix I, 10 CFR 50, to a MEMBER OF THE PUBLIC, and (2) the limits of 10CFR20.1301.

TABLE 12.3-1

ALLOWABLE CONCENTRATION OF DISSOLVED OR ENTRAINED NOBLE GASES RELEASED FROM THE SITE TO UNRESTRICTED AREAS IN LIQUID EFFLUENTS

NUCLIDE	A(μCi/ml)*
Kr-85m	2×10^{-4}
Kr-85	5×10^{-4}
Kr-87	4×10^{-5}
Kr-88	9×10^{-5}
Ar-41	7×10^{-5}
Xe-131m	7×10^{-4}
Xe-133m	5×10^{-4}
Xe-133	6×10^{-4}
Xe-135m	2×10^{-4}
Xe-135	2×10^{-4}

* Computed from Equation 20 of ICRP Publication 2(1959), adjusted for infinite cloud submersion in water, and R = 0.01 rem/week, density = 1.0 g/cc and Pw/Pt = 1.0.

TABLE 12.3-2

RADIOACTIVE LIQUID EFFLUENT SAMPLING AND ANALYSIS SURVEILLANCE

LIQUID RELEASE TYPE	SAMPLING FREQUENCY	MINIMUM ANALYSIS FREQUENCY	TYPE OF ACTIVITY ANALYSIS	LOWER LIMIT OF DETECTION (LLD) (µCi/ml) (a,e)
A. Lake Release (Boric Acid Tank)	Prior to Each Release (c)	Prior to Each Release	Principal Gamma Emitters (e)	5E-7
	P One Batch/M(c)	M	Dissolved and Entrained Gases (Gamma Emitters)	1E-5
	P Each Batch (c)	M Composite (b)	Tritium	1E-5
			Gross Alpha	1E-7
	P Each Batch (c)	Q Composite (b)	Sr-90	5E-8
			Fe-55, Ni-63	1E-6
B. Turbine Building Fire Sump (f)	Continuous During Release (d)	W	Principal Gamma Emitters(e)	5E-7
			Dissolved and Entrained Gases (Gamma Emitters)	1E-5
	Continuous (d)	M Composite (b)	Tritium	1E-5
			Gross Alpha	1E-7
	Continuous (d)	Q Composite (b)	Sr-90	5E-8
			Fe-55, Ni-63	1E-6
C. Waste Neutralizing Tank	Prior to each Release	Prior to each Release	Principal Gamma Emitters (e)	5E-7
	P Each Batch (c)	M Composite (b)	Tritium	1E-5
			Gross Alpha	1E-7

TABLE 12.3-2

RADIOACTIVE LIQUID EFFLUENT SAMPLING AND ANALYSIS SURVEILLANCE
(Cont'd)

TABLE NOTATIONS

a. The LLD is the smallest concentration of radioactive material in a sample that will be detected with 95% probability with 5% probability of falsely concluding that a blank observation represents a "real" signal.

For a particular measurement system (which may include radiochemical separation):

$$LLD = \frac{4.66\ s_b}{A \cdot E \cdot V \cdot 2.22 \cdot Y \cdot \exp(-\lambda \Delta t)}$$

Where:

LLD is the lower limit of detection as defined above in picocuries (pCi) per unit mass or volume,

s_b is the square root of the background counting rate or of the counting rate of a blank sample as appropriate (as counts per minute),

A is the number of gamma rays emitted per disintegration for gamma ray radionuclide analysis (A = 1.0) for gross alpha, strontium, and tritium measurement.

E is the counting efficiency (as counts per gamma),

V is the sample size (in units of mass or volume),

2.22 is the number of disintegrations per minute per picocurie,

Y is the fractional radiochemical yield when applicable (otherwise Y = 1.0)

λ is the radioactive decay constant for the particular radionuclide, and

Δt is the elapsed time between midpoint of sample collection and time of counting (for plant effluents, not environmental sample).

The value of s_b used in the calculation of the LLD for a detection system shall be based on the actual observed variance of the background counting rate or of the counting rate of the blank samples (as appropriate) rather than on an unverified theoretically predicted variance. In calculating the LLD for a radionuclide determined by gamma ray spectrometry, the background shall include the typical contributions of other radionuclides normally present in the samples. Typical values of E, V, Y, and Δt shall be used in the calculation. The background count rate is calculated from the background counts that are determined to be within $\pm$ one FWHM (Full Width at Half Maximum) energy band about the energy of the gamma ray peak used for the quantitative analysis for that radionuclide.

TABLE 12.3-2

RADIOACTIVE LIQUID EFFLUENT SAMPLING AND ANALYSIS SURVEILLANCE
(Cont'd)

TABLE NOTATIONS

For certain mixtures of gamma emitters, it may not be possible to measure radionuclides in concentrations near their sensitivity limits when other nuclides are present in the sample in much greater concentrations. Under these circumstances, it will be more appropriate to calculate the concentrations of such radionuclides using observed ratios with those radionuclides which are measurable.

b. A COMPOSITE SAMPLE is one in which the quantity of liquid sampled is proportional to the quantity of liquid waste discharged and in which the method of sampling employed results in a specimen which is representative of the liquids released.

   1) To be representative of the quantities and concentrations of radioactive materials in liquid effluents, all samples taken for the composite shall be thoroughly mixed in order for the composite sample to be representative of the effluent release.

   2) The weekly and monthly Proportional Composite samples are not required provided that (1) the analysis required for each of these composite samples has been run on each batch discharged, and (2) a monthly record of radionuclides discharged (isotope and quantity) is maintained.

c. A BATCH RELEASE is the discharge of liquid wastes of a discrete volume. Prior to sampling for analyses, each batch shall be isolated, and then thoroughly mixed to assure representative sampling.

d. A CONTINUOUS RELEASE is the discharge of liquid wastes of a nondiscrete volume; e.g., from a volume of system that has an input flow during the continuous release.

e. The principal gamma emitters for which the LLD specification applies exclusively are the following radionuclides: Mn-54, Co-58, Co-60, Zn-65, Mo-99, Cs-134, Cs-137, Ce-141. Ce-144 shall also be measured, but with an LLD of 5E-06. This list does not mean that only these nuclides are to be detected and reported. Other peaks which are measurable and identifiable, together with the above nuclides, shall also be identified and reported. Nuclides which are below the LLD for the analyses shall be reported as "less than" the nuclide's LLD, and shall not be reported as being present at the LLD level for that nuclide. The "less than" values shall not be used in the required dose calculations.

f. If the fire sump composite sampler is inoperable, grab samples shall be taken from the turbine building fire sump once per day.

12.3.2 Dose

Operability Requirements

12.3.2.A The dose or dose commitment to a MEMBER OF THE PUBLIC above background from radioactive materials in liquid effluents released from each unit to UNRESTRICTED AREAS (see Zion Station ODCM Annex, Appendix F, Figure F-1) shall be limited:

1. During any calendar quarter to less than or equal to 1.5 mrem to the total body and to less than or equal to 5 mrem to any organ, and

2. *During any calendar year to less than or equal to 3 mrem to the total body and to less* than or equal to 10 mrem to any organ.

Applicability: At all times.

Action

1. With the calculated dose from the release of radioactive materials in liquid effluents exceeding twice the limits specified in Section 12.3.2.A, limit the subsequent releases such that the dose or dose commitment to a MEMBER OF THE PUBLIC from all uranium fuel cycle sources is limited to less than or equal to 25 mrem to the total body or any organ (except thyroid, which is limited to less than or equal to 75 mrem) over 12 consecutive months. Demonstrate that radiation exposures to all MEMBERS OF THE PUBLIC from all uranium fuel cycle sources (including all effluent pathways and direct radiation) are less than the 40CFR Part 190 and 40CFR Part 141 Standard, otherwise obtain a variance from the Commission to permit releases which exceed the 40CFR Part 141 or 190 Standard. The radiation exposure analysis shall use methods prescribed in the ODCM.

Surveillance Requirements

12.3.2.B Cumulative dose contributions from liquid effluents for the current calendar quarter and the current calendar year shall be determined in accordance with the methodologies and parameters of the ODCM at least once per 31 days.

Bases

12.3.2.C This Section is provided to implement the requirements of Sections II.A, III.A and IV.A of Appendix I, 10CFR Part 50. The limiting Condition of Operation implements the guides set forth in Section II.A of Appendix I. The ACTION statements provide the required OPERATING flexibility and at the same time implement the guides set forth in Section IV.A of Appendix I to assure that the releases of radioactive material in liquid effluents will be kept "as low as is reasonably achievable." Also, for fresh water sites with drinking water supplies, which can be potentially affected by plant operations, there is reasonable assurance that the operation of the facility will not result in radionuclide concentrations in the finished drinking water that are excess of the requirements of 40CFR 141. The dose calculations in the ODCM implement the requirements in Section III.A of Appendix I that conformance with the guides of Appendix I be shown by calculational procedures based on models and data, such that the actual exposure of an individual through appropriate pathways is unlikely to be substantially underestimated. The equations specified in the ODCM for calculating the dose due to the actual release rate of radioactive materials in liquid effluents are consistent with the methodology provided in Regulatory Guide 1.109; Calculation of Annual Doses to Man from Routine Releases of Radioactive Effluents for the Purpose of Evaluating Compliance with 10CFR Part 50, Appendix I, Revision 1, October 1977 and Regulatory Guides 1.113, "Estimating Aquatic Dispersion of Effluents from Accidental and Routine Reactor Releases for the Purpose of Implementing Appendix I," April 1977.

This Section applies to the release of liquid effluents from each unit at the site. For shared radwaste treatment systems, the liquid effluents from the shared systems are proportioned among the units sharing the system.

12.3.3 Liquid Radwaste Treatment System

Operability Requirements

12.3.3.A The Liquid Radwaste Treatment System shall be OPERABLE* and appropriate portions of the system shall be used to reduce the radioactive materials in liquid effluents prior to discharge when the projected doses due to liquid effluent, from each unit, to UNRESTRICTED AREAS (see Zion Station ODCM Annex, Appendix F, Figure F-1) would exceed 0.06 mrem to the total body or 0.20 to any organ in a 31-day period.

* The liquid Radwaste Treatment System shall be considered OPERABLE, if liquid waste can be held up and/or discharged within applicable limits.

Applicability: At all times.

Action With the Liquid Radwaste Treatment System inoperable for more than 30 days or with radioactive liquid waste being discharged without treatment and in excess of the above limits, return the system to OPERABLE status and place the appropriate portions of the system in use.

Surveillance Requirements

12.3.3.B Doses due to liquid releases from the site to UNRESTRICTED AREAS, shall be projected at least once per 31 days in accordance with the methodologies and parameters of the ODCM when the Liquid Radwaste Treatment System is not being fully utilized.

Bases

12.3.3.C The OPERABILITY of the Liquid Radwaste Treatment System ensures that the system will be available for use whenever liquid effluents require treatment prior to release to the environment. The requirement that the appropriate portions of this system be used when specified, provides assurance that the releases of radioactive materials in liquid effluents will be kept "as low as is reasonably achievable." This Section implements the requirements of 10CFR Part 50.36a, General Design Criterion of Appendix A to 10CFR Part 50 and the design objective given in Section II.D of Appendix I to 10CFR Part 50. The specified limits governing the use of appropriate portions of the Liquid Radwaste Treatment System were specified as a 2% fraction of the dose design objectives set forth in Section II.A of Appendix I, 10CFR Part 50, for liquid effluents.

12.4 GASEOUS EFFLUENTS

12.4.1 Dose Rate

Operating Requirements

12.4.1.A The dose rate due to radioactive materials released in gaseous effluents from the site to areas at or beyond the SITE BOUNDARY (see Zion Station ODCM Annex, Appendix F, Figure F-1), shall be limited to the following:

1. For noble gases: Less than or equal to 500 mrem/yr to the whole body and less than or equal to 3000 mrem/yr to the skin, and
2. For Iodine-131, Iodine-133, tritium and all radionuclides in particulate form with half-lives greater than 8 days: Less than or equal to 1500 mrem/yr to any organ.

Applicability: At all times.

Action

With a release exceeding the above limits, immediately reduce the release rate to within the above limits.

Surveillance Requirements

12.4.1.B The dose rate due to radioactive materials in gaseous effluents shall be determined to be within the prescribed limits in accordance with the methods and procedures of the ODCM by obtaining representative samples and performing analyses in accordance with the sampling and analysis program specified in Table 12.4-1.

Bases

12.4.1.C This Section is provided to ensure that radioactive material discharged in gaseous effluents will not result in the exposure of a Member of the Public in an Unrestricted Area, either at or beyond the Site Boundary in excess of the design objectives of appendix I to 10 CFR part 50. This section is provided to ensure that gaseous effluents from all units on the site will be appropriately controlled. It provides operational flexibility for releasing gaseous effluents to satisfy the Section II.A and II. design objectives of appendix I to 10 CFR part 50. The specified release-rate limits restrict, at all times, the corresponding gamma and beta dose rates above background to an individual at or beyond the SITE BOUNDARY to 500 mrem/year to the total body or to less than or equal to 3000 mrem/year to the skin. These release-rate limits also restrict, at all times, the corresponding organ dose rate above background to a child via the inhalation pathway to less than or equal to 1500 mrem/year. For purposes of calculating dose resulting from airborne releases, the stack is considered a ground-level release.

The Sampling and Analysis Program requirements prescribed in Table 12.4-1 are established to provide representative and appropriate sampling of the radiologically controlled areas. The method and frequency of sampling is based on the effluent flowrate. Continuous Releases are defined for areas with forced ventilation release points. Unventilated Building Releases are defined for areas with no specific release point.

TABLE 12.4-1

RADIOACTIVE GASEOUS EFFLUENT SAMPLING AND ANALYSIS PROGRAM

GASEOUS RELEASE TYPE	SAMPLING METHOD	MINIMUM ANALYSIS FREQUENCY	TYPE OF ACTIVITY ANALYSIS	LOWER LIMIT OF DETECTION (LLD) (μCi/cc) (f)
A. Deleted				
B. Continuous Releases [1] Containment Vent and Purge	Continuous (b)(h)	Weekly(c) Daily(a)	Particulate Principal Gamma Emitters (e)	1E-11
C. Continuous Releases[1] Aux Building Unit 2 Ventilation Stack Unit 1 Vent Stack	Grab (b)	Monthly	Noble Gases[2] Principal Gamma Emitters (d)	1E-4
			Tritium[2]	1E-6
	Continuous (b)(h)	Weekly(c) Daily(a)	Particulate Principal Gamma Emitters (e)	1E-11
	Composite	Quarterly		
			Sr-90 Particulate	1E-11
			Fe-55 Particulate	3E-11
			Ni-63 Particulate	1E-11
			Gross Alpha	1E-11
	Continuous (g)(h) [2]. Noble Gas Monitor	N.A.	Noble Gases, Gross Beta or Gamma	1E-6

(1) The requirements listed in this table for Continuous Releases are applicable for release paths that are available.

(2) These requirements apply only to Aux Building Unit 2 Ventilation Stack

TABLE 12.4-1

RADIOACTIVE GASEOUS EFFLUENT SAMPLING AND ANALYSIS PROGRAM
(Cont'd)

GASEOUS RELEASE TYPE	SAMPLING METHOD	MINIMUM ANALYSIS FREQUENCY	TYPE OF ACTIVITY ANALYSIS	LOWER LIMIT OF DETECTION (LLD) (μCi/cc) (f)
D. Unventilated Building Releases[2] Aux Building, Fuel Building, and Unit 1 and Unit 2 Containments (i)(j)	Grab	Daily	Noble Gases Principal Gamma Emitters (d)	1E-4
			Tritium	1E-6
	Continuous (h)	Daily(c)	Particulate Principal Gamma Emitters (e)	1E-11
	Composite	Quarterly		
			Sr-90 Particulate	1E-11
			Fe-55 Particulate	3E-11
			Ni-63 Particulate	1E-11
			Gross Alpha	1E-11

(2) *The sampling requirements listed in this table for Unventilated Building Releases are applicable for buildings as detailed below:*

- Auxiliary Building and Fuel Building – All Unit 2 Auxiliary Building exhaust fans are secured
- Unit 1 Containment – All Unit 1 Main Purge Exhaust Fans are secured
- Unit 2 Containment – All Unit 2 Containment Main Purge Exhaust Fans are secured
  AND EITHER The Containment Access Construction Door is OPEN
  OR
  All AB Exhaust fans are secured

TABLE 12.4-1

RADIOACTIVE GASEOUS EFFLUENT SAMPLING AND ANALYSIS PROGRAM
(Cont'd)

TABLE NOTATIONS

a. The daily sampling requirement is applicable when 1RIA-PR49 or 2R-PR49A is inoperable AND decommissioning activities are in progress in the associated building (Containment and/or AB).

b. The ratio of the sample flow rate to the sampled stream flow rate shall be known for the time period in Section 12.4.1.

c. The particulate filter(s) shall be saved for a quarterly composite analysis for Sr-90, Ni-63, Fe-55 and gross alpha.

d. For gaseous emissions, the principal gamma emitters for which the LLD specification applies exclusively are the following radionuclides: Kr-87, Kr-88, Xe-133, Xe-133m, Xe-135, and Xe-138. Other peaks which are measurable and identifiable by gamma-ray spectrometry, together with the above nuclides, shall also be identified and reported when an actual analysis is performed on a sample. Nuclides which are below the LLD for the analyses shall not be reported as being at the LLD level for that nuclide.

e. For particulate emissions, the principal gamma emitters for which the LLD specification applies exclusively are the following radionuclides: Mn-54, Co-60, Zn-65, Co-58, Mo-99, Cs-134, Cs-137, Ce-141, and Ce-144. Other peaks which are measurable and identifiable by gamma-ray spectrometry, together with the above nuclides, shall also be identified and reported when an actual analysis is performed on a sample. Nuclides which are below the LLD for the analyses shall not be reported as being at the LLD level for that nuclide.

f. The LLD is defined in Notation a of Table 12.3-2.

g. Refer to Table 12.2-3 for required actions when the noble gas monitor is not in service.

h. Sampling interruptions of short duration for routine activities, e.g. filter replacement or opening/closing of the construction door, do not constitute a deviation from the requirements for continuous sampling.

i. Estimate the effluent flowrate for Unventilated Building Releases from the Aux Bldg, Fuel Building, Unit 1 and/or Unit 2 Containment. When the flowrate cannot be determined; the maximum flowrate of one AB exhaust fan, 67000 cfm, shall be used as the AB/FB effluent flowrate, the maximum flowrate from one Purge exhaust fan; 45,000 cfm for Unit 1, 36,500 cfm for Unit 2, shall be used as the Containment effluent flowrate.

j. Daily sampling for noble gases and tritium are not required for Unit 1 or Unit 2 Containment.

12.4.2 Dose - Noble Gases

Operability Requirements

12.4.2.A The air dose due to noble gases released in gaseous effluents from each unit to areas at or beyond the SITE BOUNDARY (see Zion Station ODCM Annex, Appendix F, Figure F-1) shall be limited to the following:

1. During any calendar quarter: Less than or equal to 5 mrad for gamma radiation and less than or equal to 10 mrad for beta radiation, and

2. During any calendar year: Less than or equal to 10 mrad for gamma radiation and less than or equal to 20 mrad for beta radiation.

Applicability: At all times

Action

1. With the calculated air dose from gaseous effluents exceeding the above limits, define the corrective action(s) to be taken to ensure that future releases are in compliance with Section 12.4.2.A.

2. With the calculated air dose from radioactive noble gases in gaseous effluents exceeding twice the limits of Section 12.4.2.A:

   a. Limit subsequent releases such that the dose or dose commitment to a MEMBER OF THE PUBLIC from all uranium fuel cycle sources is limited to less than or equal to 25 mrem to the total body or any organ (except the thyroid, which is limited to less than or equal to 75 mrem) over 12 consecutive months.

   b. Prepare an analysis which demonstrates that radiation exposures to all MEMBERS OF THE PUBLIC from all uranium fuel cycle sources (including all effluents pathways and direct radiation) are less than the 40 CFR Part 190 Standard.

Surveillance Requirements

12.4.2.B Cumulative dose contributions for the current calendar quarter and current calendar year for noble gases shall be determined in accordance with the methodologies and parameters of the ODCM at least once every 31 days.

Bases

12.4.2.C This Section implements the requirements of Sections II.B, III.A and IV.A of Appendix I, 10CFR Part 50. The Operability Requirements implement the guides set forth in Section II.B of Appendix I. The ACTION statements provide the required operating flexibility and at the same time implement the guides set forth in Section IV.A of Appendix I to assure that the releases of radioactive material in gaseous effluents will be kept "as low as is reasonably achievable." The Surveillance Requirements implement the requirements in Section III.A of Appendix I that conformance with the guides of Appendix I is to be shown by calculation procedures based on models and data such that the actual exposure of an individual through the appropriate pathways is unlikely to be substantially underestimated.

12.4.3 Dose - I-131, I-133, Tritium, and Radioactive Material in Particulate Form

Operability Requirements

12.4.3.A The dose to a MEMBER OF THE PUBLIC from I-131, I-133, tritium, and all radionuclides in particulate form with half-lives greater than 8 days in gaseous effluents released from each unit to areas at or beyond the SITE BOUNDARY (see Zion Station ODCM Annex, Appendix F, Figure F-1) shall be limited to the following:

1. During any calendar quarter: Less than or equal to 7.5 mrem to any organ, and

2. During any calendar year: Less than or equal to 15 mrem to any organ.

Applicability: At all times.

Action

With the calculated dose from the release of Iodine-131, Iodine-133, tritium and all radionuclides in particulate form with half-lives greater than 8 days in gaseous effluents exceeding twice the limits of Section 12.4.3.A:

1. Limit subsequent releases such that the dose or dose commitment to a MEMBER OF THE PUBLIC from all uranium fuel cycle sources to less than or equal to 25 mrem to the total body or organ (except the thyroid which is limited to less than or equal to 75 mrem) over 12 consecutive months.

2. Prepare an analysis which demonstrates that radiation exposures to all MEMBERS OF THE PUBLIC from all uranium fuel cycle sources (including all effluent pathways and direct radiation) are less than the 40CFR Part 190 Standard. Otherwise, request a variance from the Commission to permit release which exceeds the 40CFR Part 190 Standard. The radiation exposure analysis shall use the methods prescribed in the ODCM.

Surveillance Requirements

12.4.3.B Cumulative dose contribution for the current calendar quarter and current calendar year for I-131, I-133, tritium, and all radionuclides in particulate form with half-lives greater than 8 days shall be determined in accordance with the methodologies and parameters in the ODCM at least once per 31 days.

Bases

12.4.3.C This Section implements the requirements of Sections II.C, III.A and IV.A of Appendix I, 10CFR Part 50. *The Operability Requirements are the guides set forth in Section II.C of Appendix I.* The ACTION statements provide the required operating flexibility and at the same time, implement the guides set forth in Section IV.A of Appendix I to assure that the releases of radioactive materials in gaseous effluents will be kept "as low as is reasonably achievable." The ODCM calculation methods specified in the Surveillance Requirements implement the requirements in Section III.A of Appendix I that conformance with the guides of Appendix I is to be shown by calculational procedures based on models and data such that the actual exposure of an individual through appropriate pathways is unlikely to be substantially underestimated. The release-rate specifications for radioiodines, radioactive material in particulate form and radioiodines other than noble gases are dependent on the existing radionuclide pathways to man, at or beyond the SITE BOUNDARY. The pathways which are examined in the development of these calculations are: 1) individual inhalation of airborne radionuclides, 2) disposition of radionuclides onto green leafy vegetation with subsequent consumption by man, 3) *deposition onto grassy areas where milk animals and meat producing animals graze with* consumption of the milk and meat by man.

12.4.4 Gaseous Effluent Treatment System

Operability Requirements

12.4.4.A The GASEOUS EFFLUENT TREATMENT SYSTEM shall be OPERABLE* and appropriate portions of these systems shall be used to reduce radioactive materials in gaseous effluents when the projected doses in 31 days due to gaseous effluent releases, from each unit, to areas at or beyond the SITE BOUNDARY (see Zion Station ODCM Annex, Appendix F, Figure F-1) would exceed:

1. 0.2 mrad to air from gamma radiation, or
2. 0.4 mrad to air from beta radiation, or
3. 0.3 mrem to any organ.

* The installed GASEOUS EFFLUENT TREATMENT SYSTEM shall be considered OPERABLE by meeting Sections 12.4.1, 12.4.2 and/or 12.4.3, as applicable.

Applicability: At all times.

Action: With the Gaseous Effluent Treatment System inoperable for more than 30 days or with radioactive gaseous waste being discharged without treatment and in excess of the above limits, return the system to OPERABLE status and place the appropriate portions of the system in use.

Surveillance Requirements

12.4.4.B Doses due to gaseous releases from each unit to areas at or beyond the SITE BOUNDARY shall be projected at least once per 31 days in accordance with the methodologies and parameters in the ODCM when the Gaseous Effluent Treatment Systems are not being fully utilized.

Bases

12.4.4.C The OPERABILITY of the GASEOUS EFFLUENT TREATMENT SYSTEM ensures that the system will be available for use whenever gaseous effluents require treatment prior to release to the environment.

The requirement that the appropriate portions of this system be used when specified provides reasonable assurance that the releases of radioactive materials in gaseous effluents will be kept "as low as is reasonably achievable." This section implements the requirement of 10CFR50.36a, General Design Criterion 60 of Appendix A to 10CFR50 and the design objective given in Section II.D of Appendix I to 10CFR50. The specified limits governing the use of appropriate portions of the Gaseous Effluent Treatment System were specified as a 2% fraction of the dose design objectives set forth in Section II.B and II.C of Appendix I, 10CFR50, for gaseous effluents.

12.5 RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

12.5.1 Monitoring Program

Operability Requirements

12.5.1.A The Radiological Environmental Monitoring Program shall be conducted as specified in Table 12.5-1.

Applicability: At all times.

Action

1. With the Radiological Environmental Monitoring Program not being conducted as specified in Table 12.5-1, prepare and submit to the Commission, in the Annual Radiological Environmental Operating Report, a description of the reasons for not conducting a program as required and the plans for preventing a recurrence.

   Deviations are permitted from the required sampling schedule if specimens are unobtainable due to hazardous conditions, seasonal unavailability, malfunction of sampling equipment, if a person who participates in the program goes out of business or no longer can provide sample, or contractor omission which is corrected as soon as discovered. If the equipment malfunctions, corrective actions shall be completed as soon as practical. If a person/business supplying samples goes out of business, a replacement supplier shall be found as soon as possible. All deviations from the sampling schedule shall be described in the Annual Radiological Environmental Operating Report.

2. With the level of radioactivity as a result of plant effluents in an environmental sampling medium at a specified location exceeding the reporting levels of Table 12.5-2 when averaged over any calendar quarter, prepare and submit to the Commission within 30 days a Special Report which identifies the cause(s) for exceeding the limit(s) and defines the corrective actions to be taken to reduce radioactive effluents so that the potential annual dose* to a MEMBER OF THE PUBLIC is less than the calendar year limits of Section 12.3.2, 12.4.2, or 12.4.3. When more than one of the radionuclides in Table 12.5.2 are detected in the sampling medium, this report shall be submitted if:

   $$\frac{\text{concentration (1)}}{\text{reporting level (1)}} + \frac{\text{concentration (2)}}{\text{reporting level (2)}} + \ldots \geq 1.0$$

   When radionuclides other than those in Table 12.5-2 are detected and are the result of plant effluents, this report shall be submitted if the potential annual dose to a MEMBER OF THE PUBLIC from all radionuclides is equal to or greater than the calendar year limits of Section 12.3.2, 12.4.2, or 12.4.3. This report is not required if the measured level of radioactivity was not the result of plant effluents; however, in such a event, the condition shall be reported and described in the Annual Radiological Environmental Operating Report.

*The methodology and parameters used to estimate the potential dose to a MEMBER OF THE PUBLIC shall be indicated in the report.

3. If the sample type or sampling location(s) required by Table 12.5-1 become(s) permanently unavailable, identify suitable alternative sampling media for the pathway of interest and/or specific locations for obtaining replacement samples and add them to the Radiological Environmental Monitoring Program as soon as practicable. The specific locations from which samples were unavailable may then be deleted from the program.

   Prepare and submit a controlled version of the ODCM within 180 days including a revised figure(s) and table reflecting the new location(s) with supporting information identifying the cause of the unavailability of samples and justifying the selection of new location(s) for obtaining samples.

Surveillance Requirements

12.5.1.B.1 The Radiological Environmental Monitoring samples shall be collected from the locations specified in the ODCM and analyzed pursuant to Table 12.5-1 and the detection capabilities required by Table 12.5-3.

Bases

12.5.1.C The Radiological Environmental Monitoring Program required by this section provides representative measurements of radiation and of radioactive materials in those exposure pathways and for those radionuclides that lead to the highest potential radiation exposures of MEMBERS OF THE PUBLIC resulting from the station operation. This monitoring program implements Section IV.B.2 of Appendix I to 10CFR50 and thereby supplements the radiological effluent monitoring program by verifying that the measurable concentrations of radioactive materials and levels of radiation are not higher than expected on the basis of the effluent measurements and modeling of the environmental exposure pathways. Guidance for this monitoring program is provided by the Radiological Assessment Branch Technical Position on Environmental Monitoring. The specified monitoring program is based on baseline/historical conditions for direct radiation measurements, soil, biota, and sediments established over years of operational experience and current site conditions/operating activities. The REMP need only be
re-evaluated for major changes to site conditions/configuration (e.g., prior to site decommissioning, if a significant release occurs, changing baseline data...). Program changes may be initiated at any time based on operational experience.

The required detection capabilities for environmental sample analyses are tabulated in terms of the lower limits of detection (LLD). The LLDs required by Table 12.5-3 are considered optimum for routine environmental measurements in industrial laboratories. It should be recognized that the LLD is defined as a before the fact limit representing the capability of a measurement system and not as an after the fact limit for a particular measurement.

Detailed discussion of the LLD, and other detection limits, can be found in HASL Procedures Manual, HASL-300 (revised annually), Currie, LA., "Limits for Qualitative Detection and Quantitative Determination-Application to Radiochemistry," Anal. Chem. 40, 586-93 (1968), and Gartwell, J.K., "Detection Limits for Radioanalytical Counting Techniques," Atlantic Richfield Hanford Company Report ARH-SA-215 (June 1975).

Interpretations

12.5.1.D Table 12.5-1 requires "one sample of each community drinking water supply downstream of the plant within 10 kilometers (6.2 miles)." Drinking water supply is defined as water taken from river, lakes, or reservoirs (not well water) which is used for drinking. Since Lake Michigan has no designated downstream or upstream direction, two drinking water locations (one north/one south) within 10 kilometers shall be sampled as drinking water indicator locations, and two other locations (one north/one south) beyond 10 kilometers shall be sampled as control locations.

TABLE 12.5-1

RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

EXPOSURE PATHWAY AND/ OR SAMPLE	NUMBER OF REPRESENTATIVE SAMPLES AND SAMPLE LOCATIONS[1]	SAMPLING AND COLLECTION FREQUENCY	TYPE AND FREQUENCY OF ANALYSIS
1. Airborne	Samples from a total of three locations: a. Indicator- Near Field Three samples from locations within 4 km (2.5 mi) in different sectors. b. Control- Far Field On sample from location 15-25 km (10-17 mi) in minimal D/Q sector.	Continuous sampler operation with particulate sample collection weekly (or more frequently if required due to dust loading).	Particulate Sampler: Gross beta analysis following weekly filter change[3] and gamma isotopic analysis[4] quarterly on composite filters by location on near field samples.

TABLE 12.5-1 (Continued)
RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

EXPOSURE PATHWAY AND/ OR SAMPLE	NUMBER OF REPRESENTATIVE SAMPLES AND SAMPLE LOCATIONS[1]	SAMPLING AND COLLECTION FREQUENCY	TYPE AND FREQUENCY OF ANALYSIS
2. Direct Radiation[5]	Thirty routine monitoring stations with thermoluminescent dosimeters (TLD), placed with at least one monitoring location in each meteorological sector, as follows: a. Indicator- Inner Ring (100 Series TLD) in the general area of the SITE BOUNDARY (0.1 to 1.5 mi); b. Other- One at each Airborne location given in part 1.a. Including 1 control TLD location located at control air sample station given in part 1.b. c. ISFSI Indicator – Inner Ring (100 Series TLD in the general area of the SITE BOUNDARY around ISFSI pad. (0.1 to 1.5 mi); d. Indicator- Outer Ring (100 Series TLD) in the general area of the 5 mile ring. (2.0 to 10 mi); Other TLDs may be placed at special interest locations beyond the Restricted Area where either a MEMBER OF THE PUBLIC or Commonwealth Edison employees have routine access.	Quarterly	Gamma dose on each TLD quarterly.

TABLE 12.5-1 (Continued)

RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

EXPOSURE PATHWAY AND/ OR SAMPLE	NUMBER OF REPRESENTATIVE SAMPLES AND SAMPLE LOCATIONS[1]	SAMPLING AND COLLECTION FREQUENCY	TYPE AND FREQUENCY OF ANALYSIS
3. Waterborne	a. Drinking Water Indicator[6]		
	One Sample from each community drinking water supply that could be affected by the station discharge within 10 km (6.2 mi) of discharge (north/south).	Weekly grab samples.	Gross beta and gamma isotopic analyses[4] on monthly composite; tritium analysis on quarterly composite.
	b. Control[6]		
	One sample upstream and downstream (north/south) of discharge.	Weekly grab samples.	Gross beta and gamma isotopic analyses[4] on monthly composite; tritium analysis on quarterly composite.
	c. Sediments		
	At least one sample within 10 km (6.2 mi) of discharge	Semiannually.	Gamma isotopic analysis [4] semiannually.

TABLE 12.5-1 (Continued)
RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

EXPOSURE PATHWAY AND/ OR SAMPLE	NUMBER OF REPRESENTATIVE SAMPLES AND SAMPLE LOCATIONS[1]	SAMPLING AND COLLECTION FREQUENCY	TYPE AND FREQUENCY OF ANALYSIS
4. Ingestion	a. Fish Indicator		
	Representative samples of commercially and recreationally important species in discharge area.	*Semiannually*	*Gamma isotopic analysis[4] on edible* portions.
	b. Control		
	Representative samples of commercially and recreationally important species not influenced by plant discharge.	Semiannually	Gamma isotopic analysis[4] on edible portions.

TABLE 12.5-1 (Continued)
RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM
TABLE NOTATIONS

(1) Specific parameters of distance and direction from the centerline of the midpoint of the two units and additional description where pertinent, shall be provided for each and every sample location in Table 11-1 of the ODCM Station Annexes. Refer to NUREG-0133, "Preparation of Radiological Effluent Technical Specifications for Nuclear Power Plants," October 1978, and to Radiological Assessment Branch Technical Position, Revision 1, November 1979.

(2) Deleted – No longer applicable.

(3) Airborne particulate sample filters shall be analyzed for gross beta radioactivity 24 hours or more after sampling to allow for radon and thorium daughter decay. If gross beta activity in any individual air particulate sample is greater than 10 times the 1999 mean of control samples, then, a gamma isotopic analysis shall be performed on that elevated individual sample.

(4) Gamma isotopic analysis means the identification and quantification of gamma emitting radionuclides that may be attributable to the effluents from the station.

(5) One or more instruments, such as a pressurized ion chamber, for measuring and recording dose rate continuously may be used in place of, or in addition to, integrating dosimeters. Film badges shall not be used as dosimeters for measuring direct radiation. The number of locations is not an absolute number. The number of direct radiation monitoring stations may be reduced according to geographical limitations; e.g., If a station is adjacent to a lake (i.e. Zion), some sectors may be over water thereby reducing the number of dosimeters which could be placed at the indicated distances. The frequency of analysis or readout for TLD systems will depend upon the characteristics of the specific system used and should be selected to obtain optimum dose information with minimal fading.

(6) Refer to Section 12.5.1.D for interpretation on the applicability of "downstream" and "upstream" . If no community drinking water supply exists within 6.2 miles of the discharge, surface water sampling shall be performed.

(7) Deleted – No longer applicable.

(8) Deleted – No longer applicable.

(9) DELETED

(10) Deleted – No longer applicable.

TABLE 12.5-2

REPORTING LEVELS FOR RADIOACTIVITY CONCENTRATIONS IN ENVIRONMENTAL SAMPLES*

ANALYSIS	WATER (pCi/l)	AIRBORNE PARTICULATE OR GASES (pCi/m^3)	FISH (pCi/kg, wet)
H-3	20,000 (1)		
Mn-54	1,000		30,000
Fe-59	400		10,000
Co-58	1,000		30,000
Co-60	300		10,000
Zn-65	300		20,000
Zr-Nb-95	400		
Cs-134	30	10	1,000
Cs-137	50	20	2,000
Ba-La-140	200		

(1) For drinking water samples. This is 40 CFR Part 141 value. If no drinking water pathway exists, a value of 30,000 pCi/l may be used.

* This table contains reporting levels for analyses beyond the requirements of Table 12.5-1.

TABLE 12.5-3

DETECTION CAPABILITIES FOR ENVIRONMENTAL SAMPLE ANALYSIS(1)

LOWER LIMIT OF DETECTION (LLD)(2)(3)

ANALYSIS	WATER (pCi/l)	AIRBORNE PARTICULATE OR GASES (pCi/m^3)	FISH (pCi/kg, wet)	SEDIMENT (pCi/kg, dry)
Gross Beta	4	0.01	1000	
H-3	2,000(7)			
Mn-54	15		130	
Co-58,60	15		130	
Zn-65	30		260	
Zr-Nb-95	15			
Cs-134	15	0.01	100	150
Cs-137	18	0.01	100	180

TABLE 12.5-3 (Continued)
DETECTION CAPABILITIES FOR ENVIRONMENTAL SAMPLE ANALYSIS
TABLE NOTATIONS

(1) This table contains lower limits of detection for analyses beyond the requirements of Table 12.5-1. This table does not imply that only these nuclides are to be detected and reported; other peaks which are measurable and identifiable in the analyses required by Table 12.5-1 shall be reported in the Annual Radiological Environmental Operating Report.

(2) Required detection capabilities for thermoluminescent dosimeters used for environmental measurements shall be in accordance with the recommendations of Regulatory Guide 4.13.

(3) The Lower Limit of Detection (LLD) is defined, for purposes of these specifications, as the smallest concentration of radioactive material in a sample that will yield a net count, above system background, that will be detected with 95% probability with only 5% probability of falsely concluding that a blank observation represents a "real" signal.

For a particular measurement system, which may include radiochemical separation, the LLD is defined as follows:

$$LLD = \frac{4.66\, S_b + 3/t_b}{(E)\,(V)\,(2.22)\,(Y)\,(\exp(-\lambda\Delta t))}$$

$$LLD \sim \frac{4.66\, S_b}{(E)\,(V)\,(2.22)\,(Y)\,(\exp(-\lambda\Delta t))}$$

Where: $4.66\, S_b >> 3/t_b$

LLD = the "a priori" Lower Limit of Detection (picocuries per unit mass or volume),

s_b = the standard deviation of the background counting rate or of the counting rate of a blank sample, as appropriate (counts per minute),

$$= \frac{\sqrt{Total\ Counts}}{t_b}$$

E = the counting efficiency(counts per disintegration),

V = the sample size (units of mass or volume),

2.22 = the number of disintegrations per minute per picocurie,

Y = the fractional radiochemical yield, when applicable,

λ = the radioactive decay constant for the particular radionuclide (sec^{-1}),

t_b = counting time of the background or blank (minutes), and

TABLE 12.5-3 (Continued)
DETECTION CAPABILITIES FOR ENVIRONMENTAL SAMPLE ANALYSIS
TABLE NOTATIONS

Δt = the elapsed time between sample collection, or end of the sample collection period, and the time of counting (sec).

Typical values of E, V, Y, and Δt should be used in the calculation.

It should be recognized that the LLD is defined as a before the fact limit representing the capability of a measurement system and not as an after the fact limit for a particular measurement.

Analyses shall be performed in such a manner that the stated LLDs will be achieved under routine conditions. Occasionally, background fluctuations, unavoidable small sample sizes, the presence of interfering nuclides, or other uncontrollable circumstances may render these LLDs unachievable. In such cases, the contributing factors shall be identified and described in the Annual Radiological Environmental Operating Report.

(4) Deleted – No longer applicable.

(5) Deleted – No longer applicable.

(6) Deleted – No longer applicable.

(7) This is the minimum required LLD, however, environmental samples analyzed off-site will be required to use 200 pCi/l.

12.5.2 LAND USE CENSUS

Operability Requirements

12.5.2.A A Land Use Census shall be conducted and shall identify within a distance of 10 km (6.2 mi) the location, in each of the following meteorological sectors, A, J, K, L, M, N, P, Q, and R**, the nearest residence. For dose calculation, a garden will be assumed at the nearest residence.

Applicability: At all times.

Action:

With a Land Use Census identifying location(s) that yields a calculated dose or dose commitment, via the same exposure pathway 20% greater than at a location from which samples are currently being obtained in accordance with Section 12.5.1, add the new location(s) within 30 days to the Radiological Environmental Monitoring Program given in Chapter 11 of the ODCM Station Annexes. The sampling location(s), excluding the control location, having the lowest calculated dose or dose commitment(s), via the same exposure pathway, may be deleted from this monitoring program after October 31 of the year in which this Land Use Census was conducted. Submit in the next Annual Radiological Environmental Operating Report documentation for a change in the ODCM including revised figure(s) and table(s) for the ODCM reflecting the new location(s) with information supporting the change in sampling locations.

** The nearest industrial facility shall also be documented if closer than the nearest residence.

Surveillance Requirements

12.5.2.B The Land Use Census shall be conducted, between June 1 and October 1, at least once per calendar year using that information that will provide the best results, such as by a door-to-door survey or aerial survey. The result of the Land Use Census shall be included in the Annual Radiological Environmental Operating Report.

Bases

12.5.2.C This specification is provided to ensure that changes in the use of areas at and beyond the SITE BOUNDARY are identified and that modifications to the Radiological Environmental Monitoring Program given in the ODCM are made if required by the results of this census.

This census satisfies the requirements of Section IV.B.3 of Appendix I to 10 CFR Part 50. An annual garden census will not be required since the licensee will assume that there is a garden at the nearest residence in each sector for dose calculations.

12.5.3 INTERLABORATORY COMPARISON PROGRAM

Operability Requirements

12.5.3.A Analyses shall be performed on radioactive materials supplied as part of an interlaboratory comparison program that correspond to samples required by Table 12.5.1.

Applicability: At all times.

Action:

1. With analyses not being performed as required above, report the corrective actions taken to prevent a recurrence to the Commission in the Annual Radiological Environmental Operating Report.

Surveillance Requirements

12.5.3.B A summary of the results obtained as part of the above required interlaboratory comparison program shall be included in the Annual Radiological Environmental Operating Report.

Bases

12.5.3.C The requirement for participation in an interlaboratory comparison program is provided to ensure that independent checks on the precision and accuracy of the measurements of radioactive material in environmental samples matrices are performed as part of the quality assurance program for environmental monitoring in order to demonstrate that the results are valid for the purposes of Section IV.B.2 of Appendix I to 10 CFR Part 50.

12.6 PROCESS CONTROL PROGRAM (PCP)

12.6.1 PCP Program Requirements

Contains the requirements and methodology for the current formulas, sampling, analyses, tests, and determinations performed to ensure the processing and packaging of solid radioactive wastes based on actual or simulated wet solid wastes is accomplished in compliance with:

- 10CFR Parts 20, 61, and 71
- State Regulations
- Burial Site Requirements
- Other Requirements Governing the Shipping and Burial of Radioactive Waste

12.6.2 Changes to the PCP

Changes to the PCP include those changes that affect the process or methodology, by which wastes are solidified, packaged to meet burial site form requirements, classified, or dewatered.

12.6.2.1. Shall be documented and records of reviews performed shall be retained, and

Shall contain sufficient information to support the change together with the appropriate analyses or evaluations justifying the change(s), and

Shall contain a determination that the change will maintain the overall conformance of the solidified waste product to existing requirements of Federal, State, or other applicable regulations, and

Shall become effective after review and acceptance by the Onsite Review and Investigative Function and the approval of the Decommissioning Plant Manager.

12.7 REPORTING REQUIREMENTS

12.7.1 Annual Radiological Environmental Operating Report*

Routine Annual Radiological Environmental Operating Report covering the operation of the Unit(s) during the previous calendar year shall be submitted according to the Permanently Defueled Technical Specifications. The Annual Radiological Environmental Operating Report shall include summaries, interpretations, and an analysis of trends of the results of the radiological environmental surveillance activities for the report period, including, as found appropriate, a comparison of preoperational studies with operational controls or with previous environmental surveillance reports, and an assessment of the observed impacts of the plant operation on the environment.

The Annual Radiological Environmental Operating Report shall include the results of all radiological environmental samples and of all environmental radiation measurements taken during the period pursuant to the locations specified in the tables and figures in the Chapter 11 of the ODCM Station Annexes, as well as summarized and tabulated results of these analyses and measurements in the format of the table in the Radiological Assessment Branch Technical Position, Revision 1, November 1979. In the event that some individual results are not available for inclusion with the report, the report shall be submitted noting and explaining the reasons for the missing results. The missing data shall be submitted as soon as possible in a supplementary report.

The reports shall also include the following: a summary description of the Radiological Environmental Monitoring Program; legible maps covering all sampling locations keyed to a table giving distances and directions from the midpoint between the two units; reasons for not conducting the Radiological Environmental Monitoring Program as required by Section 12.5.1, and discussion for all deviations from the sampling schedule of Table 11.1-1; a Table of Missed Samples and a Table of Sample Anomalies for all deviations from the sampling schedule of Table 11.1-1; discussion of environmental sample measurements that exceed the reporting levels of Table 12.5-2 but are not the result of plant effluents; discussion of all analyses in which the LLD required by Table 12.5-3 was not achievable; results of the Land Use Census required by Section 12.5.2; and the results of licensee participation in an interlaboratory comparison program and the corrective actions being taken if the specified program is not being performed as required by Section 12.5.3.

The Annual Radiological Environmental Operating Report shall also include an annual summary of hourly meteorological data collected over the applicable year. This annual summary may be either in the form of an hour-by-hour listing on magnetic tape of wind speed, wind direction, atmospheric stability, and precipitation (if measured), or in the form of joint frequency distributions of wind speed, wind direction, and atmospheric stability. In lieu of submission with the Annual Radiological Environmental Operating Report, the licensee has the option of retaining this summary of required meteorological data on site in a file that shall be provided to the NRC upon request.

* A single submittal may be made for a multiple unit station.

The Annual Radiological Environmental Operating Report shall also include an assessment of the radiation doses due to the radioactive liquid and gaseous effluents released from the Unit or Station during the previous calendar year. This report shall also include an assessment of radiation doses to the most likely exposed MEMBER OF THE PUBLIC from reactor releases and other nearby uranium fuel cycle sources, including doses from primary effluent pathways and direct radiation, for the previous calendar year. The assessment of radiation doses shall be performed in accordance with the methodology and parameters in the ODCM and in compliance with 10 CFR 20 and 40 CFR Part 190, "Environmental Radiation Protection Standards for Nuclear Power Operation."

12.7.2 Annual Radioactive Effluent Release Report**

The Annual Radioactive Effluent Release Reports shall include a summary of the quantities of radioactive liquid and gaseous effluents and solid waste released from the unit as outlined in Regulatory Guide 1.21, "Measuring, Evaluating, and Reporting Radioactivity in Solid Wastes and Releases of Radioactive Material in Liquid and Gaseous Effluent from Light-Water-Cooled Nuclear Power Plants," Revision 1, June 1974, with data summarized on a quarterly basis following the format of Appendix B thereof.

The Annual Radioactive Effluent Release Report shall include a list and description of unplanned releases of radioactive material in liquid effluents from the site to UNRESTRICTED AREAS and of unplanned releases of radioactive material in gaseous effluents from the site to areas at or beyond the SITE BOUNDARY during the reporting period.

The Annual Radioactive Effluent Release Report shall include any changes made during the reporting period to the Process Control Program as well as any major changes to Liquid, Gaseous or Solid Radwaste Treatment Systems, pursuant to Section 12.7.4.

The Annual Radioactive Effluent Release Report shall also include the following: an explanation as to why the inoperability of liquid or gaseous effluent monitoring instrumentation was not corrected within the time specified in Section 12.2.1 or 12.2.2, respectively; and description of the events leading to liquid holdup tanks exceeding the limits of to the Permanently Defueled Technical Specifications.

12.7.2.1 Exceptions to Regulatory Guide 1.21 Reporting Requirements:

a. All references to "semiannual" are not applicable. The report will be submitted according to Technical Specifications.

b. Hourly meteorological data is recorded for all periods throughout the year, and quarterly summaries will be reported. Separate meteorological data for periods of batch releases are not required to be included.

c. Total body and significant organ doses to the maximally exposed individual from receiving-water-related exposure pathways will be provided. Associated population dose is not required to be included.

d. Organ doses to the maximally exposed individual in unrestricted areas from radioactive iodine and radioactive material in particulate form from all exposure pathways will be provided. Associated population dose is not required to be included.

e. Total body doses to the maximally exposed individual in unrestricted areas from direct radiation from the facility should be included in the report. Associated population dose is not required to be included.

f. Total body doses to the population and average doses to individuals in the population from all receiving-water-related pathways are not required to be included.

g. Total body doses to the population and average doses to individuals in the population from gaseous effluents to a distance of 50 miles from the site and beyond will not be included.

** A single submittal may be made for a multiple unit station. The submittal should combine those sections that are common to all units at the station; however, for units with separate radwaste systems, the submittal shall specify the releases of radioactive material from each unit.

12.7.3 Offsite Dose Calculation Manual (ODCM)

12.7.3.1 Changes to the ODCM:

a. Shall be documented and records of reviews performed shall be retained as required by Permanently Defueled Technical Specifications. This documentation shall contain:

1. Sufficient Information to support the change together with the appropriate analyses or evaluations justifying the change(s); and

2. A determination that the change will maintain the level of radioactive effluent control required by 10 CFR 20.1302, 40 CFR Part 190, 10 CFR 50.36a, and Appendix I to 10 CFR Part 50 and not adversely impact the accuracy or reliability of effluent, dose, or setpoint calculations.

3. Documentation of the fact that the change has been reviewed and found acceptable by a Qualified Technical Review.

b. Shall become effective after the approval of the Plant Manager on the date specified by the Qualified Technical Review.

c. Shall be submitted to the Commission in the form of a complete, legible copy of the entire ODCM as a part of or concurrent with the Annual Radioactive Effluent Release Report for the period of the report in which any change to the ODCM was made effective. Each change shall be identified by markings in the margin of the affected pages, clearly indicating the area of the page that was changed, and shall indicate the date (e.g., month/year) the change was implemented.

12.7.4 <u>Major Changes to Liquid and Gaseous Effluent Treatment Systems</u>***

Licensee-initiated major changes to the Effluent Treatment Systems (liquid and gaseous):

a. Shall be reported to the Commission in the Annual Radioactive Effluent Release Report for the period in which the evaluation was reviewed by a Qualified Technical Review. The discussion of each change shall contain:

   1) A summary of the evaluation that led to the determination that the change could be made in accordance with 10 CFR 50.59;

   2) Sufficient detailed information to totally support the reason for the change without benefit of additional and supplemental information;

   3) A detailed description of the equipment, components, and processes involved and the interfaces with other plant systems.

   4) An evaluation of the change which shows the predicted releases of radioactive materials in liquid and gaseous effluents that differ from those previously predicted in the License application and amendments thereto;

   5) An evaluation of the change, which shows the expected maximum exposures to a MEMBER OF THE PUBLIC and to the general population that differ from those previously estimated in the License application and amendments thereto;

   6) A comparison of the predicted releases of radioactive materials, in liquid and gaseous effluents, to the actual releases for the period prior to when the changes are to be made;

   7) An estimate of the exposure to plant operating personnel as a result of the change; and

   8) Documentation of the fact that the change was reviewed and found acceptable by a Qualified Technical Review.

b. Shall become effective upon review and acceptance by the Qualified Technical Review.

*** Licensees may choose to submit the information called for in this standard as part of the biennial DSAR update.

APPENDIX F

ZION ANNEX INDEX

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STATION-SPECIFIC DATA FOR ZION UNITS 1 AND 2

F.1 INTRODUCTION

This appendix contains data relevant to the Zion site. Included is a figure showing the unrestricted area boundary, restricted area boundary and values of parameters used in offsite dose assessment.

F.2 REFERENCES

1. Sargent & Lundy, Nuclear Analysis and Technology Division, Calculation No. ATD-0090, Revision 0.

2. "Verification of Environmental Parameter Used for Commonwealth Edison Company's Offsite Dose Calculations," NUS Corporation, 1988.

3. "Verification of Environmental Parameter Used for Commonwealth Edison Company's Offsite Dose Calculations," NUTECH Engineering Group, 1992.

Table F-1
Aquatic Environmental Dose Parameters

General Information[a]

The existence of irrigation is not mentioned in Zion Environmental Report.

Recreation includes one or more of the following: boating, water skiing, swimming, and sport fishing.

Water and Fish Ingestion Parameters

Parameter[b]	Value
D^w	6
Z	10

Limits on Radioactivity in Unprotected Outdoor Tanks[c]

Outside Temporary Tank $\leq$ 10Ci[d]

(per Technical Specification 3.11)

[a] This is based on information in Zion Environmental Report Section 2.3.2.2.

[b] The parameters are defined in Section A.2.1 of Appendix A. Based on Lake Michigan Model discussed in Section C.1.3.1.2 of Appendix C.

[c] See Section A.2.4 of Appendix A.

[d] Tritium and dissolved or entrained noble gases are excluded from this limit

Table F-2

Station Characteristics

STATION: Zion Nuclear Power Station

LOCATION: Zion, Illinios

Characteristics of Elevated Release Point

1) Release Height = ____m 2) Diameter = _____m

3) Exit Speed = _____ms^{-1} 4) Heat Content = ____Kcal s^{-1}

Characteristics of Vent Stack Release Point

1) Release Height = 55.32 m[a] 2) Diameter = 2.32 m

3) Exit Speed = 11.2 ms^{-1}[a]

Characteristics of Ground Level Point

1) Release Height = 0 m

2) Building Factor (D) = 57.6 m^a

Meterological Data

A 250 ft Tower is Located 700 m NNW of elevated reease point

Tower Data Used in Calculations

Release Point	Wind Speed and Direction	Differential Temperature
Elevated	(NA)	(NA)
Vent	125	250-35
Ground	35	250-35

[a] Used in calculating the meteorological and dose factors in Tables F-5, F-6, and F-7. See Sections B.3 through B.6 of Appendix B.

Table F-3

Critical Ranges

Direction	Unrestricted Area Boundary[a] (m)	Restricted Area Boundary (m)	Nearest Resident[b] (m)	Nearest Dairy Farm Within 5 Miles[c] (m)
N	469	375	4000	None
NNE	475	400	d	None
NE	400	325	d	None
ENE	400	200	d	None
E	400	175	d	None
ESE	400	175	d	None
SE	400	175	d	None
SSE	400	200	d	None
S	433	350	d	None
SSW	439	375	3700	None
SW	518	475	2000	None
WSW	671	671	2000	None
W	658	658	1100	None
WNW	893	893	2000	None
NW	847	847	2000	None
NNW	725	250	2400	None

[a]Used in calculating the meteorological and dose factors in Tables F-5 and F-7. See Sections B.3 through B.6 of Appendix B.

[b]1992 annual survey by Teledyne Isotopes Midwest Laboratories. The distances are rounded to the nearest conservative 100 meters.

[c]1992 annual milch animal census by Teledyne Isotopes Midwest Laboratories. Used in calculating the D/Q values in Table F-6. The distances are rounded to the nearest conservative 100 meters.

[d]Lake Michigan.

Table F-4

Average Wind Speeds

Table F-4

Average Wind Speeds

Downwind Direction	Average Wind Speed (m/sec)[a] Mixed Mode	Ground Level
N	5.0	3.2
NNE	5.3	3.3
NE	5.8	4.1
ENE	5.6	3.9
E	5.7	3.9
ESE	5.1	3.3
SE	4.9	3.0
SSE	5.1	3.4
S	5.9	4.6
SSW	5.8	4.4
SW	5.1	4.0
WSW	5.2	4.6
W	5.1	4.4
WNW	4.8	3.7
NW	4.7	3.1
NNW	5.1	3.9

[a]Calculated in Reference 1 of Section F.2 using formulas in Section B.1.3 of Appendix B. Based on Zion site meteorological data, January 1979 through December 1987.

Table F-5
X/Q and D/Q Maxima at or Beyond the Unrestricted Area Boundary

Downwind	Mixed Mode(Vent) Release				Ground Level Release		
Direction	Radius (meters)	X/Q (sec/m**3)	Radius (meters)	D/Q (1/m**2)	Radius (meters)	X/Q (sec/m**3)	D/Q (1/m**2)
N	469.	2.032E-06	469.	1.168E-08	469.	9.548E-06	3.680E-08
NNE	475.	1.792E-06	475.	9.983E-09	476.	1.004E-05	3.256E-08
NE	400.	2.710E-06	400.	1.997E-08	400.	1.386E-05	5.708E-08
ENE	400.	2.180E-06	400.	1.734E-08	400.	1.160E-05	4.855E-08
E	400.	1.949E-06	400.	1.889E-08	400.	1.169E-05	5.211E-08
ESE	400.	1.650E-06	400.	1.319E-08	400.	1.280E-05	4.730E-08
SE	400.	1.646E-06	400.	1.237E-08	400.	1.312E-05	4.985E-08
SSE	400.	1.001E-06	400.	9.230E-09	400.	7.852E-06	3.238E-08
S	433.	1.272E-06	433.	1.524E-08	433.	7.058E-06	3.562E-08
SSW	439.	9.650E-07	439.	1.357E-08	439.	5.768E-06	3.290E-08
SW	518.	4.590E-07	518.	6.081E-09	518.	3.125E-06	1.625E-08
WSW	671.	2.311E-07	671.	3.509E-09	671.	1.393E-06	8.964E-09
W	658.	2.394E-07	658.	3.381E-09	658.	1.445E-06	8.440E-09
WNW	893.	1.427E-07	893.	1.869E-09	893.	8.817E-07	4.789E-09
NW	847.	2.110E-07	847.	2.671E-09	847.	1.310E-06	6.607E-09
NNW	725.	3.740E-07	725.	4.535E-09	725.	2.038E-06	1.148E-08

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Note: Based on the formulas in Sections B.3 and B.4 of Appendix B.

X/Q is used for beta skin, and inhalation dose pathways. See Sections A.1.2, A.1.3, and A.1.4.2 of Apprendix A.

D/Q is used for produce and leafy vegetable pathways. Section A.1.4 of Appendix A.

The mixed mode level release data are provided for reference purposes only. Routine dose calculations are performed using ground level data.

Radius is the approximate distance from the midpoint between gaseous effluent release points to the location of highest X/Q or D/Q at or beyond the unrestricted area boundary (UAB).

Table F-5a

X/Q and D/Q Maxima at or Beyond the Restricted Area Boundary

Downwind	Mixed Mode(Vent) Release				Ground Level Release		
Direction	Radius (meters)	X/Q (sec/m**3)	Radius (meters)	D/Q (1/m**2)	Radius (meters)	X/Q (sec/m**3)	D/Q (1/m**2)
N	375.	3.015E-06	375.	1.605E-08	375.	1.420E-05	5.165E-08
NNE	400.	2.426E-06	400.	1.278E-08	400.	1.363E-05	4.230E-08
NE	325.	3.917E-06	325.	2.653E-08	325.	2.009E-05	7.781E-08
ENE	200.	7.441E-06	200.	4.345E-08	200.	4.027E-05	1.330E-07
E	175.	8.400E-06	175.	5.512E-08	175.	5.177E-05	1.719E-07
ESE	175.	7.025E-06	175.	3.590E-08	175.	5.670E-05	1.559E-07
SE	175.	7.002E-06	175.	3.298E-08	175.	5.811E-05	1.644E-07
SSE	200.	3.362E-06	200.	2.113E-08	200.	2.730E-05	8.871E-08
S	350.	1.851E-06	350.	2.054E-08	350.	1.031E-05	4.906E-08
SSW	375.	1.270E-06	375.	1.676E-08	375.	7.631E-06	4.174E-08
SW	475.	5.307E-07	475.	6.818E-09	475.	3.626E-06	1.858E-08
WSW	671.	2.311E-07	671.	3.509E-09	671.	1.393E-06	8.964E-09
W	658.	2.394E-07	658.	3.381E-09	658.	1.445E-06	8.440E-09
WNW	893.	1.427E-07	893.	1.869E-09	893.	8.817E-07	4.789E-09
NW	847.	2.110E-07	847.	2.871E-09	847.	1.310E-06	6.607E-09
NNW	250.	2.279E-06	250.	1.778E-08	250.	1.316E-05	5.779E-08

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Note: Based on the formulas in Sections B.3 and B.4 of Appendix B.

The mixed mode release data are provided for reference purposes only. Routine dose calculations are performed using ground level data.

Radius is the approximate distance from the midpoint between gaseous effluent release points to the location of highest X/Q or D/Q at or beyond the restricted area boundary (RAB).

Table F-5b
Maximum Offsite Gamma-χ/Q

Downwind Direction	Radius (meters)	Ground Gamma-χ/Q (sec/m**3)	Vent Gamma-χ/Q (sec/m**3)
N	469	2.51E-06	8.16E-07
NNE	475	2.51E-06	7.26E-07
NE	400	3.33E-06	1.05E-06
ENE	400	2.90E-06	8.87E-07
E	400	2.97E-06	8.62E-07
ESE	400	3.17E-06	7.84E-07
SE	400	3.52E-06	8.35E-07
SSE	400	2.13E-06	5.70E-07
S	433	1.98E-06	6.29E-07
SSW	439	1.78E-06	5.65E-07
SW	518	1.05E-06	3.39E-07
WSW	671	5.32E-07	2.17E-07
W	658	5.42E-07	2.13E-07
WNW	893	3.58E-07	1.41E-07
NW	847	5.15E-07	2.00E-07
NNW	725	7.59E-07	3.26E-07

Table F-6

χ/Q and D/Q at the Nearest Resident Locations within 5 miles

Location Description	Direction	Distance		Ground Level Release		Mixed Mode (Vent) Release	
				χ/Q	D/Q	χ/Q	D/Q
		miles	meters	sec/m^3	m^{-2}	sec/m^3	m^{-2}
NEAREST RESIDENCE	N	2.49	4000	5.00E-07	7.30E-10	5.60E-08	5.80E-11
NEAREST RESIDENCE	NNE	4.97	8000	2.20E-07	2.20E-10	4.20E-08	2.50E-11
NEAREST RESIDENCE	NE	4.97	8000	2.40E-07	3.10E-10	5.20E-08	6.40E-11
NEAREST RESIDENCE	ENE	4.97	8000	2.00E-07	2.80E-10	4.80E-08	7.10E-11
NEAREST RESIDENCE	E	4.97	8000	2.40E-07	4.30E-10	6.80E-08	1.40E-10
NEAREST RESIDENCE	ESE	4.97	8000	1.80E-07	3.10E-10	5.50E-08	1.00E-10
NEAREST RESIDENCE	SE	4.97	8000	1.50E-07	2.70E-10	5.20E-08	8.80E-11
NEAREST RESIDENCE	SSE	4.97	8000	1.10E-07	1.70E-10	3.50E-08	5.30E-11
NEAREST RESIDENCE	S	4.97	8000	1.10E-07	2.40E-10	4.20E-08	7.70E-11
NEAREST RESIDENCE	SSW	2.30	3700	3.20E-07	1.20E-09	9.30E-08	4.70E-10
NEAREST RESIDENCE	SW	1.86	3000	3.70E-07	1.20E-09	7.80E-08	3.80E-10
NEAREST RESIDENCE	WSW	1.24	2000	4.70E-07	1.50E-09	5.00E-08	4.20E-10
NEAREST RESIDENCE	W	0.68	1100	1.50E-06	3.70E-09	3.40E-08	5.30E-10
NEAREST RESIDENCE	WNW	1.24	2000	5.20E-07	1.40E-09	4.10E-08	2.20E-10
NEAREST RESIDENCE	NW	1.24	2000	5.60E-07	1.50E-09	4.20E-08	2.30E-10
NEAREST RESIDENCE	NNW	1.49	2400	6.30E-07	1.90E-09	6.80E-08	4.10E-10

Table F-6a

χ/Q and D/Q at the Nearest Cow Milk Locations within 5 miles

Location Description	Direction	Distance		Ground Level Release		Mixed Mode (Vent) Release	
				χ/Q	D/Q	χ/Q	D/Q
		miles	meters	sec/m^3	m^{-2}	sec/m^3	m^{-2}
COW MILK	N	4.97	8000	1.90E-07	2.10E-10	4.10E-08	1.90E-11
COW MILK	NNE	4.97	8000	2.20E-07	2.20E-10	4.20E-08	2.50E-11
COW MILK	NE	4.97	8000	2.40E-07	3.10E-10	5.20E-08	6.40E-11
COW MILK	ENE	4.97	8000	2.00E-07	2.80E-10	4.80E-08	7.10E-11
COW MILK	E	4.97	8000	2.40E-07	4.30E-10	6.80E-08	1.40E-10
COW MILK	ESE	4.97	8000	1.80E-07	3.10E-10	5.50E-08	1.00E-10
COW MILK	SE	4.97	8000	1.50E-07	2.70E-10	5.20E-08	8.80E-11
COW MILK	SSE	4.97	8000	1.10E-07	1.70E-10	3.50E-08	5.30E-11
COW MILK	S	4.97	8000	1.10E-07	2.40E-10	4.20E-08	7.70E-11
COW MILK	SSW	4.97	8000	1.00E-07	3.10E-10	4.90E-08	1.40E-10
COW MILK	SW	4.97	8000	8.50E-08	2.20E-10	3.90E-08	8.20E-11
COW MILK	WSW	4.97	8000	5.80E-08	1.30E-10	2.40E-08	5.00E-11
COW MILK	W	4.97	8000	6.90E-08	1.20E-10	2.50E-08	3.40E-11
COW MILK	WNW	4.97	8000	6.60E-08	1.20E-10	2.60E-08	2.70E-11
COW MILK	NW	4.97	8000	7.10E-08	1.30E-10	2.70E-08	2.90E-11
COW MILK	NNW	4.97	8000	1.10E-07	2.20E-10	3.40E-08	5.70E-11

Table F-6b

χ/Q and D/Q at the Nearest Cow Milk Locations within 5 miles

Location Description	Direction	Distance		Ground Level Release		Mixed Mode (Vent) Release	
		miles	meters	χ/Q sec/m^3	D/Q m^{-2}	χ/Q sec/m^3	D/Q m^{-2}
COW MEAT	N	4.97	8000	1.90E-07	2.10E-10	4.10E-08	1.90E-11
COW MEAT	NNE	4.97	8000	2.20E-07	2.20E-10	4.20E-08	2.50E-11
COW MEAT	NE	4.97	8000	2.40E-07	3.10E-10	5.20E-08	6.40E-11
COW MEAT	ENE	4.97	8000	2.00E-07	2.80E-10	4.80E-08	7.10E-11
COW MEAT	E	4.97	8000	2.40E-07	4.30E-10	6.80E-08	1.40E-10
COW MEAT	ESE	4.97	8000	1.80E-07	3.10E-10	5.50E-08	1.00E-10
COW MEAT	SE	4.97	8000	1.50E-07	2.70E-10	5.20E-08	8.80E-11
COW MEAT	SSE	4.97	8000	1.10E-07	1.70E-10	3.50E-08	5.30E-11
COW MEAT	S	4.97	8000	1.10E-07	2.40E-10	4.20E-08	7.70E-11
COW MEAT	SSW	4.97	8000	1.00E-07	3.10E-10	4.90E-08	1.40E-10
COW MEAT	SW	4.97	8000	8.50E-08	2.20E-10	3.90E-08	8.20E-11
COW MEAT	WSW	4.47	7200	6.70E-08	1.60E-10	2.70E-08	6.00E-11
COW MEAT	W	3.48	5600	1.10E-07	2.20E-10	3.30E-08	6.10E-11
COW MEAT	WNW	4.97	8000	6.60E-08	1.20E-10	2.60E-08	2.70E-11
COW MEAT	NW	4.97	8000	7.10E-08	1.30E-10	2.70E-08	2.90E-11
COW MEAT	NNW	4.97	8000	1.10E-07	2.20E-10	3.40E-08	5.70E-11

Table F-7

Maximum Offsite Finite Plume Gamma Dose Factors Based on 1 cm Depth at the Unrestricted Area Boundary for Kr-83m

Downwind Direction	Unrestricted Area Bound (meters)	Mixed Mode(Vent) Release Radius (meters)	V (mrad/yr)/(uCi/sec)	VBAR (mrad/yr)/(uCi/sec)	Ground Level Release Radius (meters)	G (mrad/yr)/(uCi/sec)	GBAR (mrad/yr)/(uCi/sec)
N	469.	469.	2.083E-04	1.571E-04	469.	9.339E-04	7.042E-04
NNE	475.	475.	1.807E-04	1.362E-04	475.	9.509E-04	7.170E-04
NE	400.	400.	2.720E-04	2.051E-04	400.	1.286E-03	9.693E-04
ENE	400.	400.	2.248E-04	1.695E-04	400.	1.092E-03	8.237E-04
E	400.	400.	2.097E-04	1.581E-04	400.	1.109E-03	8.363E-04
ESE	400.	400.	1.722E-04	1.298E-04	400.	1.193E-03	8.995E-04
SE	400.	400.	1.769E-04	1.334E-04	400.	1.277E-03	9.630E-04
SSE	400.	400.	1.100E-04	8.298E-05	400.	7.648E-04	5.767E-04
S	433.	433.	1.458E-04	1.099E-04	433.	7.104E-04	5.356E-04
SSW	439.	439.	1.151E-04	8.679E-05	439.	6.071E-04	4.578E-04
SW	518.	518.	5.574E-05	4.203E-05	518.	3.385E-04	2.553E-04
WSW	671.	671.	3.032E-05	2.286E-05	671.	1.629E-04	1.228E-04
W	658.	658.	3.056E-05	2.304E-05	658.	1.657E-04	1.249E-04
WNW	893.	893.	1.812E-05	1.366E-05	893.	1.004E-04	7.567E-05
NW	847.	847.	2.674E-05	2.016E-05	847.	1.483E-04	1.118E-04
NNW	725.	725.	4.752E-05	3.583E-05	725.	2.306E-04	1.739E-04

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Note: Based on the formulas in Sections B.5 and B.6 of Appendix B.

Approximate distance from midpoint between gaseous effluent release points.

Table F-7 (Continued)

Maximum Offsite Finite Plume Gamma Dose Factors Based on 1 cm Depth at the Unrestricted Area Boundary for Kr-85m

Downwind Direction	Unrestricted Area Bound (meters)	Mixed Mode(Vent) Release Radius (meters)	V (mrad/yr)/(uCi/sec)	VBAR (mrad/yr)/(uCi/sec)	Ground Level Release Radius (meters)	G (mrad/yr)/(uCi/sec)	GBAR (mrad/yr)/(uCi/sec)
N	469.	469.	1.249E-03	1.198E-03	469.	3.995E-03	3.816E-03
NNE	475.	475.	1.110E-03	1.064E-03	475.	3.989E-03	3.809E-03
NE	400.	400.	1.611E-03	1.545E-03	400.	5.315E-03	5.074E-03
ENE	400.	400.	1.363E-03	1.307E-03	400.	4.613E-03	4.406E-03
E	400.	400.	1.323E-03	1.269E-03	400.	4.732E-03	4.519E-03
ESE	400.	400.	1.189E-03	1.142E-03	400.	5.043E-03	4.817E-03
SE	400.	400.	1.263E-03	1.213E-03	400.	5.581E-03	5.332E-03
SSE	400.	400.	8.562E-04	8.228E-04	400.	3.369E-03	3.219E-03
S	433.	433.	9.628E-04	9.241E-04	433.	3.136E-03	2.997E-03
SSW	439.	439.	8.568E-04	8.231E-04	439.	2.804E-03	2.681E-03
SW	518.	518.	5.038E-04	4.847E-04	518.	1.645E-03	1.573E-03
WSW	671.	671.	3.185E-04	3.067E-04	671.	8.367E-04	8.009E-04
W	658.	658.	3.128E-04	3.011E-04	658.	8.482E-04	8.118E-04
WNW	893.	893.	2.051E-04	1.976E-04	893.	5.554E-04	5.320E-04
NW	847.	847.	2.935E-04	2.827E-04	847.	8.008E-04	7.668E-04
NNW	725.	725.	4.801E-04	4.621E-04	725.	1.185E-03	1.134E-03

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Table F-7 (Continued)

Maximum Offsite Finite Plume Gamma Dose Factors Based on 1 cm Depth at the Unrestricted Area Boundary for Kr-85

Downwind Direction	Unrestricted Area Bound (meters)	Mixed Mode(Vent) Release Radius (meters)	V (mrad/yr)/(uCi/sec)	VBAR (mrad/yr)/(uCi/sec)	Ground Level Release Radius (meters)	G (mrad/yr)/(uCi/sec)	GBAR (mrad/yr)/(uCi/sec)
N	469.	469.	1.403E-05	1.356E-05	469.	4.313E-05	4.171E-05
NNE	475.	475.	1.249E-05	1.207E-05	475.	4.315E-05	4.173E-05
NE	400.	400.	1.803E-05	1.743E-05	400.	5.723E-05	5.534E-05
ENE	400.	400.	1.526E-05	1.476E-05	400.	4.984E-05	4.819E-05
E	400.	400.	1.482E-05	1.433E-05	400.	5.110E-05	4.941E-05
ESE	400.	400.	1.349E-05	1.304E-05	400.	5.450E-05	5.270E-05
SE	400.	400.	1.436E-05	1.388E-05	400.	6.049E-05	5.849E-05
SSE	400.	400.	9.798E-06	9.474E-06	400.	3.657E-05	3.536E-05
S	433.	433.	1.082E-05	1.046E-05	433.	3.398E-05	3.286E-05
SSW	439.	439.	9.715E-06	9.394E-06	439.	3.053E-05	2.952E-05
SW	518.	518.	5.829E-06	5.636E-06	518.	1.805E-05	1.746E-05
WSW	671.	671.	3.737E-06	3.614E-06	671.	9.147E-06	8.845E-06
W	658.	658.	3.664E-06	3.543E-06	658.	9.329E-06	9.021E-06
WNW	893.	893.	2.425E-06	2.345E-06	893.	6.158E-06	5.955E-06
NW	847.	847.	3.444E-06	3.330E-06	847.	8.861E-06	8.569E-06
NNW	725.	725.	5.601E-06	5.416E-06	725.	1.305E-05	1.262E-05

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Table F-7 (Continued)

Maximum Offsite Finite Plume Gamma Dose Factors Based on 1 cm Depth at the Unrestricted Area Boundary for Kr-87

Downwind Direction	Unrestricted Area Bound (meters)	Mixed Mode(Vent) Release Radius (meters)	V (mrad/yr)/(uCi/sec)	VBAR (mrad/yr)/(uCi/sec)	Ground Level Release Radius (meters)	G (mrad/yr)/(uCi/sec)	GBAR (mrad/yr)/(uCi/sec)
N	469.	469.	4.083E-03	3.965E-03	469.	1.194E-02	1.159E-02
NNE	475.	475.	3.638E-03	3.533E-03	475.	1.182E-02	1.148E-02
NE	400.	400.	5.285E-03	5.132E-03	400.	1.594E-02	1.548E-02
ENE	400.	400.	4.477E-03	4.347E-03	400.	1.378E-02	1.338E-02
E	400.	400.	4.372E-03	4.245E-03	400.	1.418E-02	1.377E-02
ESE	400.	400.	3.997E-03	3.882E-03	400.	1.509E-02	1.465E-02
SE	400.	400.	4.251E-03	4.128E-03	400.	1.660E-02	1.612E-02
SSE	400.	400.	2.913E-03	2.829E-03	400.	1.000E-02	9.709E-03
S	433.	433.	3.188E-03	3.096E-03	433.	9.319E-03	9.048E-03
SSW	439.	439.	2.882E-03	2.799E-03	439.	8.294E-03	8.053E-03
SW	518.	518.	1.737E-03	1.687E-03	518.	4.802E-03	4.663E-03
WSW	671.	671.	1.105E-03	1.073E-03	671.	2.485E-03	2.413E-03
W	658.	658.	1.086E-03	1.055E-03	658.	2.484E-03	2.412E-03
WNW	893.	893.	7.089E-04	6.884E-04	893.	1.620E-03	1.573E-03
NW	847.	847.	1.016E-03	9.866E-04	847.	2.339E-03	2.271E-03
NNW	725.	725.	1.646E-03	1.599E-03	725.	3.466E-03	3.365E-03

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Table F-7 (Continued)

Maximum Offsite Finite Plume Gamma Dose Factors Based on 1 cm Depth at the Unrestricted Area Boundary for Kr-88

Downwind Direction	Unrestricted Area Bound (meters)	Mixed Mode(Vent) Release Radius (meters)	V (mrad/yr)/(uCi/sec)	VBAR (mrad/yr)/(uCi/sec)	Ground Level Release Radius (meters)	G (mrad/yr)/(uCi/sec)	GBAR (mrad/yr)/(uCi/sec)
N	469.	469.	9.857E-03	9.577E-03	469.	2.869E-02	2.785E-02
NNE	475.	475.	8.789E-03	8.540E-03	475.	2.857E-02	2.773E-02
NE	400.	400.	1.269E-02	1.233E-02	400.	3.819E-02	3.707E-02
ENE	400.	400.	1.076E-02	1.045E-02	400.	3.315E-02	3.217E-02
E	400.	400.	1.049E-02	1.019E-02	400.	3.406E-02	3.306E-02
ESE	400.	400.	9.643E-03	9.372E-03	400.	3.629E-02	3.523E-02
SE	400.	400.	1.027E-02	9.982E-03	400.	4.011E-02	3.893E-02
SSE	400.	400.	7.051E-03	6.854E-03	400.	2.420E-02	2.350E-02
S	433.	433.	7.661E-03	7.445E-03	433.	2.251E-02	2.185E-02
SSW	439.	439.	6.944E-03	6.750E-03	439.	2.014E-02	1.955E-02
SW	518.	518.	4.228E-03	4.111E-03	518.	1.180E-02	1.146E-02
WSW	671.	671.	2.722E-03	2.647E-03	671.	6.046E-03	5.872E-03
W	658.	658.	2.671E-03	2.597E-03	658.	6.106E-03	5.930E-03
WNW	893.	893.	1.763E-03	1.715E-03	893.	4.018E-03	3.902E-03
NW	847.	847.	2.507E-03	2.438E-03	847.	5.787E-03	5.620E-03
NNW	725.	725.	4.046E-03	3.934E-03	725.	8.527E-03	8.281E-03

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Table F-7 (Continued)

Maximum Offsite Finite Plume Gamma Dose Factors Based on 1 cm Depth at the Unrestricted Area Boundary for Kr-89

Downwind Direction	Unrestricted Area Bound (meters)	Mixed Mode(Vent) Release Radius (meters)	V (mrad/yr)/(uCi/sec)	VBAR (mrad/yr)/(uCi/sec)	Ground Level Release Radius (meters)	G (mrad/yr)/(uCi/sec)	GBAR (mrad/yr)/(uCi/sec)
N	469.	469.	5.171E-03	5.022E-03	469.	1.200E-02	1.165E-02
NNE	475.	475.	4.511E-03	4.381E-03	475.	1.066E-02	1.036E-02
NE	400.	400.	7.533E-03	7.317E-03	400.	1.769E-02	1.718E-02
ENE	400.	400.	6.385E-03	6.202E-03	400.	1.487E-02	1.444E-02
E	400.	400.	6.418E-03	6.235E-03	400.	1.553E-02	1.509E-02
ESE	400.	400.	5.519E-03	5.361E-03	400.	1.536E-02	1.492E-02
SE	400.	400.	5.718E-03	5.554E-03	400.	1.603E-02	1.557E-02
SSE	400.	400.	4.006E-03	3.891E-03	400.	9.747E-03	9.467E-03
S	433.	433.	4.618E-03	4.486E-03	433.	9.634E-03	9.357E-03
SSW	439.	439.	4.165E-03	4.045E-03	439.	8.417E-03	8.175E-03
SW	518.	518.	2.197E-03	2.134E-03	518.	4.032E-03	3.916E-03
WSW	671.	671.	1.160E-03	1.127E-03	671.	1.945E-03	1.889E-03
W	658.	658.	1.147E-03	1.115E-03	658.	1.835E-03	1.782E-03
WNW	893.	893.	5.673E-04	5.511E-04	893.	8.457E-04	8.215E-04
NW	847.	847.	8.765E-04	8.515E-04	847.	1.278E-03	1.241E-03
NNW	725.	725.	1.729E-03	1.679E-03	725.	2.580E-03	2.506E-03

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Table F-7 (Continued)

Maximum Offsite Finite Plume Gamma Dose Factors Based on 1 cm Depth at the Unrestricted Area Boundary for Kr-90

Downwind Direction	Unrestricted Area Bound (meters)	Mixed Mode(Vent) Release Radius (meters)	V (mrad/yr)/(uCi/sec)	VBAR (mrad/yr)/(uCi/sec)	Ground Level Release Radius (meters)	G (mrad/yr)/(uCi/sec)	GBAR (mrad/yr)/(uCi/sec)
N	469.	469.	9.956E-04	9.656E-04	469.	1.150E-03	1.115E-03
NNE	475.	475.	9.477E-04	9.192E-04	475.	9.696E-04	9.400E-04
NE	400.	400.	2.318E-03	2.248E-03	400.	3.045E-03	2.952E-03
ENE	400.	400.	1.891E-03	1.834E-03	400.	2.413E-03	2.339E-03
E	400.	400.	1.967E-03	1.908E-03	400.	2.548E-03	2.470E-03
ESE	400.	400.	1.417E-03	1.375E-03	400.	1.823E-03	1.767E-03
SE	400.	400.	1.347E-03	1.306E-03	400.	1.778E-03	1.723E-03
SSE	400.	400.	1.054E-03	1.022E-03	400.	1.311E-03	1.271E-03
S	433.	433.	1.426E-03	1.382E-03	433.	1.738E-03	1.685E-03
SSW	439.	439.	1.208E-03	1.171E-03	439.	1.463E-03	1.419E-03
SW	518.	518.	4.444E-04	4.310E-04	518.	4.833E-04	4.686E-04
WSW	671.	671.	1.729E-04	1.677E-04	671.	1.891E-04	1.833E-04
W	658.	658.	1.667E-04	1.617E-04	658.	1.789E-04	1.735E-04
WNW	893.	893.	4.046E-05	3.924E-05	893.	3.380E-05	3.277E-05
NW	847.	847.	5.538E-05	5.372E-05	847.	2.908E-05	2.820E-05
NNW	725.	725.	1.911E-04	1.854E-04	725.	1.565E-04	1.518E-04

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Table F-7 (Continued)

Maximum Offsite Finite Plume Gamma Dose Factors Based on 1 cm Depth at the Unrestricted Area Boundary for Xe-131m

Downwind Direction	Unrestricted Area Bound (meters)	Mixed Mode(Vent) Release Radius (meters)	V (mrad/yr)/(uCi/sec)	VBAR (mrad/yr)/(uCi/sec)	Ground Level Release Radius (meters)	G (mrad/yr)/(uCi/sec)	GBAR (mrad/yr)/(uCi/sec)
N	469.	469.	1.905E-04	1.491E-04	469.	8.286E-04	6.420E-04
NNE	475.	475.	1.665E-04	1.304E-04	475.	8.472E-04	6.560E-04
NE	400.	400.	2.477E-04	1.938E-04	400.	1.132E-03	8.762E-04
ENE	400.	400.	2.053E-04	1.607E-04	400.	9.692E-04	7.507E-04
E	400.	400.	1.919E-04	1.505E-04	400.	9.833E-04	7.618E-04
ESE	400.	400.	1.605E-04	1.263E-04	400.	1.058E-03	8.194E-04
SE	400.	400.	1.662E-04	1.309E-04	400.	1.144E-03	8.865E-04
SSE	400.	400.	1.049E-04	8.286E-05	400.	6.876E-04	5.330E-04
S	433.	433.	1.345E-04	1.056E-04	433.	6.368E-04	4.937E-04
SSW	439.	439.	1.084E-04	8.552E-05	439.	5.513E-04	4.279E-04
SW	518.	518.	5.468E-05	4.347E-05	518.	3.136E-04	2.437E-04
WSW	671.	671.	3.075E-05	2.461E-05	671.	1.499E-04	1.167E-04
W	658.	658.	3.092E-05	2.471E-05	658.	1.546E-04	1.203E-04
WNW	893.	893.	1.899E-05	1.525E-05	893.	9.547E-05	7.446E-05
NW	847.	847.	2.776E-05	2.225E-05	847.	1.405E-04	1.095E-04
NNW	725.	725.	4.826E-05	3.854E-05	725.	2.156E-04	1.678E-04

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Table F-7 (Continued)

Maximum Offsite Finite Plume Gamma Dose Factors Based on 1 cm Depth at the Unrestricted Area Boundary for Xe-133m

Downwind Direction	Unrestricted Area Bound (meters)	Mixed Mode(Vent) Release Radius (meters)	V (mrad/yr)/(uCi/sec)	VBAR (mrad/yr)/(uCi/sec)	Ground Level Release Radius (meters)	G (mrad/yr)/(uCi/sec)	GBAR (mrad/yr)/(uCi/sec)
N	469.	469.	3.416E-04	2.939E-04	469.	1.313E-03	1.105E-03
NNE	475.	475.	3.007E-04	2.590E-04	475.	1.332E-03	1.119E-03
NE	400.	400.	4.421E-04	3.801E-04	400.	1.776E-03	1.491E-03
ENE	400.	400.	3.697E-04	3.184E-04	400.	1.529E-03	1.285E-03
E	400.	400.	3.514E-04	3.034E-04	400.	1.557E-03	1.310E-03
ESE	400.	400.	3.040E-04	2.640E-04	400.	1.670E-03	1.404E-03
SE	400.	400.	3.187E-04	2.773E-04	400.	1.822E-03	1.535E-03
SSE	400.	400.	2.082E-04	1.822E-04	400.	1.098E-03	9.249E-04
S	433.	433.	2.506E-04	2.170E-04	433.	1.018E-03	8.582E-04
SSW	439.	439.	2.117E-04	1.848E-04	439.	8.932E-04	7.547E-04
SW	518.	518.	1.156E-04	1.020E-04	518.	5.152E-04	4.366E-04
WSW	671.	671.	6.940E-05	6.183E-05	671.	2.520E-04	2.144E-04
W	658.	658.	6.885E-05	6.122E-05	658.	2.586E-04	2.199E-04
WNW	893.	893.	4.398E-05	3.931E-05	893.	1.638E-04	1.399E-04
NW	847.	847.	6.341E-05	5.658E-05	847.	2.390E-04	2.038E-04
NNW	725.	725.	1.065E-04	9.463E-05	725.	3.610E-04	3.070E-04

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Table F-7 (Continued)

Maximum Offsite Finite Plume Gamma Dose Factors Based on 1 cm Depth at the Unrestricted Area Boundary for Xe-133

Downwind Direction	Unrestricted Area Bound (meters)	Mixed Mode(Vent) Release Radius (meters)	V (mrad/yr)/(uCi/sec)	VBAR (mrad/yr)/(uCi/sec)	Ground Level Release Radius (meters)	G (mrad/yr)/(uCi/sec)	GBAR (mrad/yr)/(uCi/sec)
N	469.	469.	3.709E-04	3.304E-04	469.	1.412E-03	1.236E-03
NNE	475.	475.	3.266E-04	2.912E-04	475.	1.427E-03	1.247E-03
NE	400.	400.	4.796E-04	4.271E-04	400.	1.899E-03	1.658E-03
ENE	400.	400.	4.020E-04	3.584E-04	400.	1.639E-03	1.433E-03
E	400.	400.	3.836E-04	3.428E-04	400.	1.672E-03	1.463E-03
ESE	400.	400.	3.316E-04	2.976E-04	400.	1.790E-03	1.565E-03
SE	400.	400.	3.485E-04	3.133E-04	400.	1.963E-03	1.720E-03
SSE	400.	400.	2.285E-04	2.063E-04	400.	1.183E-03	1.037E-03
S	433.	433.	2.749E-04	2.464E-04	433.	1.099E-03	9.639E-04
SSW	439.	439.	2.337E-04	2.106E-04	439.	9.702E-04	8.527E-04
SW	518.	518.	1.278E-04	1.163E-04	518.	5.633E-04	4.965E-04
WSW	671.	671.	7.715E-05	7.065E-05	671.	2.779E-04	2.459E-04
W	658.	658.	7.644E-05	6.990E-05	658.	2.848E-04	2.518E-04
WNW	893.	893.	4.907E-05	4.506E-05	893.	1.820E-04	1.616E-04
NW	847.	847.	7.083E-05	6.495E-05	847.	2.647E-04	2.347E-04
NNW	725.	725.	1.188E-04	1.086E-04	725.	3.978E-04	3.518E-04

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Table F-7 (Continued)

Maximum Offsite Finite Plume Gamma Dose Factors Based on 1 cm Depth at the Unrestricted Area Boundary for Xe-135m

Downwind Direction	Unrestricted Area Bound (meters)	Mixed Mode(Vent) Release Radius (meters)	V (mrad/yr)/(uCi/sec)	VBAR (mrad/yr)/(uCi/sec)	Ground Level Release Radius (meters)	G (mrad/yr)/(uCi/sec)	GBAR (mrad/yr)/(uCi/sec)
N	469.	469.	2.366E-03	2.281E-03	469.	6.852E-03	6.594E-03
NNE	475.	475.	2.093E-03	2.017E-03	475.	6.600E-03	6.351E-03
NE	400.	400.	3.146E-03	3.032E-03	400.	9.348E-03	8.994E-03
ENE	400.	400.	2.661E-03	2.565E-03	400.	7.926E-03	7.627E-03
E	400.	400.	2.620E-03	2.525E-03	400.	8.209E-03	7.900E-03
ESE	400.	400.	2.337E-03	2.253E-03	400.	8.641E-03	8.315E-03
SE	400.	400.	2.463E-03	2.376E-03	400.	9.291E-03	8.942E-03
SSE	400.	400.	1.680E-03	1.620E-03	400.	5.550E-03	5.342E-03
S	433.	433.	1.896E-03	1.828E-03	433.	5.246E-03	5.049E-03
SSW	439.	439.	1.697E-03	1.637E-03	439.	4.559E-03	4.389E-03
SW	518.	518.	9.762E-04	9.419E-04	518.	2.487E-03	2.394E-03
WSW	671.	671.	5.877E-04	5.672E-04	671.	1.323E-03	1.274E-03
W	658.	658.	5.810E-04	5.608E-04	658.	1.274E-03	1.227E-03
WNW	893.	893.	3.547E-04	3.424E-04	893.	7.789E-04	7.504E-04
NW	847.	847.	5.237E-04	5.055E-04	847.	1.144E-03	1.102E-03
NNW	725.	725.	8.818E-04	8.511E-04	725.	1.784E-03	1.718E-03

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Table F-7 (Continued)

Maximum Offsite Finite Plume Gamma Dose Factors Based on 1 cm Depth at the Unrestricted Area Boundary for Xe-135

Downwind Direction	Unrestricted Area Bound (meters)	Mixed Mode(Vent) Release Radius (meters)	V (mrad/yr)/(uCi/sec)	VBAR (mrad/yr)/(uCi/sec)	Ground Level Release Radius (meters)	G (mrad/yr)/(uCi/sec)	GBAR (mrad/yr)/(uCi/sec)
N	469.	469.	1.686E-03	1.628E-03	469.	5.315E-03	5.130E-03
NNE	475.	475.	1.498E-03	1.447E-03	475.	5.309E-03	5.124E-03
NE	400.	400.	2.171E-03	2.097E-03	400.	7.053E-03	6.807E-03
ENE	400.	400.	1.837E-03	1.775E-03	400.	6.136E-03	5.922E-03
E	400.	400.	1.785E-03	1.724E-03	400.	6.293E-03	6.074E-03
ESE	400.	400.	1.611E-03	1.556E-03	400.	6.707E-03	6.474E-03
SE	400.	400.	1.713E-03	1.655E-03	400.	7.442E-03	7.183E-03
SSE	400.	400.	1.164E-03	1.125E-03	400.	4.497E-03	4.340E-03
S	433.	433.	1.301E-03	1.257E-03	433.	4.184E-03	4.039E-03
SSW	439.	439.	1.163E-03	1.124E-03	439.	3.754E-03	3.624E-03
SW	518.	518.	6.885E-04	6.656E-04	518.	2.214E-03	2.137E-03
WSW	671.	671.	4.379E-04	4.234E-04	671.	1.126E-03	1.087E-03
W	658.	658.	4.296E-04	4.153E-04	658.	1.144E-03	1.105E-03
WNW	893.	893.	2.830E-04	2.737E-04	893.	7.530E-04	7.273E-04
NW	847.	847.	4.040E-04	3.906E-04	847.	1.084E-03	1.047E-03
NNW	725.	725.	6.593E-04	6.374E-04	725.	1.600E-03	1.545E-03

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Table F-7 (Continued)

Maximum Offsite Finite Plume Gamma Dose Factors Based on 1 cm Depth at the Unrestricted Area Boundary for Xe-137

Downwind Direction	Unrestricted Area Bound (meters)	Mixed Mode(Vent) Release Radius (meters)	V (mrad/yr)/(uCi/sec)	VBAR (mrad/yr)/(uCi/sec)	Ground Level Release Radius (meters)	G (mrad/yr)/(uCi/sec)	GBAR (mrad/yr)/(uCi/sec)
N	469.	469.	7.660E-04	7.413E-04	469.	1.897E-03	1.835E-03
NNE	475.	475.	6.673E-04	6.458E-04	475.	1.711E-03	1.656E-03
NE	400.	400.	1.095E-03	1.059E-03	400.	2.748E-03	2.659E-03
ENE	400.	400.	9.276E-04	8.977E-04	400.	2.310E-03	2.235E-03
E	400.	400.	9.288E-04	8.988E-04	400.	2.409E-03	2.330E-03
ESE	400.	400.	7.993E-04	7.735E-04	400.	2.416E-03	2.337E-03
SE	400.	400.	8.297E-04	8.029E-04	400.	2.529E-03	2.447E-03
SSE	400.	400.	5.768E-04	5.582E-04	400.	1.528E-03	1.478E-03
S	433.	433.	6.693E-04	6.476E-04	433.	1.497E-03	1.449E-03
SSW	439.	439.	5.999E-04	5.806E-04	439.	1.302E-03	1.260E-03
SW	518.	518.	3.198E-04	3.094E-04	518.	6.382E-04	6.175E-04
WSW	671.	671.	1.729E-04	1.673E-04	671.	3.149E-04	3.047E-04
W	658.	658.	1.710E-04	1.655E-04	658.	2.974E-04	2.878E-04
WNW	893.	893.	8.763E-05	8.480E-05	893.	1.447E-04	1.400E-04
NW	847.	847.	1.343E-04	1.300E-04	847.	2.191E-04	2.120E-04
NNW	725.	725.	2.582E-04	2.499E-04	725.	4.200E-04	4.064E-04

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Table F-7 (Continued)

Maximum Offsite Finite Plume Gamma Dose Factors Based on 1 cm Depth at the Unrestricted Area Boundary for Xe-138

Downwind Direction	Unrestricted Area Bound (meters)	Mixed Mode(Vent) Release Radius (meters)	V (mrad/yr)/(uCi/sec)	VBAR (mrad/yr)/(uCi/sec)	Ground Level Release Radius (meters)	G (mrad/yr)/(uCi/sec)	GBAR (mrad/yr)/(uCi/sec)
N	469.	469.	5.120E-03	4.970E-03	469.	1.421E-02	1.379E-02
NNE	475.	475.	4.542E-03	4.409E-03	475.	1.365E-02	1.324E-02
NE	400.	400.	6.821E-03	6.622E-03	400.	1.940E-02	1.883E-02
ENE	400.	400.	5.776E-03	5.607E-03	400.	1.645E-02	1.596E-02
E	400.	400.	5.700E-03	5.534E-03	400.	1.706E-02	1.655E-02
ESE	400.	400.	5.130E-03	4.981E-03	400.	1.793E-02	1.740E-02
SE	400.	400.	5.415E-03	5.258E-03	400.	1.926E-02	1.869E-02
SSE	400.	400.	3.711E-03	3.603E-03	400.	1.151E-02	1.117E-02
S	433.	433.	4.129E-03	4.008E-03	433.	1.088E-02	1.056E-02
SSW	439.	439.	3.727E-03	3.619E-03	439.	9.468E-03	9.188E-03
SW	518.	518.	2.169E-03	2.106E-03	518.	5.153E-03	5.001E-03
WSW	671.	671.	1.308E-03	1.271E-03	671.	2.749E-03	2.668E-03
W	658.	658.	1.295E-03	1.258E-03	658.	2.641E-03	2.564E-03
WNW	893.	893.	7.908E-04	7.680E-04	893.	1.612E-03	1.565E-03
NW	847.	847.	1.169E-03	1.135E-03	847.	2.370E-03	2.300E-03
NNW	725.	725.	1.959E-03	1.903E-03	725.	3.702E-03	3.593E-03

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Table F-7 (Continued)

Maximum Offsite Finite Plume Gamma Dose Factors Based on 1 cm Depth at the Unrestricted Area Boundary for Ar-41

Downwind Direction	Unrestricted Area Bound (meters)	Mixed Mode(Vent) Release Radius (meters)	V (mrad/yr)/(uCi/sec)	VBAR (mrad/yr)/(uCi/sec)	Ground Level Release Radius (meters)	G (mrad/yr)/(uCi/sec)	GBAR (mrad/yr)/(uCi/sec)
N	469.	469.	6.355E-03	6.152E-03	469.	1.886E-02	1.826E-02
NNE	475.	475.	5.659E-03	5.478E-03	475.	1.875E-02	1.815E-02
NE	400.	400.	8.206E-03	7.944E-03	400.	2.516E-02	2.435E-02
ENE	400.	400.	6.950E-03	6.727E-03	400.	2.179E-02	2.109E-02
E	400.	400.	6.775E-03	6.558E-03	400.	2.239E-02	2.168E-02
ESE	400.	400.	6.188E-03	5.990E-03	400.	2.385E-02	2.309E-02
SE	400.	400.	6.582E-03	6.371E-03	400.	2.630E-02	2.546E-02
SSE	400.	400.	4.506E-03	4.362E-03	400.	1.585E-02	1.535E-02
S	433.	433.	4.941E-03	4.783E-03	433.	1.476E-02	1.429E-02
SSW	439.	439.	4.458E-03	4.315E-03	439.	1.316E-02	1.274E-02
SW	518.	518.	2.685E-03	2.599E-03	518.	7.664E-03	7.419E-03
WSW	671.	671.	1.713E-03	1.658E-03	671.	3.940E-03	3.814E-03
W	658.	658.	1.682E-03	1.628E-03	658.	3.961E-03	3.834E-03
WNW	893.	893.	1.103E-03	1.068E-03	893.	2.591E-03	2.508E-03
NW	847.	847.	1.576E-03	1.525E-03	847.	3.736E-03	3.617E-03
NNW	725.	725.	2.554E-03	2.472E-03	725.	5.528E-03	5.351E-03

Zion Site Meteorological Data 1/79 - 12/87

Table 8
Site Specific Potable Water Dose Factors for Adult Age Group

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	8.31E-01	8.31E-01	8.31E-01	8.31E-01	8.31E-01	8.31E-01
Na-24	2.36E+01	2.36E+01	2.36E+01	2.36E+01	2.36E+01	2.36E+01	2.36E+01
Cr-51	0.00E+00	0.00E+00	3.69E-02	2.21E-02	8.13E-03	4.90E-02	9.28E+00
Mn-54	0.00E+00	6.34E+01	1.21E+01	0.00E+00	1.89E+01	0.00E+00	1.94E+02
Mn-56	0.00E+00	1.60E+00	2.83E-01	0.00E+00	2.03E+00	0.00E+00	5.09E+01
Fe-55	3.81E+01	2.64E+01	6.14E+00	0.00E+00	0.00E+00	1.47E+01	1.51E+01
Fe-59	6.02E+01	1.41E+02	5.42E+01	0.00E+00	0.00E+00	3.95E+01	4.72E+02
Co-58	0.00E+00	1.03E+01	2.32E+01	0.00E+00	0.00E+00	0.00E+00	2.09E+02
Co-60	0.00E+00	2.97E+01	6.55E+01	0.00E+00	0.00E+00	0.00E+00	5.58E+02
Ni-63	1.80E+03	1.25E+02	6.05E+01	0.00E+00	0.00E+00	0.00E+00	2.61E+01
Ni-65	7.32E+00	9.51E-01	4.34E-01	0.00E+00	0.00E+00	0.00E+00	2.41E+01
Cu-64	0.00E+00	1.16E+00	5.42E-01	0.00E+00	2.91E+00	0.00E+00	9.85E+01
Zn-65	6.71E+01	2.14E+02	9.65E+01	0.00E+00	1.43E+02	0.00E+00	1.35E+02
Zn-69	1.43E-01	2.73E-01	1.90E-02	0.00E+00	1.78E-01	0.00E+00	4.11E-02
Br-83	0.00E+00	0.00E+00	5.58E-01	0.00E+00	0.00E+00	0.00E+00	8.03E-01
Br-84	0.00E+00	0.00E+00	7.23E-01	0.00E+00	0.00E+00	0.00E+00	5.67E-06
Br-85	0.00E+00	0.00E+00	2.97E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	2.93E+02	1.36E+02	0.00E+00	0.00E+00	0.00E+00	5.77E+01
Rb-88	0.00E+00	8.39E-01	4.45E-01	0.00E+00	0.00E+00	0.00E+00	1.16E-11
Rb-89	0.00E+00	5.56E-01	3.91E-01	0.00E+00	0.00E+00	0.00E+00	3.23E-14
Sr-89	4.27E+03	0.00E+00	1.23E+02	0.00E+00	0.00E+00	0.00E+00	6.85E+02
Sr-90	1.21E+05	0.00E+00	2.43E+03	0.00E+00	0.00E+00	0.00E+00	3.04E+03
Sr-91	7.86E+01	0.00E+00	3.18E+00	0.00E+00	0.00E+00	0.00E+00	3.74E+02
Sr-92	2.98E+01	0.00E+00	1.29E+00	0.00E+00	0.00E+00	0.00E+00	5.91E+02
Y-90	1.33E-01	0.00E+00	3.58E-03	0.00E+00	0.00E+00	0.00E+00	1.41E+03
Y-91M	1.26E-03	0.00E+00	4.88E-05	0.00E+00	0.00E+00	0.00E+00	3.70E-03
Y-91	1.96E+00	0.00E+00	5.23E-02	0.00E+00	0.00E+00	0.00E+00	1.08E+03
Y-92	1.17E-02	0.00E+00	3.43E-04	0.00E+00	0.00E+00	0.00E+00	2.05E+02
Y-93	3.72E-02	0.00E+00	1.03E-03	0.00E+00	0.00E+00	0.00E+00	1.18E+03
Zr-95	4.22E-01	1.35E-01	9.15E-02	0.00E+00	2.12E-01	0.00E+00	4.29E+02
Zr-97	2.33E-02	4.70E-03	2.15E-03	0.00E+00	7.10E-03	0.00E+00	1.46E+03
Nb-95	8.63E-02	4.80E-02	2.58E-02	0.00E+00	4.74E-02	0.00E+00	2.91E+02
Mo-99	0.00E+00	5.98E+01	1.14E+01	0.00E+00	1.35E+02	0.00E+00	1.39E+02
Tc- 99M	3.43E-03	9.68E-03	1.23E-01	0.00E+00	1.47E-01	4.74E-03	5.73E+00
Tc-101	3.52E-03	5.08E-03	4.98E-02	0.00E+00	9.14E-02	2.59E-03	1.53E-14
Ru-103	2.57E+00	0.00E+00	1.11E+00	0.00E+00	9.79E+00	0.00E+00	3.00E+02
Ru-105	2.14E-01	0.00E+00	8.43E-02	0.00E+00	2.76E+00	0.00E+00	1.31E+02
Ru-106	3.81E+01	0.00E+00	4.83E+00	0.00E+00	7.36E+01	0.00E+00	2.47E+03
Ag-110M	2.22E+00	2.05E+00	1.22E+00	0.00E+00	4.04E+00	0.00E+00	8.38E+02
Te-125M	3.72E+01	1.35E+01	4.98E+00	1.12E+01	1.51E+02	0.00E+00	1.48E+02

Table 8 (continued)
Site Specific Potable Water Dose Factors for Adult Age Group

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-127M	9.39E+01	3.36E+01	1.14E+01	2.40E+01	3.81E+02	0.00E+00	3.15E+02
Te-127	1.53E+00	5.48E-01	3.30E-01	1.13E+00	6.21E+00	0.00E+00	1.20E+02
Te-129M	1.60E+02	5.95E+01	2.52E+01	5.48E+01	6.66E+02	0.00E+00	8.03E+02
Te-129	4.36E-01	1.64E-01	1.06E-01	3.34E-01	1.83E+00	0.00E+00	3.29E-01
Te-131M	2.40E+01	1.17E+01	9.78E+00	1.86E+01	1.19E+02	0.00E+00	1.17E+03
Te-131	2.73E-01	1.14E-01	8.63E-02	2.25E-01	1.20E+00	0.00E+00	3.87E-02
Te-132	3.50E+01	2.26E+01	2.12E+01	2.50E+01	2.18E+02	0.00E+00	1.07E+03
I-130	1.05E+01	3.09E+01	1.22E+01	2.62E+03	4.83E+01	0.00E+00	2.66E+01
I-131	5.77E+01	8.25E+01	4.73E+01	2.70E+04	1.41E+02	0.00E+00	2.18E+01
I-132	2.82E+00	7.53E+00	2.64E+00	2.64E+02	1.20E+01	0.00E+00	1.41E+00
I-133	1.97E+01	3.43E+01	1.04E+01	5.03E+03	5.98E+01	0.00E+00	3.08E+01
I-134	1.47E+00	3.99E+00	1.43E+00	6.92E+01	6.35E+00	0.00E+00	3.48E-03
I-135	6.14E+00	1.61E+01	5.94E+00	1.06E+03	2.58E+01	0.00E+00	1.82E+01
Cs-134	8.63E+02	2.05E+03	1.68E+03	0.00E+00	6.64E+02	2.21E+02	3.59E+01
Cs-136	9.03E+01	3.56E+02	2.57E+02	0.00E+00	1.98E+02	2.72E+01	4.05E+01
Cs-137	1.11E+03	1.51E+03	9.90E+02	0.00E+00	5.13E+02	1.71E+02	2.93E+01
Cs-138	7.66E-01	1.51E+00	7.49E-01	0.00E+00	1.11E+00	1.10E-01	6.45E-06
Ba-139	1.35E+00	9.58E-04	3.94E-02	0.00E+00	8.96E-04	5.44E-04	2.39E+00
Ba-140	2.82E+02	3.54E-01	1.84E+01	0.00E+00	1.20E-01	2.03E-01	5.80E+02
Ba-141	6.53E-01	4.94E-04	2.21E-02	0.00E+00	4.59E-04	2.80E-04	3.08E-10
Ba-142	2.95E-01	3.04E-04	1.86E-02	0.00E+00	2.57E-04	1.72E-04	4.16E-19
La-140	3.47E-02	1.75E-02	4.62E-03	0.00E+00	0.00E+00	0.00E+00	1.28E+03
La-142	1.78E-03	8.07E-04	2.01E-04	0.00E+00	0.00E+00	0.00E+00	5.89E+00
Ce-141	1.30E-01	8.78E-02	9.96E-03	0.00E+00	4.08E-02	0.00E+00	3.36E+02
Ce-143	2.29E-02	1.69E+01	1.87E-03	0.00E+00	7.45E-03	0.00E+00	6.32E+02
Ce-144	6.77E+00	2.83E+00	3.63E-01	0.00E+00	1.68E+00	0.00E+00	2.29E+03
Pr-143	1.28E-01	5.12E-02	6.32E-03	0.00E+00	2.95E-02	0.00E+00	5.59E+02
Pr-144	4.17E-04	1.73E-04	2.12E-05	0.00E+00	9.78E-05	0.00E+00	6.01E-11
Nd-147	8.72E-02	1.01E-01	6.03E-03	0.00E+00	5.89E-02	0.00E+00	4.84E+02
W-187	1.43E+00	1.19E+00	4.17E-01	0.00E+00	0.00E+00	0.00E+00	3.91E+02
Np-239	1.65E-02	1.62E-03	8.95E-04	0.00E+00	5.06E-03	0.00E+00	3.33E+02

Notes:

1) Units are mrem/hr per μCi/ml.

Table 8a
Site Specific Potable Water Dose Factors for Teen Age Group

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	5.85E-01	5.85E-01	5.85E-01	5.85E-01	5.85E-01	5.85E-01
Na-24	2.23E+01	2.23E+01	2.23E+01	2.23E+01	2.23E+01	2.23E+01	2.23E+01
Cr-51	0.00E+00	0.00E+00	3.49E-02	1.94E-02	7.65E-03	4.98E-02	5.86E+00
Mn-54	0.00E+00	5.72E+01	1.13E+01	0.00E+00	1.71E+01	0.00E+00	1.17E+02
Mn-56	0.00E+00	1.53E+00	2.72E-01	0.00E+00	1.94E+00	0.00E+00	1.01E+02
Fe-55	3.66E+01	2.60E+01	6.06E+00	0.00E+00	0.00E+00	1.65E+01	1.12E+01
Fe-59	5.69E+01	1.33E+02	5.13E+01	0.00E+00	0.00E+00	4.19E+01	3.14E+02
Co-58	0.00E+00	9.42E+00	2.17E+01	0.00E+00	0.00E+00	0.00E+00	1.30E+02
Co-60	0.00E+00	2.72E+01	6.13E+01	0.00E+00	0.00E+00	0.00E+00	3.55E+02
Ni-63	1.72E+03	1.21E+02	5.81E+01	0.00E+00	0.00E+00	0.00E+00	1.93E+01
Ni-65	7.26E+00	9.27E-01	4.22E-01	0.00E+00	0.00E+00	0.00E+00	5.03E+01
Cu-64	0.00E+00	1.11E+00	5.24E-01	0.00E+00	2.82E+00	0.00E+00	8.64E+01
Zn-65	5.58E+01	1.94E+02	9.04E+01	0.00E+00	1.24E+02	0.00E+00	8.21E+01
Zn-69	1.42E-01	2.71E-01	1.90E-02	0.00E+00	1.77E-01	0.00E+00	5.00E-01
Br-83	0.00E+00	0.00E+00	5.56E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	7.00E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	2.96E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	2.89E+02	1.36E+02	0.00E+00	0.00E+00	0.00E+00	4.27E+01
Rb-88	0.00E+00	8.26E-01	4.40E-01	0.00E+00	0.00E+00	0.00E+00	7.07E-08
Rb-89	0.00E+00	5.33E-01	3.77E-01	0.00E+00	0.00E+00	0.00E+00	8.17E-10
Sr-89	4.26E+03	0.00E+00	1.22E+02	0.00E+00	0.00E+00	0.00E+00	5.08E+02
Sr-90	9.88E+04	0.00E+00	1.98E+03	0.00E+00	0.00E+00	0.00E+00	2.26E+03
Sr-91	7.82E+01	0.00E+00	3.11E+00	0.00E+00	0.00E+00	0.00E+00	3.55E+02
Sr-92	2.96E+01	0.00E+00	1.26E+00	0.00E+00	0.00E+00	0.00E+00	7.53E+02
Y-90	1.33E-01	0.00E+00	3.58E-03	0.00E+00	0.00E+00	0.00E+00	1.09E+03
Y-91M	1.25E-03	0.00E+00	4.78E-05	0.00E+00	0.00E+00	0.00E+00	5.90E-02
Y-91	1.95E+00	0.00E+00	5.22E-02	0.00E+00	0.00E+00	0.00E+00	7.98E+02
Y-92	1.17E-02	0.00E+00	3.39E-04	0.00E+00	0.00E+00	0.00E+00	3.22E+02
Y-93	3.71E-02	0.00E+00	1.02E-03	0.00E+00	0.00E+00	0.00E+00	1.13E+03
Zr-95	3.99E-01	1.26E-01	8.66E-02	0.00E+00	1.85E-01	0.00E+00	2.91E+02
Zr-97	2.30E-02	4.54E-03	2.09E-03	0.00E+00	6.89E-03	0.00E+00	1.23E+03
Nb-95	7.97E-02	4.42E-02	2.43E-02	0.00E+00	4.28E-02	0.00E+00	1.89E+02
Mo-99	0.00E+00	5.84E+01	1.11E+01	0.00E+00	1.34E+02	0.00E+00	1.05E+02
Tc- 99M	3.22E-03	8.97E-03	1.16E-01	0.00E+00	1.34E-01	4.98E-03	5.89E+00
Tc-101	3.49E-03	4.96E-03	4.87E-02	0.00E+00	8.97E-02	3.02E-03	8.48E-10
Ru-103	2.47E+00	0.00E+00	1.06E+00	0.00E+00	8.71E+00	0.00E+00	2.06E+02
Ru-105	2.11E-01	0.00E+00	8.20E-02	0.00E+00	2.66E+00	0.00E+00	1.71E+02
Ru-106	3.80E+01	0.00E+00	4.79E+00	0.00E+00	7.33E+01	0.00E+00	1.82E+03
Ag-110M	1.99E+00	1.88E+00	1.14E+00	0.00E+00	3.59E+00	0.00E+00	5.28E+02
Te-125M	3.71E+01	1.34E+01	4.96E+00	1.04E+01	0.00E+00	0.00E+00	1.09E+02

Table 8a (continued)
Site Specific Potable Water Dose Factors for Teen Age Group

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-127M	9.37E+01	3.32E+01	1.11E+01	2.23E+01	3.80E+02	0.00E+00	2.34E+02
Te-127	1.53E+00	5.43E-01	3.29E-01	1.06E+00	6.20E+00	0.00E+00	1.18E+02
Te-129M	1.58E+02	5.86E+01	2.50E+01	5.10E+01	6.61E+02	0.00E+00	5.93E+02
Te-129	4.34E-01	1.62E-01	1.06E-01	3.10E-01	1.82E+00	0.00E+00	2.37E+00
Te-131M	2.36E+01	1.13E+01	9.46E+00	1.71E+01	1.18E+02	0.00E+00	9.10E+02
Te-131	2.70E-01	1.11E-01	8.45E-02	2.08E-01	1.18E+00	0.00E+00	2.22E-02
Te-132	3.38E+01	2.14E+01	2.02E+01	2.26E+01	2.05E+02	0.00E+00	6.78E+02
I-130	9.98E+00	2.89E+01	1.15E+01	2.35E+03	4.45E+01	0.00E+00	2.22E+01
I-131	5.67E+01	7.94E+01	4.26E+01	2.32E+04	1.37E+02	0.00E+00	1.57E+01
I-132	2.70E+00	7.07E+00	2.54E+00	2.38E+02	1.11E+01	0.00E+00	3.08E+00
I-133	1.95E+01	3.30E+01	1.01E+01	4.61E+03	5.79E+01	0.00E+00	2.50E+01
I-134	1.41E+00	3.75E+00	1.35E+00	6.25E+01	5.91E+00	0.00E+00	4.94E-02
I-135	5.91E+00	1.52E+01	5.64E+00	9.79E+02	2.40E+01	0.00E+00	1.69E+01
Cs-134	8.11E+02	1.91E+03	8.86E+02	0.00E+00	6.07E+02	2.32E+02	2.37E+01
Cs-136	8.32E+01	3.28E+02	2.20E+02	0.00E+00	1.78E+02	2.81E+01	2.64E+01
Cs-137	1.09E+03	1.44E+03	5.03E+02	0.00E+00	4.91E+02	1.91E+02	2.05E+01
Cs-138	7.52E-01	1.44E+00	7.22E-01	0.00E+00	1.07E+00	1.24E-01	6.55E-04
Ba-139	1.35E+00	9.48E-04	3.92E-02	0.00E+00	8.93E-04	6.53E-04	1.20E+01
Ba-140	2.75E+02	3.37E-01	1.77E+01	0.00E+00	1.14E-01	2.27E-01	4.24E+02
Ba-141	6.50E-01	4.85E-04	2.17E-02	0.00E+00	4.51E-04	3.32E-04	1.39E-06
Ba-142	2.90E-01	2.90E-04	1.78E-02	0.00E+00	2.45E-04	1.93E-04	8.90E-13
La-140	3.37E-02	1.66E-02	4.41E-03	0.00E+00	0.00E+00	0.00E+00	9.52E+02
La-142	1.73E-03	7.70E-04	1.92E-04	0.00E+00	0.00E+00	0.00E+00	2.34E+01
Ce-141	1.29E-01	8.60E-02	9.88E-03	0.00E+00	4.05E-02	0.00E+00	2.46E+02
Ce-143	2.28E-02	1.66E+01	1.85E-03	0.00E+00	7.43E-03	0.00E+00	4.98E+02
Ce-144	6.74E+00	2.79E+00	3.62E-01	0.00E+00	1.67E+00	0.00E+00	1.70E+03
Pr-143	1.27E-01	5.07E-02	6.32E-03	0.00E+00	2.95E-02	0.00E+00	4.18E+02
Pr-144	4.17E-04	1.71E-04	2.11E-05	0.00E+00	9.79E-05	0.00E+00	4.59E-07
Nd-147	9.09E-02	9.88E-02	5.92E-03	0.00E+00	5.80E-02	0.00E+00	3.57E+02
W-187	1.41E+00	1.15E+00	4.04E-01	0.00E+00	0.00E+00	0.00E+00	3.12E+02
Np-239	1.71E-02	1.61E-03	8.93E-04	0.00E+00	5.05E-03	0.00E+00	2.59E+02

Notes:

1) Units are mrem/hr per μCi/ml.

Table 8b
Site Specific Potable Water Dose Factors for Child Age Group

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	1.12E+00	1.12E+00	1.12E+00	1.12E+00	1.12E+00	1.12E+00
Na-24	5.62E+01	5.62E+01	5.62E+01	5.62E+01	5.62E+01	5.62E+01	5.62E+01
Cr-51	0.00E+00	0.00E+00	8.62E-02	4.79E-02	1.31E-02	8.74E-02	4.57E+00
Mn-54	0.00E+00	1.04E+02	2.76E+01	0.00E+00	2.91E+01	0.00E+00	8.70E+01
Mn-56	0.00E+00	3.24E+00	7.31E-01	0.00E+00	3.91E+00	0.00E+00	4.69E+02
Fe-55	1.11E+02	5.91E+01	1.83E+01	0.00E+00	0.00E+00	3.34E+01	1.09E+01
Fe-59	1.60E+02	2.59E+02	1.29E+02	0.00E+00	0.00E+00	7.50E+01	2.69E+02
Co-58	0.00E+00	1.74E+01	5.34E+01	0.00E+00	0.00E+00	0.00E+00	1.02E+02
Co-60	0.00E+00	5.13E+01	1.51E+02	0.00E+00	0.00E+00	0.00E+00	2.84E+02
Ni-63	5.21E+03	2.79E+02	1.77E+02	0.00E+00	0.00E+00	0.00E+00	1.88E+01
Ni-65	2.15E+01	2.03E+00	1.18E+00	0.00E+00	0.00E+00	0.00E+00	2.48E+02
Cu-64	0.00E+00	2.37E+00	1.43E+00	0.00E+00	5.74E+00	0.00E+00	1.11E+02
Zn-65	1.33E+02	3.54E+02	2.20E+02	0.00E+00	2.23E+02	0.00E+00	6.21E+01
Zn-69	4.24E-01	6.13E-01	5.67E-02	0.00E+00	3.72E-01	0.00E+00	3.87E+01
Br-83	0.00E+00	0.00E+00	1.66E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	1.92E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	8.84E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	6.49E+02	3.99E+02	0.00E+00	0.00E+00	0.00E+00	4.18E+01
Rb-88	0.00E+00	1.84E+00	1.28E+00	0.00E+00	0.00E+00	0.00E+00	9.03E-02
Rb-89	0.00E+00	1.13E+00	1.01E+00	0.00E+00	0.00E+00	0.00E+00	9.88E-03
Sr-89	1.28E+04	0.00E+00	3.65E+02	0.00E+00	0.00E+00	0.00E+00	4.95E+02
Sr-90	2.48E+05	0.00E+00	4.99E+03	0.00E+00	0.00E+00	0.00E+00	2.22E+03
Sr-91	2.33E+02	0.00E+00	8.78E+00	0.00E+00	0.00E+00	0.00E+00	5.14E+02
Sr-92	8.75E+01	0.00E+00	3.51E+00	0.00E+00	0.00E+00	0.00E+00	1.66E+03
Y-90	3.98E-01	0.00E+00	1.07E-02	0.00E+00	0.00E+00	0.00E+00	1.13E+03
Y-91M	3.70E-03	0.00E+00	1.35E-04	0.00E+00	0.00E+00	0.00E+00	7.25E+00
Y-91	5.83E+00	0.00E+00	1.56E-01	0.00E+00	0.00E+00	0.00E+00	7.77E+02
Y-92	3.49E-02	0.00E+00	9.98E-04	0.00E+00	0.00E+00	0.00E+00	1.01E+03
Y-93	1.10E-01	0.00E+00	3.03E-03	0.00E+00	0.00E+00	0.00E+00	1.65E+03
Zr-95	1.12E+00	2.47E-01	2.20E-01	0.00E+00	3.54E-01	0.00E+00	2.58E+02
Zr-97	6.77E-02	9.79E-03	5.78E-03	0.00E+00	1.41E-02	0.00E+00	1.48E+03
Nb-95	2.18E-01	8.49E-02	6.07E-02	0.00E+00	7.97E-02	0.00E+00	1.57E+02
Mo-99	0.00E+00	1.29E+02	3.19E+01	0.00E+00	2.75E+02	0.00E+00	1.07E+02
Tc- 99M	8.94E-03	1.75E-02	2.91E-01	0.00E+00	2.55E-01	8.91E-03	9.98E+00
Tc-101	1.04E-02	1.09E-02	1.38E-01	0.00E+00	1.85E-01	5.74E-03	3.45E-02
Ru-103	7.08E+00	0.00E+00	2.72E+00	0.00E+00	1.78E+01	0.00E+00	1.83E+02
Ru-105	6.25E-01	0.00E+00	2.27E-01	0.00E+00	5.49E+00	0.00E+00	4.08E+02
Ru-106	1.13E+02	0.00E+00	1.41E+01	0.00E+00	1.53E+02	0.00E+00	1.76E+03
Ag-110M	5.22E+00	3.53E+00	2.82E+00	0.00E+00	6.57E+00	0.00E+00	4.20E+02
Te-125M	1.10E+02	2.99E+01	1.47E+01	3.10E+01	0.00E+00	0.00E+00	1.07E+02

Table 8b (continued)
Site Specific Potable Water Dose Factors for Child Age Group

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-127M	2.80E+02	7.54E+01	3.32E+01	6.70E+01	7.98E+02	0.00E+00	2.27E+02
Te-127	4.56E+00	1.23E+00	9.79E-01	3.16E+00	1.30E+01	0.00E+00	1.78E+02
Te-129M	4.72E+02	1.32E+02	7.33E+01	1.52E+02	1.39E+03	0.00E+00	5.76E+02
Te-129	1.30E+00	3.62E-01	3.08E-01	9.26E-01	3.80E+00	0.00E+00	8.08E+01
Te-131M	6.98E+01	2.41E+01	2.57E+01	4.96E+01	2.34E+02	0.00E+00	9.79E+02
Te-131	8.04E-01	2.45E-01	2.39E-01	6.15E-01	2.43E+00	0.00E+00	4.22E+00
Te-132	9.79E+01	4.33E+01	5.23E+01	6.31E+01	4.02E+02	0.00E+00	4.36E+02
I-130	2.83E+01	5.72E+01	2.95E+01	6.30E+03	8.55E+01	0.00E+00	2.67E+01
I-131	1.67E+02	1.68E+02	9.53E+01	5.54E+04	2.75E+02	0.00E+00	1.49E+01
I-132	7.75E+00	1.42E+01	6.55E+00	6.61E+02	2.18E+01	0.00E+00	1.68E+01
I-133	5.74E+01	7.09E+01	2.68E+01	1.32E+04	1.18E+02	0.00E+00	2.86E+01
I-134	4.06E+00	7.54E+00	3.47E+00	1.73E+02	1.15E+01	0.00E+00	5.00E+00
I-135	1.70E+01	3.05E+01	1.44E+01	2.70E+03	4.68E+01	0.00E+00	2.33E+01
Cs-134	2.27E+03	3.72E+03	7.85E+02	0.00E+00	1.15E+03	4.14E+02	2.01E+01
Cs-136	2.28E+02	6.26E+02	4.05E+02	0.00E+00	3.33E+02	4.97E+01	2.20E+01
Cs-137	3.17E+03	3.03E+03	4.48E+02	0.00E+00	9.88E+02	3.56E+02	1.90E+01
Cs-138	2.21E+00	3.07E+00	1.95E+00	0.00E+00	2.16E+00	2.33E-01	1.41E+00
Ba-139	4.01E+00	2.14E-03	1.16E-01	0.00E+00	1.87E-03	1.26E-03	2.32E+02
Ba-140	8.05E+02	7.05E-01	4.70E+01	0.00E+00	2.30E-01	4.21E-01	4.08E+02
Ba-141	1.94E+00	1.09E-03	6.31E-02	0.00E+00	9.39E-04	6.38E-03	1.10E+00
Ba-142	8.47E-01	6.10E-04	4.73E-02	0.00E+00	4.93E-04	3.59E-04	1.10E-02
La-140	9.79E-02	3.42E-02	1.15E-02	0.00E+00	0.00E+00	0.00E+00	9.53E+02
La-142	5.08E-03	1.62E-03	5.07E-04	0.00E+00	0.00E+00	0.00E+00	3.21E+02
Ce-141	3.85E-01	1.92E-01	2.85E-02	0.00E+00	8.41E-02	0.00E+00	2.39E+02
Ce-143	6.77E-02	3.67E+01	5.32E-03	0.00E+00	1.54E-02	0.00E+00	5.38E+02
Ce-144	2.02E+01	6.32E+00	1.08E+00	0.00E+00	3.50E+00	0.00E+00	1.65E+03
Pr-143	3.81E-01	1.14E-01	1.89E-02	0.00E+00	6.19E-02	0.00E+00	4.11E+02
Pr-144	1.25E-03	3.87E-04	6.29E-05	0.00E+00	2.04E-04	0.00E+00	8.32E-01
Nd-147	2.70E-01	2.19E-01	1.70E-02	0.00E+00	1.20E-01	0.00E+00	3.47E+02
W-187	4.16E+00	2.46E+00	1.10E+00	0.00E+00	0.00E+00	0.00E+00	3.46E+02
Np-239	5.09E-02	3.65E-03	2.57E-03	0.00E+00	1.06E-02	0.00E+00	2.70E+02

Notes:

1) Units are mrem/hr per μCi/ml.

Table 8c
Site Specific Potable Water Dose Factors for Infant Age Group

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	1.10E+00	1.10E+00	1.10E+00	1.10E+00	1.10E+00	1.10E+00
Na-24	6.33E+01	6.33E+01	6.33E+01	6.33E+01	6.33E+01	6.33E+01	6.33E+01
Cr-51	0.00E+00	0.00E+00	8.84E-02	5.77E-02	1.26E-02	1.12E-01	2.58E+00
Mn-54	0.00E+00	1.25E+02	2.83E+01	0.00E+00	2.77E+01	0.00E+00	4.58E+01
Mn-56	0.00E+00	5.13E+00	8.84E-01	0.00E+00	4.41E+00	0.00E+00	4.66E+02
Fe-55	8.72E+01	5.63E+01	1.50E+01	0.00E+00	0.00E+00	2.75E+01	7.15E+00
Fe-59	1.93E+02	3.37E+02	1.33E+02	0.00E+00	0.00E+00	9.97E+01	1.61E+02
Co-58	0.00E+00	2.26E+01	5.63E+01	0.00E+00	0.00E+00	0.00E+00	5.62E+01
Co-60	0.00E+00	6.77E+01	1.60E+02	0.00E+00	0.00E+00	0.00E+00	1.61E+02
Ni-63	3.98E+03	2.46E+02	1.38E+02	0.00E+00	0.00E+00	0.00E+00	1.22E+01
Ni-65	2.95E+01	3.34E+00	1.52E+00	0.00E+00	0.00E+00	0.00E+00	2.54E+02
Cu-64	0.00E+00	3.82E+00	1.77E+00	0.00E+00	6.46E+00	0.00E+00	7.84E+01
Zn-65	1.15E+02	3.96E+02	1.82E+02	0.00E+00	1.92E+02	0.00E+00	3.34E+02
Zn-69	5.85E-01	1.05E+00	7.84E-02	0.00E+00	4.38E-01	0.00E+00	8.59E+01
Br-83	0.00E+00	0.00E+00	2.28E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	2.40E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	1.22E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	1.07E+03	5.27E+02	0.00E+00	0.00E+00	0.00E+00	2.73E+01
Rb-88	0.00E+00	3.12E+00	1.71E+00	0.00E+00	0.00E+00	0.00E+00	3.04E+00
Rb-89	0.00E+00	1.79E+00	1.24E+00	0.00E+00	0.00E+00	0.00E+00	6.11E-01
Sr-89	1.57E+04	0.00E+00	4.51E+02	0.00E+00	0.00E+00	0.00E+00	3.24E+02
Sr-90	1.77E+05	0.00E+00	3.60E+03	0.00E+00	0.00E+00	0.00E+00	1.45E+03
Sr-91	3.14E+02	0.00E+00	1.13E+01	0.00E+00	0.00E+00	0.00E+00	3.71E+02
Sr-92	1.20E+02	0.00E+00	4.47E+00	0.00E+00	0.00E+00	0.00E+00	1.30E+03
Y-90	5.45E-01	0.00E+00	1.46E-02	0.00E+00	0.00E+00	0.00E+00	7.52E+02
Y-91M	5.08E-03	0.00E+00	1.73E-04	0.00E+00	0.00E+00	0.00E+00	1.69E+01
Y-91	7.09E+00	0.00E+00	1.89E-01	0.00E+00	0.00E+00	0.00E+00	5.08E+02
Y-92	4.80E-02	0.00E+00	1.35E-03	0.00E+00	0.00E+00	0.00E+00	9.15E+02
Y-93	1.52E-01	0.00E+00	4.15E-03	0.00E+00	0.00E+00	0.00E+00	1.20E+03
Zr-95	1.29E+00	3.15E-01	2.23E-01	0.00E+00	3.39E-01	0.00E+00	1.57E+02
Zr-97	9.28E-02	1.59E-02	7.27E-03	0.00E+00	1.61E-02	0.00E+00	1.02E+03
Nb-95	2.63E-01	1.08E-01	6.27E-02	0.00E+00	7.77E-02	0.00E+00	9.15E+01
Mo-99	0.00E+00	2.13E+02	4.16E+01	0.00E+00	3.19E+02	0.00E+00	7.02E+01
Tc- 99M	1.20E-02	2.48E-02	3.20E-01	0.00E+00	2.67E-01	1.30E-02	7.21E+00
Tc-101	1.42E-02	1.79E-02	1.77E-01	0.00E+00	2.13E-01	9.78E-03	3.05E+00
Ru-103	9.28E+00	0.00E+00	3.10E+00	0.00E+00	1.93E+01	0.00E+00	1.13E+02
Ru-105	8.53E-01	0.00E+00	2.87E-01	0.00E+00	6.27E+00	0.00E+00	3.39E+02
Ru-106	1.51E+02	0.00E+00	1.89E+01	0.00E+00	1.79E+02	0.00E+00	1.15E+03
Ag-110M	6.24E+00	4.56E+00	3.02E+00	0.00E+00	6.52E+00	0.00E+00	2.36E+02
Te-125M	1.46E+02	4.88E+01	1.98E+01	4.92E+01	0.00E+00	0.00E+00	6.96E+01

Table 8c (continued)
Site Specific Potable Water Dose Factors for Infant Age Group

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-127M	3.67E+02	1.22E+02	4.44E+01	1.06E+02	9.03E+02	0.00E+00	1.48E+02
Te-127	6.27E+00	2.10E+00	1.35E+00	5.10E+00	1.53E+01	0.00E+00	1.32E+02
Te-129M	6.27E+02	2.15E+02	9.66E+01	2.41E+02	1.57E+03	0.00E+00	3.74E+02
Te-129	1.78E+00	6.14E-01	4.16E-01	1.49E+00	4.43E+00	0.00E+00	1.42E+02
Te-131M	9.53E+01	3.84E+01	3.17E+01	7.77E+01	2.64E+02	0.00E+00	6.46E+02
Te-131	1.10E+00	4.08E-01	3.10E-01	9.84E-01	2.82E+00	0.00E+00	4.46E+01
Te-132	1.30E+02	6.46E+01	6.03E+01	9.53E+01	4.04E+02	0.00E+00	2.39E+02
I-130	3.76E+01	8.28E+01	3.32E+01	9.28E+03	9.09E+01	0.00E+00	1.77E+01
I-131	2.25E+02	2.65E+02	1.17E+02	8.72E+04	3.10E+02	0.00E+00	9.47E+00
I-132	1.04E+01	2.11E+01	7.52E+00	9.91E+02	2.36E+01	0.00E+00	1.71E+01
I-133	7.84E+01	1.14E+02	3.34E+01	2.08E+04	1.34E+02	0.00E+00	1.93E+01
I-134	5.45E+00	1.12E+01	3.97E+00	2.60E+02	1.25E+01	0.00E+00	1.15E+01
I-135	2.28E+01	4.54E+01	1.66E+01	4.07E+03	5.06E+01	0.00E+00	1.64E+01
Cs-134	2.36E+03	4.41E+03	4.45E+02	0.00E+00	1.13E+03	4.65E+02	1.20E+01
Cs-136	2.88E+02	8.46E+02	3.16E+02	0.00E+00	3.37E+02	6.90E+01	1.29E+01
Cs-137	3.27E+03	3.83E+03	2.71E+02	0.00E+00	1.03E+03	4.16E+02	1.20E+01
Cs-138	3.02E+00	4.90E+00	2.38E+00	0.00E+00	2.45E+00	3.82E-01	7.84E+00
Ba-139	5.52E+00	3.66E-03	1.60E-01	0.00E+00	2.20E-03	2.22E-03	3.50E+02
Ba-140	1.07E+03	1.07E+00	5.52E+01	0.00E+00	2.55E-01	6.58E-01	2.63E+02
Ba-141	2.66E+00	1.82E-03	8.40E-02	0.00E+00	1.10E-03	1.11E-03	3.25E+01
Ba-142	1.15E+00	9.59E-04	5.68E-02	0.00E+00	5.52E-04	5.81E-04	4.76E+00
La-140	1.32E-01	5.22E-02	1.34E-02	0.00E+00	0.00E+00	0.00E+00	6.13E+02
La-142	6.90E-03	2.53E-03	6.06E-04	0.00E+00	0.00E+00	0.00E+00	4.30E+02
Ce-141	4.93E-01	3.01E-01	3.54E-02	0.00E+00	9.28E-02	0.00E+00	1.55E+02
Ce-143	9.28E-02	6.16E+01	7.02E-03	0.00E+00	1.79E-02	0.00E+00	3.59E+02
Ce-144	1.87E+01	7.65E+00	1.05E+00	0.00E+00	3.09E+00	0.00E+00	1.07E+03
Pr-143	5.10E-01	1.91E-01	2.53E-02	0.00E+00	7.09E-02	0.00E+00	2.69E+02
Pr-144	1.72E-03	6.65E-04	8.65E-05	0.00E+00	2.41E-04	0.00E+00	3.09E+01
Nd-147	3.47E-01	3.56E-01	2.18E-02	0.00E+00	1.37E-01	0.00E+00	2.26E+02
W-187	5.66E+00	3.94E+00	1.36E+00	0.00E+00	0.00E+00	0.00E+00	2.31E+02
Np-239	6.96E-02	6.23E-03	3.52E-03	0.00E+00	1.24E-02	0.00E+00	1.80E+02

Notes:

1) Units are mrem/hr per μCi/ml.

Table 9
Site Specific Fish Ingestion Dose Factors for Adult Age Group

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	1.29E-01	1.29E-01	1.29E-01	1.29E-01	1.29E-01	1.29E-01
Na-24	4.07E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02
Cr-51	0.00E+00	0.00E+00	1.27E+00	7.61E-01	2.81E-01	1.69E+00	3.20E+02
Mn-54	0.00E+00	4.38E+03	8.35E+02	0.00E+00	1.30E+03	0.00E+00	1.34E+04
Mn-56	0.00E+00	1.10E+02	1.95E+01	0.00E+00	1.40E+02	0.00E+00	3.51E+03
Fe-55	6.58E+02	4.55E+02	1.06E+02	0.00E+00	0.00E+00	2.54E+02	2.61E+02
Fe-59	1.04E+03	2.44E+03	9.36E+02	0.00E+00	0.00E+00	6.82E+02	8.14E+03
Co-58	0.00E+00	8.92E+01	2.00E+02	0.00E+00	0.00E+00	0.00E+00	1.81E+03
Co-60	0.00E+00	2.56E+02	5.65E+02	0.00E+00	0.00E+00	0.00E+00	4.81E+03
Ni-63	3.11E+04	2.16E+03	1.04E+03	0.00E+00	0.00E+00	0.00E+00	4.50E+02
Ni-65	1.26E+02	1.64E+01	7.49E+00	0.00E+00	0.00E+00	0.00E+00	4.17E+02
Cu-64	0.00E+00	9.97E+00	4.68E+00	0.00E+00	2.51E+01	0.00E+00	8.50E+02
Zn-65	2.32E+04	7.37E+04	3.33E+04	0.00E+00	4.93E+04	0.00E+00	4.64E+04
Zn-69	4.93E+01	9.43E+01	6.56E+00	0.00E+00	6.13E+01	0.00E+00	1.42E+01
Br-83	0.00E+00	0.00E+00	4.04E+01	0.00E+00	0.00E+00	0.00E+00	5.82E+01
Br-84	0.00E+00	0.00E+00	5.24E+01	0.00E+00	0.00E+00	0.00E+00	4.11E-04
Br-85	0.00E+00	0.00E+00	2.15E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	1.01E+05	4.71E+04	0.00E+00	0.00E+00	0.00E+00	1.99E+04
Rb-88	0.00E+00	2.90E+02	1.54E+02	0.00E+00	0.00E+00	0.00E+00	4.00E-09
Rb-89	0.00E+00	1.92E+02	1.35E+02	0.00E+00	0.00E+00	0.00E+00	1.12E-11
Sr-89	2.21E+04	0.00E+00	6.35E+02	0.00E+00	0.00E+00	0.00E+00	3.55E+03
Sr-90	6.26E+05	0.00E+00	1.26E+04	0.00E+00	0.00E+00	0.00E+00	1.57E+04
Sr-91	4.07E+02	0.00E+00	1.64E+01	0.00E+00	0.00E+00	0.00E+00	1.94E+03
Sr-92	1.54E+02	0.00E+00	6.68E+00	0.00E+00	0.00E+00	0.00E+00	3.06E+03
Y-90	5.76E-01	0.00E+00	1.54E-02	0.00E+00	0.00E+00	0.00E+00	6.10E+03
Y-91M	5.44E-03	0.00E+00	2.11E-04	0.00E+00	0.00E+00	0.00E+00	1.60E-02
Y-91	8.44E+00	0.00E+00	2.26E-01	0.00E+00	0.00E+00	0.00E+00	4.64E+03
Y-92	5.06E-02	0.00E+00	1.48E-03	0.00E+00	0.00E+00	0.00E+00	8.86E+02
Y-93	1.60E-01	0.00E+00	4.43E-03	0.00E+00	0.00E+00	0.00E+00	5.09E+03
Zr-95	2.40E-01	7.70E-02	5.21E-02	0.00E+00	1.21E-01	0.00E+00	2.44E+02
Zr-97	1.33E-02	2.68E-03	1.22E-03	0.00E+00	4.04E-03	0.00E+00	8.30E+02
Nb-95	4.47E+02	2.48E+02	1.34E+02	0.00E+00	2.46E+02	0.00E+00	1.51E+06
Mo-99	0.00E+00	1.03E+02	1.96E+01	0.00E+00	2.34E+02	0.00E+00	2.39E+02
Tc- 99M	8.87E-03	2.51E-02	3.19E-01	0.00E+00	3.81E-01	1.23E-02	1.48E+01
Tc-101	9.12E-03	1.31E-02	1.29E-01	0.00E+00	2.37E-01	6.72E-03	3.95E-14
Ru-103	4.43E+00	0.00E+00	1.91E+00	0.00E+00	1.69E+01	0.00E+00	5.17E+02
Ru-105	3.69E-01	0.00E+00	1.46E-01	0.00E+00	4.76E+00	0.00E+00	2.26E+02
Ru-106	6.58E+01	0.00E+00	8.33E+00	0.00E+00	1.27E+02	0.00E+00	4.26E+03
Ag-110M	8.81E-01	8.15E-01	4.84E-01	0.00E+00	1.60E+00	0.00E+00	3.33E+02
Te-125M	2.57E+03	9.30E+02	3.44E+02	7.72E+02	1.04E+04	0.00E+00	1.02E+04

Table 9 (continued)
Site Specific Fish Ingestion Dose Factors for Adult Age Group

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-127M	6.48E+03	2.32E+03	7.90E+02	1.66E+03	2.63E+04	0.00E+00	2.17E+04
Te-127	1.05E+02	3.78E+01	2.28E+01	7.80E+01	4.29E+02	0.00E+00	8.31E+03
Te-129M	1.10E+04	4.11E+03	1.74E+03	3.78E+03	4.60E+04	0.00E+00	5.54E+04
Te-129	3.01E+01	1.13E+01	7.33E+00	2.31E+01	1.26E+02	0.00E+00	2.27E+01
Te-131M	1.66E+03	8.10E+02	6.75E+02	1.28E+03	8.21E+03	0.00E+00	8.04E+04
Te-131	1.89E+01	7.88E+00	5.96E+00	1.55E+01	8.26E+01	0.00E+00	2.67E+00
Te-132	2.41E+03	1.56E+03	1.47E+03	1.72E+03	1.50E+04	0.00E+00	7.38E+04
I-130	2.71E+01	8.01E+01	3.16E+01	6.79E+03	1.25E+02	0.00E+00	6.89E+01
I-131	1.49E+02	2.14E+02	1.22E+02	7.00E+04	3.66E+02	0.00E+00	5.64E+01
I-132	7.29E+00	1.95E+01	6.82E+00	6.82E+02	3.11E+01	0.00E+00	3.66E+00
I-133	5.10E+01	8.87E+01	2.70E+01	1.30E+04	1.55E+02	0.00E+00	7.97E+01
I-134	3.81E+00	1.03E+01	3.70E+00	1.79E+02	1.64E+01	0.00E+00	9.01E-03
I-135	1.59E+01	4.17E+01	1.54E+01	2.75E+03	6.68E+01	0.00E+00	4.70E+01
Cs-134	2.98E+05	7.09E+05	5.79E+05	0.00E+00	2.29E+05	7.61E+04	1.24E+04
Cs-136	3.12E+04	1.23E+05	8.86E+04	0.00E+00	6.85E+04	9.38E+03	1.40E+04
Cs-137	3.82E+05	5.22E+05	3.42E+05	0.00E+00	1.77E+05	5.89E+04	1.01E+04
Cs-138	2.64E+02	5.22E+02	2.59E+02	0.00E+00	3.84E+02	3.79E+01	2.23E-03
Ba-139	9.29E-01	6.62E-04	2.72E-02	0.00E+00	6.19E-04	3.75E-04	1.65E+00
Ba-140	1.94E+02	2.44E-01	1.27E+01	0.00E+00	8.30E-02	1.40E-01	4.00E+02
Ba-141	4.51E-01	3.41E-04	1.52E-02	0.00E+00	3.17E-04	1.93E-04	2.13E-10
Ba-142	2.04E-01	2.10E-04	1.28E-02	0.00E+00	1.77E-04	1.19E-04	2.87E-19
La-140	1.50E-01	7.54E-02	1.99E-02	0.00E+00	0.00E+00	0.00E+00	5.54E+03
La-142	7.66E-03	3.48E-03	8.68E-04	0.00E+00	0.00E+00	0.00E+00	2.54E+01
Ce-141	2.24E-02	1.52E-02	1.72E-03	0.00E+00	7.04E-03	0.00E+00	5.79E+01
Ce-143	3.95E-03	2.92E+00	3.23E-04	0.00E+00	1.29E-03	0.00E+00	1.09E+02
Ce-144	1.17E+00	4.88E-01	6.27E-02	0.00E+00	2.90E-01	0.00E+00	3.95E+02
Pr-143	5.51E-01	2.21E-01	2.73E-02	0.00E+00	1.27E-01	0.00E+00	2.41E+03
Pr-144	1.80E-03	7.48E-04	9.16E-05	0.00E+00	4.22E-04	0.00E+00	2.59E-10
Nd-147	3.76E-01	4.35E-01	2.60E-02	0.00E+00	2.54E-01	0.00E+00	2.09E+03
W-187	2.96E+02	2.47E+02	8.65E+01	0.00E+00	0.00E+00	0.00E+00	8.10E+04
Np-239	2.85E-02	2.80E-03	1.54E-03	0.00E+00	8.74E-03	0.00E+00	5.75E+02

Table 9a
Site Specific Fish Ingestion Dose Factors for Teen Age Group

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	9.92E-02	9.92E-02	9.92E-02	9.92E-02	9.92E-02	9.92E-02
Na-24	4.20E+02	4.20E+02	4.20E+02	4.20E+02	4.20E+02	4.20E+02	4.20E+02
Cr-51	0.00E+00	0.00E+00	1.31E+00	7.30E-01	2.88E-01	1.88E+00	2.21E+02
Mn-54	0.00E+00	4.30E+03	8.54E+02	0.00E+00	1.28E+03	0.00E+00	8.83E+03
Mn-56	0.00E+00	1.15E+02	2.05E+01	0.00E+00	1.46E+02	0.00E+00	7.59E+03
Fe-55	6.89E+02	4.89E+02	1.14E+02	0.00E+00	0.00E+00	3.10E+02	2.12E+02
Fe-59	1.07E+03	2.50E+03	9.65E+02	0.00E+00	0.00E+00	7.88E+02	5.91E+03
Co-58	0.00E+00	8.86E+01	2.04E+02	0.00E+00	0.00E+00	0.00E+00	1.22E+03
Co-60	0.00E+00	2.56E+02	5.77E+02	0.00E+00	0.00E+00	0.00E+00	3.34E+03
Ni-63	3.23E+04	2.28E+03	1.09E+03	0.00E+00	0.00E+00	0.00E+00	3.63E+02
Ni-65	1.37E+02	1.75E+01	7.95E+00	0.00E+00	0.00E+00	0.00E+00	9.47E+02
Cu-64	0.00E+00	1.05E+01	4.93E+00	0.00E+00	2.65E+01	0.00E+00	8.14E+02
Zn-65	2.10E+04	7.30E+04	3.40E+04	0.00E+00	4.67E+04	0.00E+00	3.09E+04
Zn-69	5.36E+01	1.02E+02	7.15E+00	0.00E+00	6.68E+01	0.00E+00	1.88E+02
Br-83	0.00E+00	0.00E+00	4.40E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	5.53E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	2.34E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	1.09E+05	5.11E+04	0.00E+00	0.00E+00	0.00E+00	1.61E+04
Rb-88	0.00E+00	3.11E+02	1.66E+02	0.00E+00	0.00E+00	0.00E+00	2.66E-05
Rb-89	0.00E+00	2.01E+02	1.42E+02	0.00E+00	0.00E+00	0.00E+00	3.08E-07
Sr-89	2.41E+04	0.00E+00	6.89E+02	0.00E+00	0.00E+00	0.00E+00	2.87E+03
Sr-90	5.58E+05	0.00E+00	1.12E+04	0.00E+00	0.00E+00	0.00E+00	1.27E+04
Sr-91	4.42E+02	0.00E+00	1.76E+01	0.00E+00	0.00E+00	0.00E+00	2.00E+03
Sr-92	1.67E+02	0.00E+00	7.11E+00	0.00E+00	0.00E+00	0.00E+00	4.25E+03
Y-90	6.25E-01	0.00E+00	1.68E-02	0.00E+00	0.00E+00	0.00E+00	5.15E+03
Y-91M	5.88E-03	0.00E+00	2.25E-04	0.00E+00	0.00E+00	0.00E+00	2.78E-01
Y-91	9.17E+00	0.00E+00	2.46E-01	0.00E+00	0.00E+00	0.00E+00	3.76E+03
Y-92	5.52E-02	0.00E+00	1.60E-03	0.00E+00	0.00E+00	0.00E+00	1.51E+03
Y-93	1.75E-01	0.00E+00	4.79E-03	0.00E+00	0.00E+00	0.00E+00	5.34E+03
Zr-95	2.48E-01	7.82E-02	5.38E-02	0.00E+00	1.15E-01	0.00E+00	1.81E+02
Zr-97	1.43E-02	2.82E-03	1.30E-03	0.00E+00	4.28E-03	0.00E+00	7.64E+02
Nb-95	4.50E+02	2.50E+02	1.37E+02	0.00E+00	2.42E+02	0.00E+00	1.07E+06
Mo-99	0.00E+00	1.10E+02	2.10E+01	0.00E+00	2.52E+02	0.00E+00	1.97E+02
Tc- 99M	9.08E-03	2.53E-02	3.28E-01	0.00E+00	3.78E-01	1.41E-02	1.66E+01
Tc-101	9.85E-03	1.40E-02	1.38E-01	0.00E+00	2.53E-01	8.54E-03	2.39E-09
Ru-103	4.65E+00	0.00E+00	1.99E+00	0.00E+00	1.64E+01	0.00E+00	3.89E+02
Ru-105	3.98E-01	0.00E+00	1.54E-01	0.00E+00	5.02E+00	0.00E+00	3.21E+02
Ru-106	7.15E+01	0.00E+00	9.01E+00	0.00E+00	1.38E+02	0.00E+00	3.43E+03
Ag-110M	8.60E-01	8.14E-01	4.95E-01	0.00E+00	1.55E+00	0.00E+00	2.29E+02
Te-125M	2.79E+03	1.01E+03	3.74E+02	7.81E+02	0.00E+00	0.00E+00	8.24E+03

Table 9a (continued)
Site Specific Fish Ingestion Dose Factors for Teen Age Group

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-127M	7.06E+03	2.50E+03	8.39E+02	1.68E+03	2.86E+04	0.00E+00	1.76E+04
Te-127	1.15E+02	4.09E+01	2.48E+01	7.95E+01	4.67E+02	0.00E+00	8.90E+03
Te-129M	1.19E+04	4.41E+03	1.88E+03	3.84E+03	4.98E+04	0.00E+00	4.47E+04
Te-129	3.27E+01	1.22E+01	7.95E+00	2.33E+01	1.37E+02	0.00E+00	1.79E+02
Te-131M	1.78E+03	8.54E+02	7.12E+02	1.28E+03	8.90E+03	0.00E+00	6.85E+04
Te-131	2.04E+01	8.39E+00	6.36E+00	1.57E+01	8.90E+01	0.00E+00	1.67E+00
Te-132	2.55E+03	1.61E+03	1.52E+03	1.70E+03	1.55E+04	0.00E+00	5.11E+04
I-130	2.82E+01	8.15E+01	3.26E+01	6.65E+03	1.26E+02	0.00E+00	6.27E+01
I-131	1.60E+02	2.24E+02	1.20E+02	6.54E+04	3.86E+02	0.00E+00	4.43E+01
I-132	7.63E+00	2.00E+01	7.17E+00	6.73E+02	3.15E+01	0.00E+00	8.70E+00
I-133	5.50E+01	9.33E+01	2.85E+01	1.30E+04	1.64E+02	0.00E+00	7.06E+01
I-134	3.99E+00	1.06E+01	3.80E+00	1.76E+02	1.67E+01	0.00E+00	1.40E-01
I-135	1.67E+01	4.30E+01	1.59E+01	2.76E+03	6.79E+01	0.00E+00	4.76E+01
Cs-134	3.05E+05	7.19E+05	3.33E+05	0.00E+00	2.28E+05	8.72E+04	8.94E+03
Cs-136	3.13E+04	1.23E+05	8.28E+04	0.00E+00	6.71E+04	1.06E+04	9.92E+03
Cs-137	4.09E+05	5.44E+05	1.89E+05	0.00E+00	1.85E+05	7.19E+04	7.73E+03
Cs-138	2.83E+02	5.44E+02	2.72E+02	0.00E+00	4.01E+02	4.67E+01	2.47E-01
Ba-139	1.01E+00	7.14E-04	2.95E-02	0.00E+00	6.73E-04	4.92E-04	9.05E+00
Ba-140	2.07E+02	2.54E-01	1.34E+01	0.00E+00	8.61E-02	1.71E-01	3.20E+02
Ba-141	4.90E-01	3.66E-04	1.63E-02	0.00E+00	3.39E-04	2.50E-04	1.04E-06
Ba-142	2.18E-01	2.18E-04	1.34E-02	0.00E+00	1.85E-04	1.45E-04	6.70E-13
La-140	1.59E-01	7.80E-02	2.07E-02	0.00E+00	0.00E+00	0.00E+00	4.48E+03
La-142	8.16E-03	3.63E-03	9.03E-04	0.00E+00	0.00E+00	0.00E+00	1.10E+02
Ce-141	2.43E-02	1.62E-02	1.86E-03	0.00E+00	7.62E-03	0.00E+00	4.63E+01
Ce-143	4.29E-03	3.12E+00	3.48E-04	0.00E+00	1.40E-03	0.00E+00	9.38E+01
Ce-144	1.27E+00	5.25E-01	6.82E-02	0.00E+00	3.14E-01	0.00E+00	3.19E+02
Pr-143	5.97E-01	2.38E-01	2.97E-02	0.00E+00	1.39E-01	0.00E+00	1.97E+03
Pr-144	1.96E-03	8.03E-04	9.94E-05	0.00E+00	4.61E-04	0.00E+00	2.16E-06
Nd-147	4.28E-01	4.65E-01	2.79E-02	0.00E+00	2.73E-01	0.00E+00	1.68E+03
W-187	3.20E+02	2.60E+02	9.13E+01	0.00E+00	0.00E+00	0.00E+00	7.05E+04
Np-239	3.21E-02	3.03E-03	1.68E-03	0.00E+00	9.50E-03	0.00E+00	4.87E+02

Notes:

1) Units are mrem/hr per μCi/ml.

Table 9b
Site Specific Fish Ingestion Dose Factors for Child Age Group

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	8.21E-02	8.21E-02	8.21E-02	8.21E-02	8.21E-02	8.21E-02
Na-24	4.56E+02	4.56E+02	4.56E+02	4.56E+02	4.56E+02	4.56E+02	4.56E+02
Cr-51	0.00E+00	0.00E+00	1.40E+00	7.77E-01	2.12E-01	1.42E+00	7.43E+01
Mn-54	0.00E+00	3.37E+03	8.97E+02	0.00E+00	9.44E+02	0.00E+00	2.83E+03
Mn-56	0.00E+00	1.05E+02	2.37E+01	0.00E+00	1.27E+02	0.00E+00	1.52E+04
Fe-55	9.05E+02	4.80E+02	1.49E+02	0.00E+00	0.00E+00	2.71E+02	8.89E+01
Fe-59	1.30E+03	2.10E+03	1.05E+03	0.00E+00	0.00E+00	6.09E+02	2.19E+03
Co-58	0.00E+00	7.08E+01	2.17E+02	0.00E+00	0.00E+00	0.00E+00	4.13E+02
Co-60	0.00E+00	2.08E+02	6.14E+02	0.00E+00	0.00E+00	0.00E+00	1.15E+03
Ni-63	4.23E+04	2.27E+03	1.44E+03	0.00E+00	0.00E+00	0.00E+00	1.53E+02
Ni-65	1.75E+02	1.64E+01	9.60E+00	0.00E+00	0.00E+00	0.00E+00	2.01E+03
Cu-64	0.00E+00	9.64E+00	5.82E+00	0.00E+00	2.33E+01	0.00E+00	4.52E+02
Zn-65	2.16E+04	5.74E+04	3.57E+04	0.00E+00	3.62E+04	0.00E+00	1.01E+04
Zn-69	6.89E+01	9.96E+01	9.20E+00	0.00E+00	6.04E+01	0.00E+00	6.28E+03
Br-83	0.00E+00	0.00E+00	5.65E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	6.54E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	3.01E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	1.05E+05	6.48E+04	0.00E+00	0.00E+00	0.00E+00	6.78E+03
Rb-88	0.00E+00	2.99E+02	2.08E+02	0.00E+00	0.00E+00	0.00E+00	1.47E+01
Rb-89	0.00E+00	1.84E+02	1.64E+02	0.00E+00	0.00E+00	0.00E+00	1.60E+00
Sr-89	3.11E+04	0.00E+00	8.90E+02	0.00E+00	0.00E+00	0.00E+00	1.21E+03
Sr-90	6.04E+05	0.00E+00	1.22E+04	0.00E+00	0.00E+00	0.00E+00	5.40E+03
Sr-91	5.66E+02	0.00E+00	2.14E+01	0.00E+00	0.00E+00	0.00E+00	1.25E+03
Sr-92	2.13E+02	0.00E+00	8.54E+00	0.00E+00	0.00E+00	0.00E+00	4.04E+03
Y-90	8.08E-01	0.00E+00	2.16E-02	0.00E+00	0.00E+00	0.00E+00	2.30E+03
Y-91M	7.51E-03	0.00E+00	2.73E-04	0.00E+00	0.00E+00	0.00E+00	1.47E+01
Y-91	1.18E+01	0.00E+00	3.17E-01	0.00E+00	0.00E+00	0.00E+00	1.58E+03
Y-92	7.08E-02	0.00E+00	2.03E-03	0.00E+00	0.00E+00	0.00E+00	2.05E+03
Y-93	2.24E-01	0.00E+00	6.16E-03	0.00E+00	0.00E+00	0.00E+00	3.34E+03
Zr-95	3.01E-01	6.62E-02	5.89E-02	0.00E+00	9.47E-02	0.00E+00	6.90E+01
Zr-97	1.81E-02	2.62E-03	1.55E-03	0.00E+00	3.76E-03	0.00E+00	3.97E+02
Nb-95	5.31E+02	2.07E+02	1.48E+02	0.00E+00	1.94E+02	0.00E+00	3.82E+05
Mo-99	0.00E+00	1.05E+02	2.59E+01	0.00E+00	2.23E+02	0.00E+00	8.65E+01
Tc- 99M	1.09E-02	2.14E-02	3.54E-01	0.00E+00	3.10E-01	1.08E-02	1.22E+01
Tc-101	1.26E-02	1.32E-02	1.68E-01	0.00E+00	2.25E-01	6.99E-03	4.20E-02
Ru-103	5.75E+00	0.00E+00	2.21E+00	0.00E+00	1.45E+01	0.00E+00	1.49E+02
Ru-105	5.07E-01	0.00E+00	1.84E-01	0.00E+00	4.46E+00	0.00E+00	3.31E+02
Ru-106	9.20E+01	0.00E+00	1.15E+01	0.00E+00	1.24E+02	0.00E+00	1.43E+03
Ag-110M	9.75E-01	6.59E-01	5.26E-01	0.00E+00	1.23E+00	0.00E+00	7.83E+01
Te-125M	3.59E+03	9.72E+02	4.78E+02	1.01E+03	0.00E+00	0.00E+00	3.46E+03

Table 9b (continued)
Site Specific Fish Ingestion Dose Factors for Child Age Group

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-127M	9.09E+03	2.45E+03	1.08E+03	2.17E+03	2.59E+04	0.00E+00	7.36E+03
Te-127	1.48E+02	4.00E+01	3.18E+01	1.03E+02	4.22E+02	0.00E+00	5.79E+03
Te-129M	1.53E+04	4.28E+03	2.38E+03	4.94E+03	4.50E+04	0.00E+00	1.87E+04
Te-129	4.22E+01	1.18E+01	1.00E+01	3.01E+01	1.23E+02	0.00E+00	2.62E+03
Te-131M	2.27E+03	7.83E+02	8.34E+02	1.61E+03	7.58E+03	0.00E+00	3.18E+04
Te-131	2.61E+01	7.96E+00	7.77E+00	2.00E+01	7.90E+01	0.00E+00	1.37E+02
Te-132	3.18E+03	1.41E+03	1.70E+03	2.05E+03	1.31E+04	0.00E+00	1.42E+04
I-130	3.45E+01	6.96E+01	3.59E+01	7.67E+03	1.04E+02	0.00E+00	3.26E+01
I-131	2.03E+02	2.04E+02	1.16E+02	6.75E+04	3.35E+02	0.00E+00	1.82E+01
I-132	9.44E+00	1.73E+01	7.98E+00	8.05E+02	2.65E+01	0.00E+00	2.04E+01
I-133	6.99E+01	8.64E+01	3.27E+01	1.60E+04	1.44E+02	0.00E+00	3.48E+01
I-134	4.94E+00	9.18E+00	4.22E+00	2.11E+02	1.40E+01	0.00E+00	6.09E+00
I-135	2.06E+01	3.72E+01	1.76E+01	3.29E+03	5.70E+01	0.00E+00	2.83E+01
Cs-134	3.68E+05	6.04E+05	1.27E+05	0.00E+00	1.87E+05	6.72E+04	3.26E+03
Cs-136	3.70E+04	1.02E+05	6.58E+04	0.00E+00	5.41E+04	8.07E+03	3.57E+03
Cs-137	5.14E+05	4.92E+05	7.27E+04	0.00E+00	1.60E+05	5.77E+04	3.08E+03
Cs-138	3.59E+02	4.99E+02	3.16E+02	0.00E+00	3.51E+02	3.78E+01	2.30E+02
Ba-139	1.30E+00	6.95E-04	3.78E-02	0.00E+00	6.07E-04	4.09E-04	7.52E+01
Ba-140	2.61E+02	2.29E-01	1.53E+01	0.00E+00	7.46E-02	1.37E-01	1.32E+02
Ba-141	6.29E-01	3.52E-04	2.05E-02	0.00E+00	3.05E-04	2.07E-03	3.59E-01
Ba-142	2.75E-01	1.98E-04	1.54E-02	0.00E+00	1.60E-04	1.16E-04	3.59E-03
La-140	1.99E-01	6.94E-02	2.34E-02	0.00E+00	0.00E+00	0.00E+00	1.94E+03
La-142	1.03E-02	3.28E-03	1.03E-03	0.00E+00	0.00E+00	0.00E+00	6.51E+02
Ce-141	3.12E-02	1.56E-02	2.31E-03	0.00E+00	6.83E-03	0.00E+00	1.94E+01
Ce-143	5.50E-03	2.98E+00	4.32E-04	0.00E+00	1.25E-03	0.00E+00	4.37E+01
Ce-144	1.64E+00	5.13E-01	8.73E-02	0.00E+00	2.84E-01	0.00E+00	1.34E+02
Pr-143	7.73E-01	2.32E-01	3.83E-02	0.00E+00	1.26E-01	0.00E+00	8.34E+02
Pr-144	2.54E-03	7.85E-04	1.28E-04	0.00E+00	4.15E-04	0.00E+00	1.69E+00
Nd-147	5.49E-01	4.44E-01	3.44E-02	0.00E+00	2.44E-01	0.00E+00	7.04E+02
W-187	4.05E+02	2.40E+02	1.08E+02	0.00E+00	0.00E+00	0.00E+00	3.37E+04
Np-239	4.13E-02	2.97E-03	2.08E-03	0.00E+00	8.57E-03	0.00E+00	2.19E+02

Notes:

1) Units are mrem/hr per μCi/ml.

2) The infant age group is assumed to receive no dose through the fish ingestion pathway, therefore no dose factors are supplied.

Table 10
Ground Plane Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Na-24	1.20E+07	1.20E+07	1.20E+07	1.20E+07	1.20E+07	1.20E+07	1.20E+07
Cr-51	4.65E+06	4.65E+06	4.65E+06	4.65E+06	4.65E+06	4.65E+06	4.65E+06
Mn-54	1.38E+09	1.38E+09	1.38E+09	1.38E+09	1.38E+09	1.38E+09	1.38E+09
Mn-56	9.03E+05	9.03E+05	9.03E+05	9.03E+05	9.03E+05	9.03E+05	9.03E+05
Fe-55	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Fe-59	2.73E+08	2.73E+08	2.73E+08	2.73E+08	2.73E+08	2.73E+08	2.73E+08
Co-58	3.80E+08	3.80E+08	3.80E+08	3.80E+08	3.80E+08	3.80E+08	3.80E+08
Co-60	2.45E+10	2.45E+10	2.45E+10	2.45E+10	2.45E+10	2.45E+10	2.45E+10
Ni-63	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ni-65	2.97E+05	2.97E+05	2.97E+05	2.97E+05	2.97E+05	2.97E+05	2.97E+05
Cu-64	6.05E+05	6.05E+05	6.05E+05	6.05E+05	6.05E+05	6.05E+05	6.05E+05
Zn-65	7.46E+08	7.46E+08	7.46E+08	7.46E+08	7.46E+08	7.46E+08	7.46E+08
Zn-69	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-83	4.87E+03	4.87E+03	4.87E+03	4.87E+03	4.87E+03	4.87E+03	4.87E+03
Br-84	2.03E+05	2.03E+05	2.03E+05	2.03E+05	2.03E+05	2.03E+05	2.03E+05
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	9.01E+06	9.01E+06	9.01E+06	9.01E+06	9.01E+06	9.01E+06	9.01E+06
Rb-88	3.31E+04	3.31E+04	3.31E+04	3.31E+04	3.31E+04	3.31E+04	3.31E+04
Rb-89	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05
Sr-89	2.16E+04	2.16E+04	2.16E+04	2.16E+04	2.16E+04	2.16E+04	2.16E+04
Sr-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-91	2.14E+06	2.14E+06	2.14E+06	2.14E+06	2.14E+06	2.14E+06	2.14E+06
Sr-92	7.76E+05	7.76E+05	7.76E+05	7.76E+05	7.76E+05	7.76E+05	7.76E+05
Y-90	4.50E+03	4.50E+03	4.50E+03	4.50E+03	4.50E+03	4.50E+03	4.50E+03
Y-91M	1.00E+05	1.00E+05	1.00E+05	1.00E+05	1.00E+05	1.00E+05	1.00E+05
Y-91	1.07E+06	1.07E+06	1.07E+06	1.07E+06	1.07E+06	1.07E+06	1.07E+06
Y-92	1.80E+05	1.80E+05	1.80E+05	1.80E+05	1.80E+05	1.80E+05	1.80E+05
Y-93	1.83E+05	1.83E+05	1.83E+05	1.83E+05	1.83E+05	1.83E+05	1.83E+05
Zr-95	2.45E+08	2.45E+08	2.45E+08	2.45E+08	2.45E+08	2.45E+08	2.45E+08
Zr-97	2.96E+06	2.96E+06	2.96E+06	2.96E+06	2.96E+06	2.96E+06	2.96E+06
Nb-95	1.37E+08	1.37E+08	1.37E+08	1.37E+08	1.37E+08	1.37E+08	1.37E+08
Mo-99	3.99E+06	3.99E+06	3.99E+06	3.99E+06	3.99E+06	3.99E+06	3.99E+06
Tc- 99M	1.84E+05	1.84E+05	1.84E+05	1.84E+05	1.84E+05	1.84E+05	1.84E+05
Tc-101	2.03E+04	2.03E+04	2.03E+04	2.03E+04	2.03E+04	2.03E+04	2.03E+04
Ru-103	1.08E+08	1.08E+08	1.08E+08	1.08E+08	1.08E+08	1.08E+08	1.08E+08
Ru-105	6.36E+05	6.36E+05	6.36E+05	6.36E+05	6.36E+05	6.36E+05	6.36E+05
Ru-106	4.22E+08	4.22E+08	4.22E+08	4.22E+08	4.22E+08	4.22E+08	4.22E+08
Ag-110M	3.45E+09	3.45E+09	3.45E+09	3.45E+09	3.45E+09	3.45E+09	3.45E+09

Table 10 (Continued)
Ground Plane Dose Factors (same for all age groups)

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	1.56E+06	1.56E+06	1.56E+06	1.56E+06	1.56E+06	1.56E+06	1.56E+06
Te-127M	9.16E+04	9.16E+04	9.16E+04	9.16E+04	9.16E+04	9.16E+04	9.16E+04
Te-127	2.99E+03	2.99E+03	2.99E+03	2.99E+03	2.99E+03	2.99E+03	2.99E+03
Te-129M	1.98E+07	1.98E+07	1.98E+07	1.98E+07	1.98E+07	1.98E+07	1.98E+07
Te-129	2.62E+04	2.62E+04	2.62E+04	2.62E+04	2.62E+04	2.62E+04	2.62E+04
Te-131M	8.02E+06	8.02E+06	8.02E+06	8.02E+06	8.02E+06	8.02E+06	8.02E+06
Te-131	2.92E+04	2.92E+04	2.92E+04	2.92E+04	2.92E+04	2.92E+04	2.92E+04
Te-132	4.22E+06	4.22E+06	4.22E+06	4.22E+06	4.22E+06	4.22E+06	4.22E+06
I-130	5.50E+06	5.50E+06	5.50E+06	5.50E+06	5.50E+06	5.50E+06	5.50E+06
I-131	1.72E+07	1.72E+07	1.72E+07	1.72E+07	1.72E+07	1.72E+07	1.72E+07
I-132	1.25E+06	1.25E+06	1.25E+06	1.25E+06	1.25E+06	1.25E+06	1.25E+06
I-133	2.45E+06	2.45E+06	2.45E+06	2.45E+06	2.45E+06	2.45E+06	2.45E+06
I-134	4.46E+05	4.46E+05	4.46E+05	4.46E+05	4.46E+05	4.46E+05	4.46E+05
I-135	2.53E+06	2.53E+06	2.53E+06	2.53E+06	2.53E+06	2.53E+06	2.53E+06
Cs-134	6.94E+09	6.94E+09	6.94E+09	6.94E+09	6.94E+09	6.94E+09	6.94E+09
Cs-136	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08
Cs-137	1.76E+10	1.76E+10	1.76E+10	1.76E+10	1.76E+10	1.76E+10	1.76E+10
Cs-138	3.59E+05	3.59E+05	3.59E+05	3.59E+05	3.59E+05	3.59E+05	3.59E+05
Ba-139	1.06E+05	1.06E+05	1.06E+05	1.06E+05	1.06E+05	1.06E+05	1.06E+05
Ba-140	2.05E+07	2.05E+07	2.05E+07	2.05E+07	2.05E+07	2.05E+07	2.05E+07
Ba-141	4.17E+04	4.17E+04	4.17E+04	4.17E+04	4.17E+04	4.17E+04	4.17E+04
Ba-142	4.44E+04	4.44E+04	4.44E+04	4.44E+04	4.44E+04	4.44E+04	4.44E+04
La-140	1.92E+07	1.92E+07	1.92E+07	1.92E+07	1.92E+07	1.92E+07	1.92E+07
La-142	7.60E+05	7.60E+05	7.60E+05	7.60E+05	7.60E+05	7.60E+05	7.60E+05
Ce-141	1.37E+07	1.37E+07	1.37E+07	1.37E+07	1.37E+07	1.37E+07	1.37E+07
Ce-143	2.31E+06	2.31E+06	2.31E+06	2.31E+06	2.31E+06	2.31E+06	2.31E+06
Ce-144	6.96E+07	6.96E+07	6.96E+07	6.96E+07	6.96E+07	6.96E+07	6.96E+07
Pr-143	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr-144	1.84E+03	1.84E+03	1.84E+03	1.84E+03	1.84E+03	1.84E+03	1.84E+03
Nd-147	8.48E+06	8.48E+06	8.48E+06	8.48E+06	8.48E+06	8.48E+06	8.48E+06
W-187	2.35E+06	2.35E+06	2.35E+06	2.35E+06	2.35E+06	2.35E+06	2.35E+06
Np-239	1.71E+06	1.71E+06	1.71E+06	1.71E+06	1.71E+06	1.71E+06	1.71E+06

Notes:

1) Units are m^2 mrem/yr per μCi/sec.

2) All age groups are assumed to receive the same dose.

Table 11
Adult Inhalation Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	7.18E+02	7.18E+02	7.18E+02	7.18E+02	7.18E+02	7.18E+02
Na-24	1.02E+04	1.02E+04	1.02E+04	1.02E+04	1.02E+04	1.02E+04	1.02E+04
Cr-51	0.00E+00	0.00E+00	1.00E+02	5.95E+01	2.28E+01	1.44E+04	3.32E+03
Mn-54	0.00E+00	3.96E+04	6.30E+03	0.00E+00	9.84E+03	1.40E+06	7.74E+04
Mn-56	0.00E+00	1.24E+00	1.83E-01	0.00E+00	1.30E+00	9.44E+03	2.02E+04
Fe-55	2.46E+04	1.70E+04	3.94E+03	0.00E+00	0.00E+00	7.21E+04	6.03E+03
Fe-59	1.18E+04	2.78E+04	1.06E+04	0.00E+00	0.00E+00	1.02E+06	1.88E+05
Co-58	0.00E+00	1.58E+03	2.07E+03	0.00E+00	0.00E+00	9.28E+05	1.06E+05
Co-60	0.00E+00	1.15E+04	1.48E+04	0.00E+00	0.00E+00	5.97E+06	2.85E+05
Ni-63	4.32E+05	3.14E+04	1.45E+04	0.00E+00	0.00E+00	1.78E+05	1.34E+04
Ni-65	1.54E+00	2.10E-01	9.12E-02	0.00E+00	0.00E+00	5.60E+03	1.23E+04
Cu-64	0.00E+00	1.46E+00	6.15E-01	0.00E+00	4.62E+00	6.78E+03	4.90E+04
Zn-65	3.24E+04	1.03E+05	4.66E+04	0.00E+00	6.90E+04	8.64E+05	5.34E+04
Zn-69	3.38E-02	6.51E-02	4.52E-03	0.00E+00	4.22E-02	9.20E+02	1.63E+01
Br-83	0.00E+00	0.00E+00	2.41E+02	0.00E+00	0.00E+00	0.00E+00	2.32E+02
Br-84	0.00E+00	0.00E+00	3.13E+02	0.00E+00	0.00E+00	0.00E+00	1.64E-03
Br-85	0.00E+00	0.00E+00	1.28E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	1.35E+05	5.90E+04	0.00E+00	0.00E+00	0.00E+00	1.66E+04
Rb-88	0.00E+00	3.87E+02	1.93E+02	0.00E+00	0.00E+00	0.00E+00	3.34E-09
Rb-89	0.00E+00	2.56E+02	1.70E+02	0.00E+00	0.00E+00	0.00E+00	9.28E-12
Sr-89	3.04E+05	0.00E+00	8.72E+03	0.00E+00	0.00E+00	1.40E+06	3.50E+05
Sr-90	2.87E+07	0.00E+00	5.77E+05	0.00E+00	0.00E+00	9.60E+06	7.22E+05
Sr-91	6.19E+01	0.00E+00	2.50E+00	0.00E+00	0.00E+00	3.65E+04	1.91E+05
Sr-92	6.74E+00	0.00E+00	2.91E-01	0.00E+00	0.00E+00	1.65E+04	4.30E+04
Y-90	2.09E+03	0.00E+00	5.61E+01	0.00E+00	0.00E+00	1.70E+05	5.06E+05
Y-91M	2.61E-01	0.00E+00	1.02E-02	0.00E+00	0.00E+00	1.92E+03	1.33E+00
Y-91	4.62E+05	0.00E+00	1.24E+04	0.00E+00	0.00E+00	1.70E+06	3.85E+05
Y-92	1.03E+01	0.00E+00	3.02E-01	0.00E+00	0.00E+00	1.57E+04	7.35E+04
Y-93	9.44E+01	0.00E+00	2.61E+00	0.00E+00	0.00E+00	4.85E+04	4.22E+05
Zr-95	1.07E+05	3.44E+04	2.33E+04	0.00E+00	5.42E+04	1.77E+06	1.50E+05
Zr-97	9.68E+01	1.96E+01	9.04E+00	0.00E+00	2.97E+01	7.87E+04	5.23E+05
Nb-95	1.41E+04	7.82E+03	4.21E+03	0.00E+00	7.74E+03	5.05E+05	1.04E+05
Mo-99	0.00E+00	1.21E+02	2.30E+01	0.00E+00	2.91E+02	9.12E+04	2.48E+05
Tc- 99M	1.03E-03	2.91E-03	3.70E-02	0.00E+00	4.42E-02	7.64E+02	4.16E+03
Tc-101	4.18E-05	6.02E-05	5.90E-04	0.00E+00	1.08E-03	3.99E+02	1.09E-11
Ru-103	1.53E+03	0.00E+00	6.58E+02	0.00E+00	5.83E+03	5.05E+05	1.10E+05
Ru-105	7.90E-01	0.00E+00	3.11E-01	0.00E+00	1.02E+00	1.10E+04	4.82E+04
Ru-106	6.91E+04	0.00E+00	8.72E+03	0.00E+00	1.34E+05	9.36E+06	9.12E+05
Ag-110M	1.08E+04	1.00E+04	5.94E+03	0.00E+00	1.97E+04	4.63E+06	3.02E+05

Table 11 (Continued)
Adult Inhalation Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	3.42E+03	1.58E+03	4.67E+02	1.05E+03	1.24E+04	3.14E+05	7.06E+04
Te-127M	1.26E+04	5.77E+03	1.57E+03	3.29E+03	4.58E+04	9.60E+05	1.50E+05
Te-127	1.40E+00	6.42E-01	3.10E-01	1.06E+00	5.10E+00	6.51E+03	5.74E+04
Te-129M	9.76E+03	4.67E+03	1.58E+03	3.44E+03	3.66E+04	1.16E+06	3.83E+05
Te-129	4.98E-02	2.39E-02	1.24E-02	3.90E-02	1.87E-01	1.94E+03	1.57E+02
Te-131M	6.99E+01	4.36E+01	2.90E+01	5.50E+01	3.09E+02	1.46E+05	5.56E+05
Te-131	1.11E-02	5.95E-03	3.59E-03	9.36E-03	4.37E-02	1.39E+03	1.84E+01
Te-132	2.60E+02	2.15E+02	1.62E+02	1.90E+02	1.46E+03	2.88E+05	5.10E+05
I-130	4.58E+03	1.34E+04	5.28E+03	1.14E+06	2.09E+04	0.00E+00	7.69E+03
I-131	2.52E+04	3.58E+04	2.05E+04	1.19E+07	6.13E+04	0.00E+00	6.28E+03
I-132	1.16E+03	3.26E+03	1.16E+03	1.14E+05	5.18E+03	0.00E+00	4.06E+02
I-133	8.64E+03	1.48E+04	4.52E+03	2.15E+06	2.58E+04	0.00E+00	8.88E+03
I-134	6.44E+02	1.73E+03	6.15E+02	2.98E+04	2.75E+03	0.00E+00	1.01E+00
I-135	2.68E+03	6.98E+03	2.57E+03	4.48E+05	1.11E+04	0.00E+00	5.25E+03
Cs-134	3.73E+05	8.48E+05	7.28E+05	0.00E+00	2.87E+05	9.76E+04	1.04E+04
Cs-136	3.90E+04	1.46E+05	1.10E+05	0.00E+00	8.56E+04	1.20E+04	1.17E+04
Cs-137	4.78E+05	6.21E+05	4.28E+05	0.00E+00	2.22E+05	7.52E+04	8.40E+03
Cs-138	3.31E+02	6.21E+02	3.24E+02	0.00E+00	4.80E+02	4.86E+01	1.86E-03
Ba-139	9.36E-01	6.66E-04	2.74E-02	0.00E+00	6.22E-04	3.76E+03	8.96E+02
Ba-140	3.90E+04	4.90E+01	2.57E+03	0.00E+00	1.67E+01	1.27E+06	2.18E+05
Ba-141	1.00E-01	7.53E-05	3.36E-03	0.00E+00	7.00E-05	1.94E+03	1.16E-07
Ba-142	2.63E-02	2.70E-05	1.66E-03	0.00E+00	2.29E-05	1.19E+03	1.57E-16
La-140	3.44E+02	1.74E+02	4.58E+01	0.00E+00	0.00E+00	1.36E+05	4.58E+05
La-142	6.83E-01	3.10E-01	7.72E-02	0.00E+00	0.00E+00	6.33E+03	2.11E+03
Ce-141	1.99E+04	1.35E+04	1.53E+03	0.00E+00	6.26E+03	3.62E+05	1.20E+05
Ce-143	1.86E+02	1.38E+02	1.53E+01	0.00E+00	6.08E+01	7.98E+04	2.26E+05
Ce-144	3.43E+06	1.43E+06	1.84E+05	0.00E+00	8.48E+05	7.78E+06	8.16E+05
Pr-143	9.36E+03	3.75E+03	4.64E+02	0.00E+00	2.16E+03	2.81E+05	2.00E+05
Pr-144	3.01E-02	1.25E-02	1.53E-03	0.00E+00	7.05E-03	1.02E+03	2.15E-08
Nd-147	5.27E+03	6.10E+03	3.65E+02	0.00E+00	3.56E+03	2.21E+05	1.73E+05
W-187	8.48E+00	7.08E+00	2.48E+00	0.00E+00	0.00E+00	2.90E+04	1.55E+05
Np-239	2.30E+02	2.03E+02	1.24E+01	0.00E+00	7.00E+01	3.76E+04	1.19E+05

Notes:

1) Units are mrem/yr per μCi/m^3.

Table 11a
Teen Inhalation Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	7.25E+02	7.25E+02	7.25E+02	7.25E+02	7.25E+02	7.25E+02
Na-24	1.38E+04	1.38E+04	1.38E+04	1.38E+04	1.38E+04	1.38E+04	1.38E+04
Cr-51	0.00E+00	0.00E+00	1.35E+02	7.50E+01	3.07E+01	2.10E+04	3.00E+03
Mn-54	0.00E+00	5.11E+04	8.40E+03	0.00E+00	1.27E+04	1.98E+06	6.68E+04
Mn-56	0.00E+00	1.70E+00	2.52E-01	0.00E+00	1.79E+00	1.52E+04	5.74E+04
Fe-55	3.34E+04	2.38E+04	5.54E+03	0.00E+00	0.00E+00	1.24E+05	6.39E+03
Fe-59	1.59E+04	3.70E+04	1.43E+04	0.00E+00	0.00E+00	1.53E+06	1.78E+05
Co-58	0.00E+00	2.07E+03	2.78E+03	0.00E+00	0.00E+00	1.34E+06	9.52E+04
Co-60	0.00E+00	1.51E+04	1.98E+04	0.00E+00	0.00E+00	8.72E+06	2.59E+05
Ni-63	5.80E+05	4.34E+04	1.98E+04	0.00E+00	0.00E+00	3.07E+05	1.42E+04
Ni-65	2.18E+00	2.93E-01	1.27E-01	0.00E+00	0.00E+00	9.36E+03	3.67E+04
Cu-64	0.00E+00	2.03E+00	8.48E-01	0.00E+00	6.41E+00	1.11E+04	6.14E+04
Zn-65	3.86E+04	1.34E+05	6.24E+04	0.00E+00	8.64E+04	1.24E+06	4.66E+04
Zn-69	4.83E-02	9.20E-02	6.46E-03	0.00E+00	6.02E-02	1.58E+03	2.85E+02
Br-83	0.00E+00	0.00E+00	3.44E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	4.33E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	1.83E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	1.90E+05	8.40E+04	0.00E+00	0.00E+00	0.00E+00	1.77E+04
Rb-88	0.00E+00	5.46E+02	2.72E+02	0.00E+00	0.00E+00	0.00E+00	2.92E-05
Rb-89	0.00E+00	3.52E+02	2.33E+02	0.00E+00	0.00E+00	0.00E+00	3.38E-07
Sr-89	4.34E+05	0.00E+00	1.25E+04	0.00E+00	0.00E+00	2.42E+06	3.71E+05
Sr-90	3.31E+07	0.00E+00	6.66E+05	0.00E+00	0.00E+00	1.65E+07	7.65E+05
Sr-91	8.80E+01	0.00E+00	3.51E+00	0.00E+00	0.00E+00	6.07E+04	2.59E+05
Sr-92	9.52E+00	0.00E+00	4.06E-01	0.00E+00	0.00E+00	2.74E+04	1.19E+05
Y-90	2.98E+03	0.00E+00	8.00E+01	0.00E+00	0.00E+00	2.93E+05	5.59E+05
Y-91M	3.70E-01	0.00E+00	1.42E-02	0.00E+00	0.00E+00	3.20E+03	3.02E+01
Y-91	6.61E+05	0.00E+00	1.77E+04	0.00E+00	0.00E+00	2.94E+06	4.09E+05
Y-92	1.47E+01	0.00E+00	4.29E-01	0.00E+00	0.00E+00	2.68E+04	1.65E+05
Y-93	1.35E+02	0.00E+00	3.72E+00	0.00E+00	0.00E+00	8.32E+04	5.79E+05
Zr-95	1.46E+05	4.58E+04	3.15E+04	0.00E+00	6.74E+04	2.69E+06	1.49E+05
Zr-97	1.38E+02	2.72E+01	1.26E+01	0.00E+00	4.12E+01	1.30E+05	6.30E+05
Nb-95	1.86E+04	1.03E+04	5.66E+03	0.00E+00	1.00E+04	7.51E+05	9.68E+04
Mo-99	0.00E+00	1.69E+02	3.22E+01	0.00E+00	4.11E+02	1.54E+05	2.69E+05
Tc- 99M	1.38E-03	3.86E-03	4.99E-02	0.00E+00	5.76E-02	1.15E+03	6.13E+03
Tc-101	5.92E-05	8.40E-05	8.24E-04	0.00E+00	1.52E-03	6.67E+02	8.72E-07
Ru-103	2.10E+03	0.00E+00	8.96E+02	0.00E+00	7.43E+03	7.83E+05	1.09E+05
Ru-105	1.12E+00	0.00E+00	4.34E-01	0.00E+00	1.41E+00	1.82E+04	9.04E+04
Ru-106	9.84E+04	0.00E+00	1.24E+04	0.00E+00	1.90E+05	1.61E+07	9.60E+05
Ag-110M	1.38E+04	1.31E+04	7.99E+03	0.00E+00	2.50E+04	6.75E+06	2.73E+05

Table 11a (Continued)
Teen Inhalation Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	4.88E+03	2.24E+03	6.67E+02	1.40E+03	0.00E+00	5.36E+05	7.50E+04
Te-127M	1.80E+04	8.16E+03	2.18E+03	4.38E+03	6.54E+04	1.66E+06	1.59E+05
Te-127	2.01E+00	9.12E-01	4.42E-01	1.42E+00	7.28E+00	1.12E+04	8.08E+04
Te-129M	1.39E+04	6.58E+03	2.25E+03	4.58E+03	5.19E+04	1.98E+06	4.05E+05
Te-129	7.10E-02	3.38E-02	1.76E-02	5.18E-02	2.66E-01	3.30E+03	1.62E+03
Te-131M	9.84E+01	6.01E+01	4.02E+01	7.25E+01	4.39E+02	2.38E+05	6.21E+05
Te-131	1.58E-02	8.32E-03	5.04E-03	1.24E-02	6.18E-02	2.34E+03	1.51E+01
Te-132	3.60E+02	2.90E+02	2.19E+02	2.46E+02	1.95E+03	4.49E+05	4.63E+05
I-130	6.24E+03	1.79E+04	7.17E+03	1.49E+06	2.75E+04	0.00E+00	9.12E+03
I-131	3.54E+04	4.91E+04	2.64E+04	1.46E+07	8.40E+04	0.00E+00	6.49E+03
I-132	1.59E+03	4.38E+03	1.58E+03	1.51E+05	6.92E+03	0.00E+00	1.27E+03
I-133	1.22E+04	2.05E+04	6.22E+03	2.92E+06	3.59E+04	0.00E+00	1.03E+04
I-134	8.88E+02	2.32E+03	8.40E+02	3.95E+04	3.66E+03	0.00E+00	2.04E+01
I-135	3.70E+03	9.44E+03	3.49E+03	6.21E+05	1.49E+04	0.00E+00	6.95E+03
Cs-134	5.02E+05	1.13E+06	5.49E+05	0.00E+00	3.75E+05	1.46E+05	9.76E+03
Cs-136	5.15E+04	1.94E+05	1.37E+05	0.00E+00	1.10E+05	1.78E+04	1.09E+04
Cs-137	6.70E+05	8.48E+05	3.11E+05	0.00E+00	3.04E+05	1.21E+05	8.48E+03
Cs-138	4.66E+02	8.56E+02	4.46E+02	0.00E+00	6.62E+02	7.87E+01	2.70E-01
Ba-139	1.34E+00	9.44E-04	3.90E-02	0.00E+00	8.88E-04	6.46E+03	6.45E+03
Ba-140	5.47E+04	6.70E+01	3.52E+03	0.00E+00	2.28E+01	2.03E+06	2.29E+05
Ba-141	1.42E-01	1.06E-04	4.74E-03	0.00E+00	9.84E-05	3.29E+03	7.46E-04
Ba-142	3.70E-02	3.70E-05	2.27E-03	0.00E+00	3.14E-05	1.91E+03	4.79E-10
La-140	4.79E+02	2.36E+02	6.26E+01	0.00E+00	0.00E+00	2.14E+05	4.87E+05
La-142	9.60E-01	4.25E-01	1.06E-01	0.00E+00	0.00E+00	1.02E+04	1.20E+04
Ce-141	2.84E+04	1.90E+04	2.17E+03	0.00E+00	8.88E+03	6.14E+05	1.26E+05
Ce-143	2.66E+02	1.94E+02	2.16E+01	0.00E+00	8.64E+01	1.30E+05	2.55E+05
Ce-144	4.89E+06	2.02E+06	2.62E+05	0.00E+00	1.21E+06	1.34E+07	8.64E+05
Pr-143	1.34E+04	5.31E+03	6.62E+02	0.00E+00	3.09E+03	4.83E+05	2.14E+05
Pr-144	4.30E-02	1.76E-02	2.18E-03	0.00E+00	1.01E-02	1.75E+03	2.35E-04
Nd-147	7.86E+03	8.56E+03	5.13E+02	0.00E+00	5.02E+03	3.72E+05	1.82E+05
W-187	1.20E+01	9.76E+00	3.43E+00	0.00E+00	0.00E+00	4.74E+04	1.77E+05
Np-239	3.38E+02	2.88E+02	1.77E+01	0.00E+00	1.00E+02	6.49E+04	1.32E+05

Notes:

1) Units are mrem/yr per $\mu Ci/m^3$.

Table 11b
Child Inhalation Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	6.40E+02	6.40E+02	6.40E+02	6.40E+02	6.40E+02	6.40E+02
Na-24	1.61E+04	1.61E+04	1.61E+04	1.61E+04	1.61E+04	1.61E+04	1.61E+04
Cr-51	0.00E+00	0.00E+00	1.54E+02	8.55E+01	2.43E+01	1.70E+04	1.08E+03
Mn-54	0.00E+00	4.29E+04	9.51E+03	0.00E+00	1.00E+04	1.58E+06	2.29E+04
Mn-56	0.00E+00	1.66E+00	3.12E-01	0.00E+00	1.67E+00	1.31E+04	1.23E+05
Fe-55	4.74E+04	2.52E+04	7.77E+03	0.00E+00	0.00E+00	1.11E+05	2.87E+03
Fe-59	2.07E+04	3.34E+04	1.67E+04	0.00E+00	0.00E+00	1.27E+06	7.07E+04
Co-58	0.00E+00	1.77E+03	3.16E+03	0.00E+00	0.00E+00	1.11E+06	3.44E+04
Co-60	0.00E+00	1.31E+04	2.26E+04	0.00E+00	0.00E+00	7.07E+06	9.62E+04
Ni-63	8.21E+05	4.63E+04	2.80E+04	0.00E+00	0.00E+00	2.75E+05	6.33E+03
Ni-65	2.99E+00	2.96E-01	1.64E-01	0.00E+00	0.00E+00	8.18E+03	8.40E+04
Cu-64	0.00E+00	1.99E+00	1.07E+00	0.00E+00	6.03E+00	9.58E+03	3.67E+04
Zn-65	4.26E+04	1.13E+05	7.03E+04	0.00E+00	7.14E+04	9.95E+05	1.63E+04
Zn-69	6.70E-02	9.66E-02	8.92E-03	0.00E+00	5.85E-02	1.42E+03	1.02E+04
Br-83	0.00E+00	0.00E+00	4.74E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	5.48E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	2.53E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	1.98E+05	1.14E+05	0.00E+00	0.00E+00	0.00E+00	7.99E+03
Rb-88	0.00E+00	5.62E+02	3.66E+02	0.00E+00	0.00E+00	0.00E+00	1.72E+01
Rb-89	0.00E+00	3.45E+02	2.90E+02	0.00E+00	0.00E+00	0.00E+00	1.89E+00
Sr-89	5.99E+05	0.00E+00	1.72E+04	0.00E+00	0.00E+00	2.16E+06	1.67E+05
Sr-90	3.85E+07	0.00E+00	7.66E+05	0.00E+00	0.00E+00	1.48E+07	3.43E+05
Sr-91	1.21E+02	0.00E+00	4.59E+00	0.00E+00	0.00E+00	5.33E+04	1.74E+05
Sr-92	1.31E+01	0.00E+00	5.25E-01	0.00E+00	0.00E+00	2.40E+04	2.42E+05
Y-90	4.11E+03	0.00E+00	1.11E+02	0.00E+00	0.00E+00	2.62E+05	2.68E+05
Y-91M	5.07E-01	0.00E+00	1.84E-02	0.00E+00	0.00E+00	2.81E+03	1.72E+03
Y-91	9.14E+05	0.00E+00	2.44E+04	0.00E+00	0.00E+00	2.63E+06	1.84E+05
Y-92	2.04E+01	0.00E+00	5.81E-01	0.00E+00	0.00E+00	2.39E+04	2.39E+05
Y-93	1.86E+02	0.00E+00	5.11E+00	0.00E+00	0.00E+00	7.44E+04	3.89E+05
Zr-95	1.90E+05	4.18E+04	3.70E+04	0.00E+00	5.96E+04	2.23E+06	6.11E+04
Zr-97	1.88E+02	2.72E+01	1.60E+01	0.00E+00	3.89E+01	1.13E+05	3.51E+05
Nb-95	2.35E+04	9.18E+03	6.55E+03	0.00E+00	8.62E+03	6.14E+05	3.70E+04
Mo-99	0.00E+00	1.72E+02	4.26E+01	0.00E+00	3.92E+02	1.35E+05	1.27E+05
Tc- 99M	1.78E-03	3.48E-03	5.77E-02	0.00E+00	5.07E-02	9.51E+02	4.81E+03
Tc-101	8.10E-05	8.51E-05	1.08E-03	0.00E+00	1.45E-03	5.85E+02	1.63E+01
Ru-103	2.79E+03	0.00E+00	1.07E+03	0.00E+00	7.03E+03	6.62E+05	4.48E+04
Ru-105	1.53E+00	0.00E+00	5.55E-01	0.00E+00	1.34E+00	1.59E+04	9.95E+04
Ru-106	1.36E+05	0.00E+00	1.69E+04	0.00E+00	1.84E+05	1.43E+07	4.29E+05
Ag-110M	1.69E+04	1.14E+04	9.14E+03	0.00E+00	2.12E+04	5.48E+06	1.00E+05

Table 11b (Continued)
Child Inhalation Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	6.73E+03	2.33E+03	9.14E+02	1.92E+03	0.00E+00	4.77E+05	3.38E+04
Te-127M	2.49E+04	8.55E+03	3.02E+03	6.07E+03	6.36E+04	1.48E+06	7.14E+04
Te-127	2.77E+00	9.51E-01	6.11E-01	1.96E+00	7.07E+00	1.00E+04	5.62E+04
Te-129M	1.92E+04	6.85E+03	3.04E+03	6.33E+03	5.03E+04	1.76E+06	1.82E+05
Te-129	9.77E-02	3.50E-02	2.38E-02	7.14E-02	2.57E-01	2.93E+03	2.55E+04
Te-131M	1.34E+02	5.92E+01	5.07E+01	9.77E+01	4.00E+02	2.06E+05	3.08E+05
Te-131	2.17E-02	8.44E-03	6.59E-03	1.70E-02	5.88E-02	2.05E+03	1.33E+03
Te-132	4.81E+02	2.72E+02	2.63E+02	3.17E+02	1.77E+03	3.77E+05	1.38E+05
I-130	8.18E+03	1.64E+04	8.44E+03	1.85E+06	2.45E+04	0.00E+00	5.11E+03
I-131	4.81E+04	4.81E+04	2.73E+04	1.62E+07	7.88E+04	0.00E+00	2.84E+03
I-132	2.12E+03	4.07E+03	1.88E+03	1.94E+05	6.25E+03	0.00E+00	3.20E+03
I-133	1.66E+04	2.03E+04	7.70E+03	3.85E+06	3.38E+04	0.00E+00	5.48E+03
I-134	1.17E+03	2.16E+03	9.95E+02	5.07E+04	3.30E+03	0.00E+00	9.55E+02
I-135	4.92E+03	8.73E+03	4.14E+03	7.92E+05	1.34E+04	0.00E+00	4.44E+03
Cs-134	6.51E+05	1.01E+06	2.25E+05	0.00E+00	3.30E+05	1.21E+05	3.85E+03
Cs-136	6.51E+04	1.71E+05	1.16E+05	0.00E+00	9.55E+04	1.45E+04	4.18E+03
Cs-137	9.07E+05	8.25E+05	1.28E+05	0.00E+00	2.82E+05	1.04E+05	3.62E+03
Cs-138	6.33E+02	8.40E+02	5.55E+02	0.00E+00	6.22E+02	6.81E+01	2.70E+02
Ba-139	1.84E+00	9.84E-04	5.37E-02	0.00E+00	8.62E-04	5.77E+03	5.77E+04
Ba-140	7.40E+04	6.48E+01	4.33E+03	0.00E+00	2.11E+01	1.74E+06	1.02E+05
Ba-141	1.96E-01	1.09E-04	6.36E-03	0.00E+00	9.47E-05	2.92E+03	2.75E+02
Ba-142	5.00E-02	3.60E-05	2.79E-03	0.00E+00	2.91E-05	1.64E+03	2.74E+00
La-140	6.44E+02	2.25E+02	7.55E+01	0.00E+00	0.00E+00	1.83E+05	2.26E+05
La-142	1.30E+00	4.11E-01	1.29E-01	0.00E+00	0.00E+00	8.70E+03	7.59E+04
Ce-141	3.92E+04	1.95E+04	2.90E+03	0.00E+00	8.55E+03	5.44E+05	5.66E+04
Ce-143	3.66E+02	1.99E+02	2.87E+01	0.00E+00	8.36E+01	1.15E+05	1.27E+05
Ce-144	6.77E+06	2.12E+06	3.61E+05	0.00E+00	1.17E+06	1.20E+07	3.89E+05
Pr-143	1.85E+04	5.55E+03	9.14E+02	0.00E+00	3.00E+03	4.33E+05	9.73E+04
Pr-144	5.96E-02	1.85E-02	3.00E-03	0.00E+00	9.77E-03	1.57E+03	1.97E+02
Nd-147	1.08E+04	8.73E+03	6.81E+02	0.00E+00	4.81E+03	3.28E+05	8.21E+04
W-187	1.63E+01	9.66E+00	4.33E+00	0.00E+00	0.00E+00	4.11E+04	9.10E+04
Np-239	4.66E+02	3.01E+02	2.35E+01	0.00E+00	9.73E+01	5.81E+04	6.40E+04

Notes:

1) Units are mrem/yr per μCi/m^3.

Table 11c
Infant Inhalation Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	3.68E+02	3.68E+02	3.68E+02	3.68E+02	3.68E+02	3.68E+02
Na-24	1.06E+04	1.06E+04	1.06E+04	1.06E+04	1.06E+04	1.06E+04	1.06E+04
Cr-51	0.00E+00	0.00E+00	8.95E+01	5.75E+01	1.32E+01	1.28E+04	3.57E+02
Mn-54	0.00E+00	2.53E+04	4.98E+03	0.00E+00	4.98E+03	1.00E+06	7.06E+03
Mn-56	0.00E+00	1.54E+00	2.21E-01	0.00E+00	1.10E+00	1.25E+04	7.17E+04
Fe-55	1.97E+04	1.17E+04	3.33E+03	0.00E+00	0.00E+00	8.69E+04	1.09E+03
Fe-59	1.36E+04	2.35E+04	9.48E+03	0.00E+00	0.00E+00	1.02E+06	2.48E+04
Co-58	0.00E+00	1.22E+03	1.82E+03	0.00E+00	0.00E+00	7.77E+05	1.11E+04
Co-60	0.00E+00	8.02E+03	1.18E+04	0.00E+00	0.00E+00	4.51E+06	3.19E+04
Ni-63	3.39E+05	2.04E+04	1.16E+04	0.00E+00	0.00E+00	2.09E+05	2.42E+03
Ni-65	2.39E+00	2.84E-01	1.23E-01	0.00E+00	0.00E+00	8.12E+03	5.01E+04
Cu-64	0.00E+00	1.88E+00	7.74E-01	0.00E+00	3.98E+00	9.30E+03	1.50E+04
Zn-65	1.93E+04	6.26E+04	3.11E+04	0.00E+00	3.25E+04	6.47E+05	5.14E+04
Zn-69	5.39E-02	9.67E-02	7.18E-03	0.00E+00	4.02E-02	1.47E+03	1.32E+04
Br-83	0.00E+00	0.00E+00	3.81E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	4.00E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	2.04E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	1.90E+05	8.82E+04	0.00E+00	0.00E+00	0.00E+00	3.04E+03
Rb-88	0.00E+00	5.57E+02	2.87E+02	0.00E+00	0.00E+00	0.00E+00	3.39E+02
Rb-89	0.00E+00	3.21E+02	2.06E+02	0.00E+00	0.00E+00	0.00E+00	6.82E+01
Sr-89	3.98E+05	0.00E+00	1.14E+04	0.00E+00	0.00E+00	2.03E+06	6.40E+04
Sr-90	1.55E+07	0.00E+00	3.12E+05	0.00E+00	0.00E+00	1.12E+07	1.31E+05
Sr-91	9.56E+01	0.00E+00	3.46E+00	0.00E+00	0.00E+00	5.26E+04	7.34E+04
Sr-92	1.05E+01	0.00E+00	3.91E-01	0.00E+00	0.00E+00	2.38E+04	1.40E+05
Y-90	3.29E+03	0.00E+00	8.82E+01	0.00E+00	0.00E+00	2.69E+05	1.04E+05
Y-91M	4.07E-01	0.00E+00	1.39E-02	0.00E+00	0.00E+00	2.79E+03	2.35E+03
Y-91	5.88E+05	0.00E+00	1.57E+04	0.00E+00	0.00E+00	2.45E+06	7.03E+04
Y-92	1.64E+01	0.00E+00	4.61E-01	0.00E+00	0.00E+00	2.45E+04	1.27E+05
Y-93	1.50E+02	0.00E+00	4.07E+00	0.00E+00	0.00E+00	7.64E+04	1.67E+05
Zr-95	1.15E+05	2.79E+04	2.03E+04	0.00E+00	3.11E+04	1.75E+06	2.17E+04
Zr-97	1.50E+02	2.56E+01	1.17E+01	0.00E+00	2.59E+01	1.10E+05	1.40E+05
Nb-95	1.57E+04	6.43E+03	3.78E+03	0.00E+00	4.72E+03	4.79E+05	1.27E+04
Mo-99	0.00E+00	1.65E+02	3.23E+01	0.00E+00	2.65E+02	1.35E+05	4.87E+04
Tc- 99M	1.40E-03	2.88E-03	3.72E-02	0.00E+00	3.11E-02	8.11E+02	2.03E+03
Tc-101	6.51E-05	8.23E-05	8.12E-04	0.00E+00	9.79E-04	5.84E+02	8.44E+02
Ru-103	2.02E+03	0.00E+00	6.79E+02	0.00E+00	4.24E+03	5.52E+05	1.61E+04
Ru-105	1.22E+00	0.00E+00	4.10E-01	0.00E+00	8.99E-01	1.57E+04	4.84E+04
Ru-106	8.68E+04	0.00E+00	1.09E+04	0.00E+00	1.07E+05	1.16E+07	1.64E+05
Ag-110M	9.98E+03	7.22E+03	5.00E+03	0.00E+00	1.09E+04	3.67E+06	3.30E+04

Table 11c (Continued)
Infant Inhalation Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	4.76E+03	1.99E+03	6.58E+02	1.62E+03	0.00E+00	4.47E+05	1.29E+04
Te-127M	1.67E+04	6.90E+03	2.07E+03	4.87E+03	3.75E+04	1.31E+06	2.73E+04
Te-127	2.23E+00	9.53E-01	4.89E-01	1.85E+00	4.86E+00	1.03E+04	2.44E+04
Te-129M	1.41E+04	6.09E+03	2.23E+03	5.47E+03	3.18E+04	1.68E+06	6.90E+04
Te-129	7.88E-02	3.47E-02	1.88E-02	6.75E-02	1.75E-01	3.00E+03	2.63E+04
Te-131M	1.07E+02	5.50E+01	3.63E+01	8.93E+01	2.65E+02	1.99E+05	1.19E+05
Te-131	1.74E-02	8.22E-03	5.00E-03	1.58E-02	3.99E-02	2.06E+03	8.22E+03
Te-132	3.72E+02	2.37E+02	1.76E+02	2.79E+02	1.03E+03	3.40E+05	4.41E+04
I-130	6.36E+03	1.39E+04	5.57E+03	1.60E+06	1.53E+04	0.00E+00	1.99E+03
I-131	3.79E+04	4.44E+04	1.96E+04	1.48E+07	5.18E+04	0.00E+00	1.06E+03
I-132	1.69E+03	3.54E+03	1.26E+03	1.69E+05	3.95E+03	0.00E+00	1.90E+03
I-133	1.32E+04	1.92E+04	5.60E+03	3.56E+06	2.24E+04	0.00E+00	2.16E+03
I-134	9.21E+02	1.88E+03	6.65E+02	4.45E+04	2.09E+03	0.00E+00	1.29E+03
I-135	3.86E+03	7.60E+03	2.77E+03	6.96E+05	8.47E+03	0.00E+00	1.83E+03
Cs-134	3.96E+05	7.03E+05	7.45E+04	0.00E+00	1.90E+05	7.97E+04	1.33E+03
Cs-136	4.83E+04	1.35E+05	5.29E+04	0.00E+00	5.64E+04	1.18E+04	1.43E+03
Cs-137	5.49E+05	6.12E+05	4.55E+04	0.00E+00	1.72E+05	7.13E+04	1.33E+03
Cs-138	5.05E+02	7.81E+02	3.98E+02	0.00E+00	4.10E+02	6.54E+01	8.76E+02
Ba-139	1.48E+00	9.84E-04	4.30E-02	0.00E+00	5.92E-04	5.95E+03	5.10E+04
Ba-140	5.60E+04	5.60E+01	2.90E+03	0.00E+00	1.34E+01	1.60E+06	3.84E+04
Ba-141	1.57E-01	1.08E-04	4.97E-03	0.00E+00	6.50E-05	2.97E+03	4.75E+03
Ba-142	3.98E-02	3.30E-05	1.96E-03	0.00E+00	1.90E-05	1.55E+03	6.93E+02
La-140	5.05E+02	2.00E+02	5.15E+01	0.00E+00	0.00E+00	1.68E+05	8.48E+04
La-142	1.03E+00	3.77E-01	9.04E-02	0.00E+00	0.00E+00	8.22E+03	5.95E+04
Ce-141	2.77E+04	1.67E+04	1.99E+03	0.00E+00	5.25E+03	5.17E+05	2.16E+04
Ce-143	2.93E+02	1.93E+02	2.21E+01	0.00E+00	5.64E+01	1.16E+05	4.97E+04
Ce-144	3.19E+06	1.21E+06	1.76E+05	0.00E+00	5.38E+05	9.84E+06	1.48E+05
Pr-143	1.40E+04	5.24E+03	6.99E+02	0.00E+00	1.97E+03	4.33E+05	3.72E+04
Pr-144	4.79E-02	1.85E-02	2.41E-03	0.00E+00	6.72E-03	1.61E+03	4.28E+03
Nd-147	7.94E+03	8.13E+03	5.00E+02	0.00E+00	3.15E+03	3.22E+05	3.12E+04
W-187	1.30E+01	9.02E+00	3.12E+00	0.00E+00	0.00E+00	3.96E+04	3.56E+04
Np-239	3.71E+02	2.98E+02	1.88E+01	0.00E+00	6.62E+01	5.95E+04	2.49E+04

Notes:

1) Units are mrem/yr per $\mu Ci/m^3$.

Table 12
Adult Vegetation Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	1.29E+03	1.29E+03	1.29E+03	1.29E+03	1.29E+03	1.29E+03
Na-24	2.69E+05	2.69E+05	2.69E+05	2.69E+05	2.69E+05	2.69E+05	2.69E+05
Cr-51	0.00E+00	0.00E+00	4.64E+04	2.77E+04	1.02E+04	6.15E+04	1.17E+07
Mn-54	0.00E+00	3.13E+08	5.97E+07	0.00E+00	9.31E+07	0.00E+00	9.58E+08
Mn-56	0.00E+00	1.54E+01	2.73E+00	0.00E+00	1.95E+01	0.00E+00	4.91E+02
Fe-55	2.10E+08	1.45E+08	3.38E+07	0.00E+00	0.00E+00	8.08E+07	8.31E+07
Fe-59	1.26E+08	2.96E+08	1.13E+08	0.00E+00	0.00E+00	8.27E+07	9.87E+08
Co-58	0.00E+00	3.08E+07	6.90E+07	0.00E+00	0.00E+00	0.00E+00	6.24E+08
Co-60	0.00E+00	1.67E+08	3.69E+08	0.00E+00	0.00E+00	0.00E+00	3.14E+09
Ni-63	1.04E+10	7.21E+08	3.49E+08	0.00E+00	0.00E+00	0.00E+00	1.50E+08
Ni-65	5.97E+01	7.75E+00	3.54E+00	0.00E+00	0.00E+00	0.00E+00	1.97E+02
Cu-64	0.00E+00	9.09E+03	4.27E+03	0.00E+00	2.29E+04	0.00E+00	7.75E+05
Zn-65	3.17E+08	1.01E+09	4.56E+08	0.00E+00	6.75E+08	0.00E+00	6.36E+08
Zn-69	4.95E-06	9.48E-06	6.59E-07	0.00E+00	6.16E-06	0.00E+00	1.42E-06
Br-83	0.00E+00	0.00E+00	3.00E+00	0.00E+00	0.00E+00	0.00E+00	4.32E+00
Br-84	0.00E+00	0.00E+00	2.20E-11	0.00E+00	0.00E+00	0.00E+00	1.72E-16
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	2.20E+08	1.03E+08	0.00E+00	0.00E+00	0.00E+00	4.34E+07
Rb-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-89	9.95E+09	0.00E+00	2.86E+08	0.00E+00	0.00E+00	0.00E+00	1.60E+09
Sr-90	6.95E+11	0.00E+00	1.40E+10	0.00E+00	0.00E+00	0.00E+00	1.75E+10
Sr-91	3.01E+05	0.00E+00	1.22E+04	0.00E+00	0.00E+00	0.00E+00	1.43E+06
Sr-92	4.12E+02	0.00E+00	1.78E+01	0.00E+00	0.00E+00	0.00E+00	8.17E+03
Y-90	1.33E+04	0.00E+00	3.57E+02	0.00E+00	0.00E+00	0.00E+00	1.41E+08
Y-91M	4.93E-09	0.00E+00	1.91E-10	0.00E+00	0.00E+00	0.00E+00	1.45E-08
Y-91	5.12E+06	0.00E+00	1.37E+05	0.00E+00	0.00E+00	0.00E+00	2.82E+09
Y-92	8.95E-01	0.00E+00	2.62E-02	0.00E+00	0.00E+00	0.00E+00	1.57E+04
Y-93	1.67E+02	0.00E+00	4.62E+00	0.00E+00	0.00E+00	0.00E+00	5.31E+06
Zr-95	1.18E+06	3.77E+05	2.55E+05	0.00E+00	5.92E+05	0.00E+00	1.20E+09
Zr-97	3.35E+02	6.77E+01	3.09E+01	0.00E+00	1.02E+02	0.00E+00	2.10E+07
Nb-95	1.43E+05	7.95E+04	4.27E+04	0.00E+00	7.86E+04	0.00E+00	4.83E+08
Mo-99	0.00E+00	6.14E+06	1.17E+06	0.00E+00	1.39E+07	0.00E+00	1.42E+07
Tc- 99M	3.06E+00	8.64E+00	1.10E+02	0.00E+00	1.31E+02	4.23E+00	5.11E+03
Tc-101	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	4.77E+06	0.00E+00	2.05E+06	0.00E+00	1.82E+07	0.00E+00	5.57E+08
Ru-105	5.27E+01	0.00E+00	2.08E+01	0.00E+00	6.81E+02	0.00E+00	3.23E+04
Ru-106	1.93E+08	0.00E+00	2.44E+07	0.00E+00	3.72E+08	0.00E+00	1.25E+10
Ag-110M	1.05E+07	9.75E+06	5.79E+06	0.00E+00	1.92E+07	0.00E+00	3.98E+09

Table 12 (Continued)
Adult Vegetation Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	9.67E+07	3.50E+07	1.30E+07	2.91E+07	3.93E+08	0.00E+00	3.86E+08
Te-127M	3.49E+08	1.25E+08	4.26E+07	8.92E+07	1.42E+09	0.00E+00	1.17E+09
Te-127	5.68E+03	2.04E+03	1.23E+03	4.21E+03	2.31E+04	0.00E+00	4.48E+05
Te-129M	2.51E+08	9.37E+07	3.97E+07	8.62E+07	1.05E+09	0.00E+00	1.26E+09
Te-129	7.14E-04	2.68E-04	1.74E-04	5.48E-04	3.00E-03	0.00E+00	5.39E-04
Te-131M	9.09E+05	4.45E+05	3.71E+05	7.04E+05	4.50E+06	0.00E+00	4.41E+07
Te-131	1.26E-15	5.26E-16	3.97E-16	1.03E-15	5.51E-15	0.00E+00	1.78E-16
Te-132	4.28E+06	2.77E+06	2.60E+06	3.06E+06	2.67E+07	0.00E+00	1.31E+08
I-130	3.89E+05	1.15E+06	4.52E+05	9.72E+07	1.79E+06	0.00E+00	9.87E+05
I-131	8.07E+07	1.15E+08	6.62E+07	3.78E+10	1.98E+08	0.00E+00	3.05E+07
I-132	5.58E+01	1.49E+02	5.22E+01	5.22E+03	2.38E+02	0.00E+00	2.80E+01
I-133	2.08E+06	3.62E+06	1.10E+06	5.32E+08	6.31E+06	0.00E+00	3.25E+06
I-134	8.55E-05	2.32E-04	8.31E-05	4.02E-03	3.69E-04	0.00E+00	2.02E-07
I-135	3.87E+04	1.01E+05	3.74E+04	6.68E+06	1.62E+05	0.00E+00	1.14E+05
Cs-134	4.67E+09	1.11E+10	9.08E+09	0.00E+00	3.59E+09	1.19E+09	1.94E+08
Cs-136	4.25E+07	1.68E+08	1.21E+08	0.00E+00	9.33E+07	1.28E+07	1.90E+07
Cs-137	6.36E+09	8.70E+09	5.70E+09	0.00E+00	2.95E+09	9.81E+08	1.68E+08
Cs-138	3.32E-11	6.56E-11	3.25E-11	0.00E+00	4.82E-11	4.76E-12	2.80E-16
Ba-139	2.71E-02	1.93E-05	7.92E-04	0.00E+00	1.80E-05	1.09E-05	4.80E-02
Ba-140	1.29E+08	1.61E+05	8.42E+06	0.00E+00	5.49E+04	9.24E+04	2.65E+08
Ba-141	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La-140	1.98E+03	9.97E+02	2.63E+02	0.00E+00	0.00E+00	0.00E+00	7.32E+07
La-142	1.94E-04	8.83E-05	2.20E-05	0.00E+00	0.00E+00	0.00E+00	6.45E-01
Ce-141	1.97E+05	1.33E+05	1.51E+04	0.00E+00	6.19E+04	0.00E+00	5.09E+08
Ce-143	9.94E+02	7.35E+05	8.13E+01	0.00E+00	3.24E+02	0.00E+00	2.75E+07
Ce-144	3.29E+07	1.38E+07	1.77E+06	0.00E+00	8.16E+06	0.00E+00	1.11E+10
Pr-143	6.27E+04	2.51E+04	3.11E+03	0.00E+00	1.45E+04	0.00E+00	2.75E+08
Pr-144	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd-147	3.37E+04	3.90E+04	2.33E+03	0.00E+00	2.28E+04	0.00E+00	1.87E+08
W-187	3.79E+04	3.17E+04	1.11E+04	0.00E+00	0.00E+00	0.00E+00	1.04E+07
Np-239	1.42E+03	1.40E+02	7.72E+01	0.00E+00	4.37E+02	0.00E+00	2.87E+07

Notes:

1) Units are m^2 mrem/yr per μCi/sec with the exception of H-3.

2) For H-3, the units are mrem/yr per $\mu Ci/m^3$.

Table 12a
Teen Vegetation Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	1.47E+03	1.47E+03	1.47E+03	1.47E+03	1.47E+03	1.47E+03
Na-24	2.39E+05	2.39E+05	2.39E+05	2.39E+05	2.39E+05	2.39E+05	2.39E+05
Cr-51	0.00E+00	0.00E+00	6.16E+04	3.42E+04	1.35E+04	8.79E+04	1.03E+07
Mn-54	0.00E+00	4.54E+08	9.01E+07	0.00E+00	1.36E+08	0.00E+00	9.32E+08
Mn-56	0.00E+00	1.39E+01	2.47E+00	0.00E+00	1.76E+01	0.00E+00	9.13E+02
Fe-55	3.26E+08	2.31E+08	5.39E+07	0.00E+00	0.00E+00	1.47E+08	1.00E+08
Fe-59	1.79E+08	4.18E+08	1.61E+08	0.00E+00	0.00E+00	1.32E+08	9.89E+08
Co-58	0.00E+00	4.37E+07	1.01E+08	0.00E+00	0.00E+00	0.00E+00	6.02E+08
Co-60	0.00E+00	2.49E+08	5.60E+08	0.00E+00	0.00E+00	0.00E+00	3.24E+09
Ni-63	1.61E+10	1.13E+09	5.45E+08	0.00E+00	0.00E+00	0.00E+00	1.81E+08
Ni-65	5.55E+01	7.10E+00	3.23E+00	0.00E+00	0.00E+00	0.00E+00	3.85E+02
Cu-64	0.00E+00	8.24E+03	3.87E+03	0.00E+00	2.08E+04	0.00E+00	6.39E+05
Zn-65	4.24E+08	1.47E+09	6.86E+08	0.00E+00	9.41E+08	0.00E+00	6.23E+08
Zn-69	4.64E-06	8.84E-06	6.19E-07	0.00E+00	5.78E-06	0.00E+00	1.63E-05
Br-83	0.00E+00	0.00E+00	2.81E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	2.00E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	2.75E+08	1.29E+08	0.00E+00	0.00E+00	0.00E+00	4.06E+07
Rb-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-89	1.51E+10	0.00E+00	4.33E+08	0.00E+00	0.00E+00	0.00E+00	1.80E+09
Sr-90	9.22E+11	0.00E+00	1.84E+10	0.00E+00	0.00E+00	0.00E+00	2.11E+10
Sr-91	2.81E+05	0.00E+00	1.12E+04	0.00E+00	0.00E+00	0.00E+00	1.27E+06
Sr-92	3.84E+02	0.00E+00	1.64E+01	0.00E+00	0.00E+00	0.00E+00	9.78E+03
Y-90	1.24E+04	0.00E+00	3.35E+02	0.00E+00	0.00E+00	0.00E+00	1.02E+08
Y-91M	4.59E-09	0.00E+00	1.75E-10	0.00E+00	0.00E+00	0.00E+00	2.17E-07
Y-91	7.84E+06	0.00E+00	2.10E+05	0.00E+00	0.00E+00	0.00E+00	3.21E+09
Y-92	8.41E-01	0.00E+00	2.43E-02	0.00E+00	0.00E+00	0.00E+00	2.31E+04
Y-93	1.57E+02	0.00E+00	4.30E+00	0.00E+00	0.00E+00	0.00E+00	4.80E+06
Zr-95	1.72E+06	5.44E+05	3.74E+05	0.00E+00	7.99E+05	0.00E+00	1.26E+09
Zr-97	3.10E+02	6.14E+01	2.83E+01	0.00E+00	9.31E+01	0.00E+00	1.66E+07
Nb-95	1.93E+05	1.07E+05	5.90E+04	0.00E+00	1.04E+05	0.00E+00	4.58E+08
Mo-99	0.00E+00	5.63E+06	1.07E+06	0.00E+00	1.29E+07	0.00E+00	1.01E+07
Tc- 99M	2.70E+00	7.52E+00	9.75E+01	0.00E+00	1.12E+02	4.17E+00	4.94E+03
Tc-101	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	6.82E+06	0.00E+00	2.91E+06	0.00E+00	2.40E+07	0.00E+00	5.69E+08
Ru-105	4.90E+01	0.00E+00	1.90E+01	0.00E+00	6.18E+02	0.00E+00	3.95E+04
Ru-106	3.09E+08	0.00E+00	3.90E+07	0.00E+00	5.97E+08	0.00E+00	1.48E+10
Ag-110M	1.52E+07	1.44E+07	8.73E+06	0.00E+00	2.74E+07	0.00E+00	4.03E+09

Table 12a (Continued)
Teen Vegetation Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	1.49E+08	5.35E+07	1.99E+07	4.15E+07	0.00E+00	0.00E+00	4.38E+08
Te-127M	5.51E+08	1.96E+08	6.56E+07	1.31E+08	2.24E+09	0.00E+00	1.37E+09
Te-127	5.36E+03	1.90E+03	1.15E+03	3.70E+03	2.17E+04	0.00E+00	4.14E+05
Te-129M	3.61E+08	1.34E+08	5.72E+07	1.17E+08	1.51E+09	0.00E+00	1.36E+09
Te-129	6.68E-04	2.49E-04	1.63E-04	4.77E-04	2.80E-03	0.00E+00	3.65E-03
Te-131M	8.42E+05	4.04E+05	3.37E+05	6.07E+05	4.21E+06	0.00E+00	3.24E+07
Te-131	1.17E-15	4.82E-16	3.66E-16	9.01E-16	5.11E-15	0.00E+00	9.60E-17
Te-132	3.89E+06	2.46E+06	2.32E+06	2.60E+06	2.36E+07	0.00E+00	7.81E+07
I-130	3.47E+05	1.01E+06	4.01E+05	8.20E+07	1.55E+06	0.00E+00	7.73E+05
I-131	7.68E+07	1.08E+08	5.78E+07	3.14E+10	1.85E+08	0.00E+00	2.13E+07
I-132	5.03E+01	1.32E+02	4.72E+01	4.43E+03	2.07E+02	0.00E+00	5.73E+01
I-133	1.93E+06	3.28E+06	1.00E+06	4.58E+08	5.75E+06	0.00E+00	2.48E+06
I-134	7.73E-05	2.05E-04	7.36E-05	3.41E-03	3.23E-04	0.00E+00	2.70E-06
I-135	3.49E+04	8.99E+04	3.33E+04	5.78E+06	1.42E+05	0.00E+00	9.97E+04
Cs-134	7.10E+09	1.67E+10	7.75E+09	0.00E+00	5.31E+09	2.03E+09	2.08E+08
Cs-136	4.35E+07	1.71E+08	1.15E+08	0.00E+00	9.31E+07	1.47E+07	1.38E+07
Cs-137	1.01E+10	1.35E+10	4.69E+09	0.00E+00	4.59E+09	1.78E+09	1.92E+08
Cs-138	3.07E-11	5.89E-11	2.94E-11	0.00E+00	4.35E-11	5.06E-12	2.67E-14
Ba-139	2.55E-02	1.79E-05	7.42E-04	0.00E+00	1.69E-05	1.23E-05	2.27E-01
Ba-140	1.38E+08	1.69E+05	8.90E+06	0.00E+00	5.74E+04	1.14E+05	2.13E+08
Ba-141	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La-140	1.81E+03	8.88E+02	2.36E+02	0.00E+00	0.00E+00	0.00E+00	5.10E+07
La-142	1.78E-04	7.92E-05	1.97E-05	0.00E+00	0.00E+00	0.00E+00	2.41E+00
Ce-141	2.83E+05	1.89E+05	2.17E+04	0.00E+00	8.89E+04	0.00E+00	5.40E+08
Ce-143	9.29E+02	6.76E+05	7.55E+01	0.00E+00	3.03E+02	0.00E+00	2.03E+07
Ce-144	5.27E+07	2.18E+07	2.83E+06	0.00E+00	1.30E+07	0.00E+00	1.33E+10
Pr-143	7.01E+04	2.80E+04	3.49E+03	0.00E+00	1.63E+04	0.00E+00	2.31E+08
Pr-144	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd-147	3.67E+04	4.00E+04	2.39E+03	0.00E+00	2.35E+04	0.00E+00	1.44E+08
W-187	3.53E+04	2.87E+04	1.01E+04	0.00E+00	0.00E+00	0.00E+00	7.78E+06
Np-239	1.38E+03	1.30E+02	7.24E+01	0.00E+00	4.09E+02	0.00E+00	2.10E+07

Notes:

1) Units are m^2 mrem/yr per μCi/sec with the exception of H-3.

2) For H-3, the units are mrem/yr per $\mu Ci/m^3$.

Table 12b
Child Vegetation Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	2.29E+03	2.29E+03	2.29E+03	2.29E+03	2.29E+03	2.29E+03
Na-24	3.73E+05	3.73E+05	3.73E+05	3.73E+05	3.73E+05	3.73E+05	3.73E+05
Cr-51	0.00E+00	0.00E+00	1.17E+05	6.49E+04	1.77E+04	1.18E+05	6.20E+06
Mn-54	0.00E+00	6.65E+08	1.77E+08	0.00E+00	1.86E+08	0.00E+00	5.58E+08
Mn-56	0.00E+00	1.82E+01	4.10E+00	0.00E+00	2.20E+01	0.00E+00	2.63E+03
Fe-55	8.01E+08	4.25E+08	1.32E+08	0.00E+00	0.00E+00	2.40E+08	7.87E+07
Fe-59	3.97E+08	6.42E+08	3.20E+08	0.00E+00	0.00E+00	1.86E+08	6.69E+08
Co-58	0.00E+00	6.45E+07	1.97E+08	0.00E+00	0.00E+00	0.00E+00	3.76E+08
Co-60	0.00E+00	3.78E+08	1.12E+09	0.00E+00	0.00E+00	0.00E+00	2.10E+09
Ni-63	3.95E+10	2.11E+09	1.34E+09	0.00E+00	0.00E+00	0.00E+00	1.42E+08
Ni-65	1.02E+02	9.59E+00	5.60E+00	0.00E+00	0.00E+00	0.00E+00	1.18E+03
Cu-64	0.00E+00	1.09E+04	6.56E+03	0.00E+00	2.62E+04	0.00E+00	5.10E+05
Zn-65	8.12E+08	2.16E+09	1.35E+09	0.00E+00	1.36E+09	0.00E+00	3.80E+08
Zn-69	8.56E-06	1.24E-05	1.14E-06	0.00E+00	7.50E-06	0.00E+00	7.80E-04
Br-83	0.00E+00	0.00E+00	5.18E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	3.39E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	4.54E+08	2.79E+08	0.00E+00	0.00E+00	0.00E+00	2.92E+07
Rb-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-89	3.59E+10	0.00E+00	1.03E+09	0.00E+00	0.00E+00	0.00E+00	1.39E+09
Sr-90	1.87E+12	0.00E+00	3.77E+10	0.00E+00	0.00E+00	0.00E+00	1.67E+10
Sr-91	5.17E+05	0.00E+00	1.95E+04	0.00E+00	0.00E+00	0.00E+00	1.14E+06
Sr-92	7.04E+02	0.00E+00	2.82E+01	0.00E+00	0.00E+00	0.00E+00	1.33E+04
Y-90	2.31E+04	0.00E+00	6.18E+02	0.00E+00	0.00E+00	0.00E+00	6.57E+07
Y-91M	8.42E-09	0.00E+00	3.06E-10	0.00E+00	0.00E+00	0.00E+00	1.65E-05
Y-91	1.87E+07	0.00E+00	4.99E+05	0.00E+00	0.00E+00	0.00E+00	2.49E+09
Y-92	1.55E+00	0.00E+00	4.43E-02	0.00E+00	0.00E+00	0.00E+00	4.47E+04
Y-93	2.89E+02	0.00E+00	7.94E+00	0.00E+00	0.00E+00	0.00E+00	4.31E+06
Zr-95	3.86E+06	8.50E+05	7.56E+05	0.00E+00	1.22E+06	0.00E+00	8.86E+08
Zr-97	5.67E+02	8.19E+01	4.83E+01	0.00E+00	1.18E+02	0.00E+00	1.24E+07
Nb-95	4.12E+05	1.61E+05	1.15E+05	0.00E+00	1.51E+05	0.00E+00	2.97E+08
Mo-99	0.00E+00	7.69E+06	1.90E+06	0.00E+00	1.64E+07	0.00E+00	6.36E+06
Tc- 99M	4.64E+00	9.10E+00	1.51E+02	0.00E+00	1.32E+02	4.62E+00	5.18E+03
Tc-101	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	1.53E+07	0.00E+00	5.89E+06	0.00E+00	3.86E+07	0.00E+00	3.96E+08
Ru-105	8.97E+01	0.00E+00	3.25E+01	0.00E+00	7.89E+02	0.00E+00	5.86E+04
Ru-106	7.45E+08	0.00E+00	9.30E+07	0.00E+00	1.01E+09	0.00E+00	1.16E+10
Ag-110M	3.21E+07	2.17E+07	1.74E+07	0.00E+00	4.04E+07	0.00E+00	2.58E+09

Table 12b (Continued)
Child Vegetation Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	3.51E+08	9.52E+07	4.68E+07	9.86E+07	0.00E+00	0.00E+00	3.39E+08
Te-127M	1.32E+09	3.56E+08	1.57E+08	3.16E+08	3.77E+09	0.00E+00	1.07E+09
Te-127	9.89E+03	2.67E+03	2.12E+03	6.84E+03	2.81E+04	0.00E+00	3.86E+05
Te-129M	8.40E+08	2.35E+08	1.30E+08	2.71E+08	2.47E+09	0.00E+00	1.02E+09
Te-129	1.24E-03	3.45E-04	2.94E-04	8.83E-04	3.62E-03	0.00E+00	7.70E-02
Te-131M	1.54E+06	5.32E+05	5.66E+05	1.09E+06	5.15E+06	0.00E+00	2.16E+07
Te-131	2.15E-15	6.57E-16	6.41E-16	1.65E-15	6.51E-15	0.00E+00	1.13E-14
Te-132	6.97E+06	3.09E+06	3.73E+06	4.49E+06	2.86E+07	0.00E+00	3.11E+07
I-130	6.10E+05	1.23E+06	6.35E+05	1.36E+08	1.84E+06	0.00E+00	5.76E+05
I-131	1.43E+08	1.44E+08	8.17E+07	4.75E+10	2.36E+08	0.00E+00	1.28E+07
I-132	8.93E+01	1.64E+02	7.54E+01	7.61E+03	2.51E+02	0.00E+00	1.93E+02
I-133	3.52E+06	4.36E+06	1.65E+06	8.09E+08	7.26E+06	0.00E+00	1.76E+06
I-134	1.37E-04	2.55E-04	1.17E-04	5.86E-03	3.90E-04	0.00E+00	1.69E-04
I-135	6.20E+04	1.12E+05	5.28E+04	9.89E+06	1.71E+05	0.00E+00	8.51E+04
Cs-134	1.60E+10	2.63E+10	5.55E+09	0.00E+00	8.16E+09	2.93E+09	1.42E+08
Cs-136	8.18E+07	2.25E+08	1.46E+08	0.00E+00	1.20E+08	1.79E+07	7.90E+06
Cs-137	2.39E+10	2.29E+10	3.38E+09	0.00E+00	7.46E+09	2.68E+09	1.43E+08
Cs-138	5.58E-11	7.75E-11	4.92E-11	0.00E+00	5.45E-11	5.87E-12	3.57E-11
Ba-139	4.69E-02	2.51E-05	1.36E-03	0.00E+00	2.19E-05	1.47E-05	2.71E+00
Ba-140	2.77E+08	2.43E+05	1.62E+07	0.00E+00	7.90E+04	1.45E+05	1.40E+08
Ba-141	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La-140	3.25E+03	1.13E+03	3.82E+02	0.00E+00	0.00E+00	0.00E+00	3.16E+07
La-142	3.23E-04	1.03E-04	3.22E-05	0.00E+00	0.00E+00	0.00E+00	2.04E+01
Ce-141	6.55E+05	3.27E+05	4.85E+04	0.00E+00	1.43E+05	0.00E+00	4.08E+08
Ce-143	1.71E+03	9.28E+05	1.34E+02	0.00E+00	3.89E+02	0.00E+00	1.36E+07
Ce-144	1.27E+08	3.98E+07	6.78E+06	0.00E+00	2.21E+07	0.00E+00	1.04E+10
Pr-143	1.46E+05	4.38E+04	7.24E+03	0.00E+00	2.37E+04	0.00E+00	1.57E+08
Pr-144	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd-147	7.27E+04	5.89E+04	4.56E+03	0.00E+00	3.23E+04	0.00E+00	9.33E+07
W-187	6.41E+04	3.80E+04	1.70E+04	0.00E+00	0.00E+00	0.00E+00	5.34E+06
Np-239	2.55E+03	1.83E+02	1.29E+02	0.00E+00	5.30E+02	0.00E+00	1.36E+07

Notes:

1) Units are m^2 mrem/yr per μCi/sec with the exception of H-3.

2) For H-3, the units are mrem/yr per $\mu Ci/m^3$.

3) The infant age group is assumed to receive no due through the vegetation ingestion pathway therefore no dose factors are supplied.

Table 13
Adult Grass-Cow-Milk Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	4.35E+02	4.35E+02	4.35E+02	4.35E+02	4.35E+02	4.35E+02
Na-24	2.46E+06	2.46E+06	2.46E+06	2.46E+06	2.46E+06	2.46E+06	2.46E+06
Cr-51	0.00E+00	0.00E+00	2.86E+04	1.71E+04	6.29E+03	3.79E+04	7.18E+06
Mn-54	0.00E+00	8.41E+06	1.61E+06	0.00E+00	2.50E+06	0.00E+00	2.58E+07
Mn-56	0.00E+00	4.13E-03	7.32E-04	0.00E+00	5.24E-03	0.00E+00	1.32E-01
Fe-55	2.51E+07	1.74E+07	4.05E+06	0.00E+00	0.00E+00	9.68E+06	9.95E+06
Fe-59	2.97E+07	6.98E+07	2.67E+07	0.00E+00	0.00E+00	1.95E+07	2.33E+08
Co-58	0.00E+00	4.72E+06	1.06E+07	0.00E+00	0.00E+00	0.00E+00	9.56E+07
Co-60	0.00E+00	1.64E+07	3.62E+07	0.00E+00	0.00E+00	0.00E+00	3.08E+08
Ni-63	6.73E+09	4.66E+08	2.26E+08	0.00E+00	0.00E+00	0.00E+00	9.73E+07
Ni-65	3.70E-01	4.81E-02	2.19E-02	0.00E+00	0.00E+00	0.00E+00	1.22E+00
Cu-64	0.00E+00	2.36E+04	1.11E+04	0.00E+00	5.95E+04	0.00E+00	2.01E+06
Zn-65	1.37E+09	4.36E+09	1.97E+09	0.00E+00	2.92E+09	0.00E+00	2.75E+09
Zn-69	2.01E-12	3.84E-12	2.67E-13	0.00E+00	2.50E-12	0.00E+00	5.78E-13
Br-83	0.00E+00	0.00E+00	9.65E-02	0.00E+00	0.00E+00	0.00E+00	1.39E-01
Br-84	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	2.60E+09	1.21E+09	0.00E+00	0.00E+00	0.00E+00	5.12E+08
Rb-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-89	1.45E+09	0.00E+00	4.16E+07	0.00E+00	0.00E+00	0.00E+00	2.33E+08
Sr-90	5.38E+10	0.00E+00	1.08E+09	0.00E+00	0.00E+00	0.00E+00	1.35E+09
Sr-91	2.87E+04	0.00E+00	1.16E+03	0.00E+00	0.00E+00	0.00E+00	1.37E+05
Sr-92	4.84E-01	0.00E+00	2.09E-02	0.00E+00	0.00E+00	0.00E+00	9.58E+00
Y-90	7.10E+01	0.00E+00	1.90E+00	0.00E+00	0.00E+00	0.00E+00	7.52E+05
Y-91M	6.42E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.89E-19
Y-91	8.59E+03	0.00E+00	2.30E+02	0.00E+00	0.00E+00	0.00E+00	4.73E+06
Y-92	5.57E-05	0.00E+00	1.63E-06	0.00E+00	0.00E+00	0.00E+00	9.75E-01
Y-93	2.22E-01	0.00E+00	6.12E-03	0.00E+00	0.00E+00	0.00E+00	7.03E+03
Zr-95	9.44E+02	3.03E+02	2.05E+02	0.00E+00	4.75E+02	0.00E+00	9.59E+05
Zr-97	4.32E-01	8.72E-02	3.99E-02	0.00E+00	1.32E-01	0.00E+00	2.70E+04
Nb-95	8.26E+04	4.60E+04	2.47E+04	0.00E+00	4.54E+04	0.00E+00	2.79E+08
Mo-99	0.00E+00	2.47E+07	4.70E+06	0.00E+00	5.60E+07	0.00E+00	5.73E+07
Tc- 99M	3.31E+00	9.35E+00	1.19E+02	0.00E+00	1.42E+02	4.58E+00	5.53E+03
Tc-101	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	1.02E+03	0.00E+00	4.39E+02	0.00E+00	3.88E+03	0.00E+00	1.19E+05
Ru-105	8.51E-04	0.00E+00	3.36E-04	0.00E+00	1.10E-02	0.00E+00	5.20E-01
Ru-106	2.04E+04	0.00E+00	2.58E+03	0.00E+00	3.94E+04	0.00E+00	1.32E+06
Ag-110M	5.82E+07	5.39E+07	3.20E+07	0.00E+00	1.06E+08	0.00E+00	2.20E+10

Table 13 (Continued)
Adult Grass-Cow-Milk Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	1.63E+07	5.91E+06	2.18E+06	4.90E+06	6.63E+07	0.00E+00	6.51E+07
Te-127M	4.58E+07	1.64E+07	5.58E+06	1.17E+07	1.86E+08	0.00E+00	1.54E+08
Te-127	6.66E+02	2.39E+02	1.44E+02	4.94E+02	2.71E+03	0.00E+00	5.26E+04
Te-129M	6.02E+07	2.24E+07	9.52E+06	2.07E+07	2.51E+08	0.00E+00	3.03E+08
Te-129	2.83E-10	1.06E-10	6.88E-11	2.17E-10	1.19E-09	0.00E+00	2.13E-10
Te-131M	3.61E+05	1.76E+05	1.47E+05	2.79E+05	1.79E+06	0.00E+00	1.75E+07
Te-131	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-132	2.39E+06	1.55E+06	1.45E+06	1.71E+06	1.49E+07	0.00E+00	7.32E+07
I-130	4.18E+05	1.23E+06	4.86E+05	1.04E+08	1.92E+06	0.00E+00	1.06E+06
I-131	2.96E+08	4.23E+08	2.43E+08	1.39E+11	7.26E+08	0.00E+00	1.12E+08
I-132	1.65E-01	4.40E-01	1.54E-01	1.54E+01	7.02E-01	0.00E+00	8.27E-02
I-133	3.88E+06	6.74E+06	2.06E+06	9.91E+08	1.18E+07	0.00E+00	6.06E+06
I-134	1.89E-12	5.13E-12	1.83E-12	8.89E-11	8.16E-12	0.00E+00	4.47E-15
I-135	1.29E+04	3.38E+04	1.25E+04	2.23E+06	5.42E+04	0.00E+00	3.82E+04
Cs-134	5.65E+09	1.35E+10	1.10E+10	0.00E+00	4.35E+09	1.45E+09	2.35E+08
Cs-136	2.63E+08	1.04E+09	7.46E+08	0.00E+00	5.77E+08	7.91E+07	1.18E+08
Cs-137	7.38E+09	1.01E+10	6.61E+09	0.00E+00	3.43E+09	1.14E+09	1.95E+08
Cs-138	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-139	4.43E-08	3.16E-11	1.30E-09	0.00E+00	2.95E-11	1.79E-11	7.86E-08
Ba-140	2.69E+07	3.38E+04	1.76E+06	0.00E+00	1.15E+04	1.93E+04	5.54E+07
Ba-141	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La-140	4.52E+00	2.28E+00	6.02E-01	0.00E+00	0.00E+00	0.00E+00	1.67E+05
La-142	1.89E-11	8.59E-12	2.14E-12	0.00E+00	0.00E+00	0.00E+00	6.28E-08
Ce-141	4.84E+03	3.28E+03	3.72E+02	0.00E+00	1.52E+03	0.00E+00	1.25E+07
Ce-143	4.15E+01	3.07E+04	3.39E+00	0.00E+00	1.35E+01	0.00E+00	1.15E+06
Ce-144	3.58E+05	1.50E+05	1.92E+04	0.00E+00	8.87E+04	0.00E+00	1.21E+08
Pr-143	1.58E+02	6.34E+01	7.83E+00	0.00E+00	3.66E+01	0.00E+00	6.92E+05
Pr-144	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd-147	9.48E+01	1.10E+02	6.56E+00	0.00E+00	6.41E+01	0.00E+00	5.26E+05
W-187	6.51E+03	5.44E+03	1.90E+03	0.00E+00	0.00E+00	0.00E+00	1.78E+06
Np-239	3.67E+00	3.61E-01	1.99E-01	0.00E+00	1.12E+00	0.00E+00	7.40E+04

Notes:

1) Units are m^2 mrem/yr per μCi/sec with the exception of H-3.

2) For H-3, the units are mrem/yr per $\mu Ci/m^3$.

Table 13a
Teen Grass-Cow-Milk Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	5.66E+02	5.66E+02	5.66E+02	5.66E+02	5.66E+02	5.66E+02
Na-24	4.29E+06	4.29E+06	4.29E+06	4.29E+06	4.29E+06	4.29E+06	4.29E+06
Cr-51	0.00E+00	0.00E+00	4.99E+04	2.77E+04	1.09E+04	7.12E+04	8.38E+06
Mn-54	0.00E+00	1.40E+07	2.78E+06	0.00E+00	4.18E+06	0.00E+00	2.87E+07
Mn-56	0.00E+00	7.32E-03	1.30E-03	0.00E+00	9.27E-03	0.00E+00	4.82E-01
Fe-55	4.45E+07	3.16E+07	7.36E+06	0.00E+00	0.00E+00	2.00E+07	1.37E+07
Fe-59	5.18E+07	1.21E+08	4.67E+07	0.00E+00	0.00E+00	3.81E+07	2.86E+08
Co-58	0.00E+00	7.94E+06	1.83E+07	0.00E+00	0.00E+00	0.00E+00	1.09E+08
Co-60	0.00E+00	2.78E+07	6.26E+07	0.00E+00	0.00E+00	0.00E+00	3.62E+08
Ni-63	1.18E+10	8.35E+08	4.01E+08	0.00E+00	0.00E+00	0.00E+00	1.33E+08
Ni-65	6.78E-01	8.66E-02	3.94E-02	0.00E+00	0.00E+00	0.00E+00	4.70E+00
Cu-64	0.00E+00	4.21E+04	1.98E+04	0.00E+00	1.06E+05	0.00E+00	3.26E+06
Zn-65	2.11E+09	7.31E+09	3.41E+09	0.00E+00	4.68E+09	0.00E+00	3.10E+09
Zn-69	3.70E-12	7.05E-12	4.94E-13	0.00E+00	4.61E-12	0.00E+00	1.30E-11
Br-83	0.00E+00	0.00E+00	1.78E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	4.73E+09	2.22E+09	0.00E+00	0.00E+00	0.00E+00	7.01E+08
Rb-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-89	2.67E+09	0.00E+00	7.66E+07	0.00E+00	0.00E+00	0.00E+00	3.18E+08
Sr-90	8.13E+10	0.00E+00	1.63E+09	0.00E+00	0.00E+00	0.00E+00	1.86E+09
Sr-91	5.27E+04	0.00E+00	2.10E+03	0.00E+00	0.00E+00	0.00E+00	2.39E+05
Sr-92	8.85E-01	0.00E+00	3.77E-02	0.00E+00	0.00E+00	0.00E+00	2.26E+01
Y-90	1.30E+02	0.00E+00	3.51E+00	0.00E+00	0.00E+00	0.00E+00	1.08E+06
Y-91M	1.18E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.55E-18
Y-91	1.58E+04	0.00E+00	4.24E+02	0.00E+00	0.00E+00	0.00E+00	6.48E+06
Y-92	1.03E-04	0.00E+00	2.98E-06	0.00E+00	0.00E+00	0.00E+00	2.82E+00
Y-93	4.09E-01	0.00E+00	1.12E-02	0.00E+00	0.00E+00	0.00E+00	1.25E+04
Zr-95	1.65E+03	5.21E+02	3.58E+02	0.00E+00	7.65E+02	0.00E+00	1.20E+06
Zr-97	7.87E-01	1.56E-01	7.17E-02	0.00E+00	2.36E-01	0.00E+00	4.22E+04
Nb-95	1.41E+05	7.82E+04	4.30E+04	0.00E+00	7.58E+04	0.00E+00	3.34E+08
Mo-99	0.00E+00	4.46E+07	8.51E+06	0.00E+00	1.02E+08	0.00E+00	8.00E+07
Tc- 99M	5.74E+00	1.60E+01	2.07E+02	0.00E+00	2.39E+02	8.89E+00	1.05E+04
Tc-101	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	1.81E+03	0.00E+00	7.74E+02	0.00E+00	6.38E+03	0.00E+00	1.51E+05
Ru-105	1.55E-03	0.00E+00	6.03E-04	0.00E+00	1.96E-02	0.00E+00	1.25E+00
Ru-106	3.75E+04	0.00E+00	4.73E+03	0.00E+00	7.24E+04	0.00E+00	1.80E+06
Ag-110M	9.63E+07	9.11E+07	5.54E+07	0.00E+00	1.74E+08	0.00E+00	2.56E+10

Table 13a (Continued)
Teen Grass-Cow-Milk Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	3.01E+07	1.08E+07	4.02E+06	8.40E+06	0.00E+00	0.00E+00	8.87E+07
Te-127M	8.44E+07	2.99E+07	1.00E+07	2.01E+07	3.42E+08	0.00E+00	2.10E+08
Te-127	1.24E+03	4.38E+02	2.66E+02	8.52E+02	5.00E+03	0.00E+00	9.54E+04
Te-129M	1.10E+08	4.09E+07	1.74E+07	3.55E+07	4.61E+08	0.00E+00	4.13E+08
Te-129	5.20E-10	1.94E-10	1.27E-10	3.72E-10	2.18E-09	0.00E+00	2.84E-09
Te-131M	6.57E+05	3.15E+05	2.63E+05	4.74E+05	3.28E+06	0.00E+00	2.53E+07
Te-131	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-132	4.27E+06	2.71E+06	2.55E+06	2.85E+06	2.60E+07	0.00E+00	8.57E+07
I-130	7.35E+05	2.13E+06	8.49E+05	1.73E+08	3.27E+06	0.00E+00	1.63E+06
I-131	5.37E+08	7.52E+08	4.04E+08	2.19E+11	1.29E+09	0.00E+00	1.49E+08
I-132	2.92E-01	7.64E-01	2.74E-01	2.57E+01	1.20E+00	0.00E+00	3.33E-01
I-133	7.08E+06	1.20E+07	3.66E+06	1.68E+09	2.11E+07	0.00E+00	9.09E+06
I-134	3.35E-12	8.89E-12	3.19E-12	1.48E-10	1.40E-11	0.00E+00	1.17E-13
I-135	2.29E+04	5.91E+04	2.19E+04	3.80E+06	9.33E+04	0.00E+00	6.54E+04
Cs-134	9.82E+09	2.31E+10	1.07E+10	0.00E+00	7.34E+09	2.80E+09	2.87E+08
Cs-136	4.47E+08	1.76E+09	1.18E+09	0.00E+00	9.58E+08	1.51E+08	1.42E+08
Cs-137	1.34E+10	1.78E+10	6.20E+09	0.00E+00	6.06E+09	2.35E+09	2.53E+08
Cs-138	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-139	8.20E-08	5.77E-11	2.39E-09	0.00E+00	5.44E-11	3.98E-11	7.31E-07
Ba-140	4.85E+07	5.95E+04	3.13E+06	0.00E+00	2.02E+04	4.00E+04	7.49E+07
Ba-141	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La-140	8.12E+00	3.99E+00	1.06E+00	0.00E+00	0.00E+00	0.00E+00	2.29E+05
La-142	3.41E-11	1.51E-11	3.77E-12	0.00E+00	0.00E+00	0.00E+00	4.61E-07
Ce-141	8.88E+03	5.93E+03	6.81E+02	0.00E+00	2.79E+03	0.00E+00	1.70E+07
Ce-143	7.62E+01	5.55E+04	6.20E+00	0.00E+00	2.49E+01	0.00E+00	1.67E+06
Ce-144	6.58E+05	2.72E+05	3.54E+04	0.00E+00	1.63E+05	0.00E+00	1.66E+08
Pr-143	2.90E+02	1.16E+02	1.44E+01	0.00E+00	6.74E+01	0.00E+00	9.55E+05
Pr-144	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd-147	1.82E+02	1.98E+02	1.19E+01	0.00E+00	1.17E+02	0.00E+00	7.16E+05
W-187	1.19E+04	9.71E+03	3.40E+03	0.00E+00	0.00E+00	0.00E+00	2.63E+06
Np-239	7.00E+00	6.60E-01	3.67E-01	0.00E+00	2.07E+00	0.00E+00	1.06E+05

Notes:

1) Units are m^2 mrem/yr per μCi/sec with the exception of H-3.

2) For H-3, the units are mrem/yr per $\mu Ci/m^3$.

Table 13b
Child Grass-Cow-Milk Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	8.97E+02	8.97E+02	8.97E+02	8.97E+02	8.97E+02	8.97E+02
Na-24	8.93E+06	8.93E+06	8.93E+06	8.93E+06	8.93E+06	8.93E+06	8.93E+06
Cr-51	0.00E+00	0.00E+00	1.02E+05	5.65E+04	1.54E+04	1.03E+05	5.39E+06
Mn-54	0.00E+00	2.10E+07	5.59E+06	0.00E+00	5.88E+06	0.00E+00	1.76E+07
Mn-56	0.00E+00	1.28E-02	2.88E-03	0.00E+00	1.54E-02	0.00E+00	1.85E+00
Fe-55	1.12E+08	5.93E+07	1.84E+07	0.00E+00	0.00E+00	3.35E+07	1.10E+07
Fe-59	1.20E+08	1.94E+08	9.69E+07	0.00E+00	0.00E+00	5.64E+07	2.02E+08
Co-58	0.00E+00	1.21E+07	3.71E+07	0.00E+00	0.00E+00	0.00E+00	7.08E+07
Co-60	0.00E+00	4.32E+07	1.27E+08	0.00E+00	0.00E+00	0.00E+00	2.39E+08
Ni-63	2.96E+10	1.59E+09	1.01E+09	0.00E+00	0.00E+00	0.00E+00	1.07E+08
Ni-65	1.66E+00	1.56E-01	9.11E-02	0.00E+00	0.00E+00	0.00E+00	1.91E+01
Cu-64	0.00E+00	7.39E+04	4.47E+04	0.00E+00	1.79E+05	0.00E+00	3.47E+06
Zn-65	4.13E+09	1.10E+10	6.85E+09	0.00E+00	6.94E+09	0.00E+00	1.93E+09
Zn-69	9.10E-12	1.32E-11	1.22E-12	0.00E+00	7.98E-12	0.00E+00	8.29E-10
Br-83	0.00E+00	0.00E+00	4.37E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	8.78E+09	5.40E+09	0.00E+00	0.00E+00	0.00E+00	5.65E+08
Rb-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-89	6.62E+09	0.00E+00	1.89E+08	0.00E+00	0.00E+00	0.00E+00	2.56E+08
Sr-90	1.68E+11	0.00E+00	3.38E+09	0.00E+00	0.00E+00	0.00E+00	1.51E+09
Sr-91	1.29E+05	0.00E+00	4.88E+03	0.00E+00	0.00E+00	0.00E+00	2.86E+05
Sr-92	2.16E+00	0.00E+00	8.67E-02	0.00E+00	0.00E+00	0.00E+00	4.09E+01
Y-90	3.23E+02	0.00E+00	8.64E+00	0.00E+00	0.00E+00	0.00E+00	9.19E+05
Y-91M	2.87E-19	0.00E+00	1.04E-20	0.00E+00	0.00E+00	0.00E+00	5.62E-16
Y-91	3.90E+04	0.00E+00	1.04E+03	0.00E+00	0.00E+00	0.00E+00	5.20E+06
Y-92	2.53E-04	0.00E+00	7.23E-06	0.00E+00	0.00E+00	0.00E+00	7.30E+00
Y-93	1.00E+00	0.00E+00	2.75E-02	0.00E+00	0.00E+00	0.00E+00	1.50E+04
Zr-95	3.83E+03	8.43E+02	7.50E+02	0.00E+00	1.21E+03	0.00E+00	8.79E+05
Zr-97	1.91E+00	2.77E-01	1.63E-01	0.00E+00	3.97E-01	0.00E+00	4.19E+04
Nb-95	3.18E+05	1.24E+05	8.85E+04	0.00E+00	1.16E+05	0.00E+00	2.29E+08
Mo-99	0.00E+00	8.12E+07	2.01E+07	0.00E+00	1.73E+08	0.00E+00	6.72E+07
Tc- 99M	1.32E+01	2.58E+01	4.28E+02	0.00E+00	3.75E+02	1.31E+01	1.47E+04
Tc-101	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	4.28E+03	0.00E+00	1.65E+03	0.00E+00	1.08E+04	0.00E+00	1.11E+05
Ru-105	3.79E-03	0.00E+00	1.38E-03	0.00E+00	3.33E-02	0.00E+00	2.48E+00
Ru-106	9.24E+04	0.00E+00	1.15E+04	0.00E+00	1.25E+05	0.00E+00	1.44E+06
Ag-110M	2.09E+08	1.41E+08	1.13E+08	0.00E+00	2.63E+08	0.00E+00	1.68E+10

Table 13b (Continued)
Child Grass-Cow-Milk Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	7.38E+07	2.00E+07	9.84E+06	2.07E+07	0.00E+00	0.00E+00	7.12E+07
Te-127M	2.08E+08	5.60E+07	2.47E+07	4.97E+07	5.93E+08	0.00E+00	1.68E+08
Te-127	3.04E+03	8.19E+02	6.51E+02	2.10E+03	8.64E+03	0.00E+00	1.19E+05
Te-129M	2.71E+08	7.58E+07	4.21E+07	8.75E+07	7.97E+08	0.00E+00	3.31E+08
Te-129	1.28E-09	3.58E-10	3.05E-10	9.16E-10	3.75E-09	0.00E+00	7.99E-08
Te-131M	1.60E+06	5.53E+05	5.88E+05	1.14E+06	5.35E+06	0.00E+00	2.24E+07
Te-131	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-132	1.02E+07	4.52E+06	5.46E+06	6.58E+06	4.19E+07	0.00E+00	4.55E+07
I-130	1.72E+06	3.47E+06	1.79E+06	3.82E+08	5.19E+06	0.00E+00	1.62E+06
I-131	1.30E+09	1.31E+09	7.45E+08	4.33E+11	2.15E+09	0.00E+00	1.17E+08
I-132	6.91E-01	1.27E+00	5.84E-01	5.89E+01	1.94E+00	0.00E+00	1.49E+00
I-133	1.72E+07	2.13E+07	8.05E+06	3.95E+09	3.55E+07	0.00E+00	8.57E+06
I-134	7.94E-12	1.47E-11	6.79E-12	3.39E-10	2.26E-11	0.00E+00	9.78E-12
I-135	5.43E+04	9.78E+04	4.62E+04	8.66E+06	1.50E+05	0.00E+00	7.45E+04
Cs-134	2.26E+10	3.72E+10	7.84E+09	0.00E+00	1.15E+10	4.13E+09	2.00E+08
Cs-136	1.01E+09	2.77E+09	1.80E+09	0.00E+00	1.48E+09	2.20E+08	9.75E+07
Cs-137	3.22E+10	3.09E+10	4.55E+09	0.00E+00	1.01E+10	3.62E+09	1.93E+08
Cs-138	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-139	2.01E-07	1.08E-10	5.84E-09	0.00E+00	9.39E-11	6.33E-11	1.16E-05
Ba-140	1.17E+08	1.03E+05	6.84E+06	0.00E+00	3.34E+04	6.12E+04	5.94E+07
Ba-141	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La-140	1.95E+01	6.80E+00	2.29E+00	0.00E+00	0.00E+00	0.00E+00	1.90E+05
La-142	8.24E-11	2.63E-11	8.22E-12	0.00E+00	0.00E+00	0.00E+00	5.20E-06
Ce-141	2.19E+04	1.09E+04	1.62E+03	0.00E+00	4.78E+03	0.00E+00	1.36E+07
Ce-143	1.87E+02	1.01E+05	1.47E+01	0.00E+00	4.26E+01	0.00E+00	1.49E+06
Ce-144	1.62E+06	5.09E+05	8.66E+04	0.00E+00	2.82E+05	0.00E+00	1.33E+08
Pr-143	7.18E+02	2.16E+02	3.57E+01	0.00E+00	1.17E+02	0.00E+00	7.75E+05
Pr-144	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd-147	4.48E+02	3.63E+02	2.81E+01	0.00E+00	1.99E+02	0.00E+00	5.75E+05
W-187	2.89E+04	1.71E+04	7.67E+03	0.00E+00	0.00E+00	0.00E+00	2.40E+06
Np-239	1.72E+01	1.24E+00	8.69E-01	0.00E+00	3.58E+00	0.00E+00	9.15E+04

Notes:

1) Units are m^2 mrem/yr per μCi/sec with the exception of H-3.

2) For H-3, the units are mrem/yr per $\mu Ci/m^3$.

Table 13c
Infant Grass-Cow-Milk Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	1.36E+03	1.36E+03	1.36E+03	1.36E+03	1.36E+03	1.36E+03
Na-24	1.56E+07	1.56E+07	1.56E+07	1.56E+07	1.56E+07	1.56E+07	1.56E+07
Cr-51	0.00E+00	0.00E+00	1.61E+05	1.05E+05	2.30E+04	2.05E+05	4.70E+06
Mn-54	0.00E+00	3.90E+07	8.84E+06	0.00E+00	8.64E+06	0.00E+00	1.43E+07
Mn-56	0.00E+00	3.13E-02	5.39E-03	0.00E+00	2.69E-02	0.00E+00	2.84E+00
Fe-55	1.35E+08	8.73E+07	2.33E+07	0.00E+00	0.00E+00	4.27E+07	1.11E+07
Fe-59	2.24E+08	3.92E+08	1.54E+08	0.00E+00	0.00E+00	1.16E+08	1.87E+08
Co-58	0.00E+00	2.43E+07	6.05E+07	0.00E+00	0.00E+00	0.00E+00	6.04E+07
Co-60	0.00E+00	8.82E+07	2.08E+08	0.00E+00	0.00E+00	0.00E+00	2.10E+08
Ni-63	3.49E+10	2.16E+09	1.21E+09	0.00E+00	0.00E+00	0.00E+00	1.07E+08
Ni-65	3.51E+00	3.97E-01	1.81E-01	0.00E+00	0.00E+00	0.00E+00	3.02E+01
Cu-64	0.00E+00	1.84E+05	8.51E+04	0.00E+00	3.11E+05	0.00E+00	3.77E+06
Zn-65	5.55E+09	1.90E+10	8.78E+09	0.00E+00	9.23E+09	0.00E+00	1.61E+10
Zn-69	1.94E-11	3.49E-11	2.60E-12	0.00E+00	1.45E-11	0.00E+00	2.85E-09
Br-83	0.00E+00	0.00E+00	9.27E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	2.23E+10	1.10E+10	0.00E+00	0.00E+00	0.00E+00	5.70E+08
Rb-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-89	1.26E+10	0.00E+00	3.61E+08	0.00E+00	0.00E+00	0.00E+00	2.59E+08
Sr-90	1.86E+11	0.00E+00	3.77E+09	0.00E+00	0.00E+00	0.00E+00	1.52E+09
Sr-91	2.70E+05	0.00E+00	9.76E+03	0.00E+00	0.00E+00	0.00E+00	3.19E+05
Sr-92	4.60E+00	0.00E+00	1.71E-01	0.00E+00	0.00E+00	0.00E+00	4.96E+01
Y-90	6.82E+02	0.00E+00	1.83E+01	0.00E+00	0.00E+00	0.00E+00	9.42E+05
Y-91M	6.09E-19	0.00E+00	2.07E-20	0.00E+00	0.00E+00	0.00E+00	2.03E-15
Y-91	7.33E+04	0.00E+00	1.95E+03	0.00E+00	0.00E+00	0.00E+00	5.25E+06
Y-92	5.37E-04	0.00E+00	1.51E-05	0.00E+00	0.00E+00	0.00E+00	1.02E+01
Y-93	2.14E+00	0.00E+00	5.83E-02	0.00E+00	0.00E+00	0.00E+00	1.69E+04
Zr-95	6.81E+03	1.66E+03	1.18E+03	0.00E+00	1.79E+03	0.00E+00	8.26E+05
Zr-97	4.05E+00	6.96E-01	3.18E-01	0.00E+00	7.01E-01	0.00E+00	4.44E+04
Nb-95	5.94E+05	2.45E+05	1.41E+05	0.00E+00	1.75E+05	0.00E+00	2.07E+08
Mo-99	0.00E+00	2.08E+08	4.05E+07	0.00E+00	3.10E+08	0.00E+00	6.84E+07
Tc- 99M	2.74E+01	5.65E+01	7.27E+02	0.00E+00	6.08E+02	2.95E+01	1.64E+04
Tc-101	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	8.67E+03	0.00E+00	2.90E+03	0.00E+00	1.80E+04	0.00E+00	1.05E+05
Ru-105	8.00E-03	0.00E+00	2.69E-03	0.00E+00	5.88E-02	0.00E+00	3.18E+00
Ru-106	1.90E+05	0.00E+00	2.38E+04	0.00E+00	2.25E+05	0.00E+00	1.44E+06
Ag-110M	3.86E+08	2.82E+08	1.86E+08	0.00E+00	4.03E+08	0.00E+00	1.46E+10

Table 13c (Continued)
Infant Grass-Cow-Milk Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	1.51E+08	5.04E+07	2.04E+07	5.08E+07	0.00E+00	0.00E+00	7.19E+07
Te-127M	4.21E+08	1.40E+08	5.10E+07	1.22E+08	1.04E+09	0.00E+00	1.70E+08
Te-127	6.45E+03	2.16E+03	1.39E+03	5.25E+03	1.57E+04	0.00E+00	1.35E+05
Te-129M	5.57E+08	1.91E+08	8.58E+07	2.14E+08	1.39E+09	0.00E+00	3.33E+08
Te-129	2.72E-09	9.38E-10	6.35E-10	2.28E-09	6.77E-09	0.00E+00	2.17E-07
Te-131M	3.37E+06	1.36E+06	1.12E+06	2.75E+06	9.35E+06	0.00E+00	2.29E+07
Te-131	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-132	2.10E+07	1.04E+07	9.71E+06	1.54E+07	6.51E+07	0.00E+00	3.85E+07
I-130	3.53E+06	7.77E+06	3.12E+06	8.71E+08	8.53E+06	0.00E+00	1.67E+06
I-131	2.72E+09	3.20E+09	1.41E+09	1.05E+12	3.74E+09	0.00E+00	1.14E+08
I-132	1.43E+00	2.91E+00	1.04E+00	1.36E+02	3.25E+00	0.00E+00	2.36E+00
I-133	3.63E+07	5.29E+07	1.55E+07	9.62E+09	6.22E+07	0.00E+00	8.95E+06
I-134	1.65E-11	3.37E-11	1.20E-11	7.87E-10	3.77E-11	0.00E+00	3.49E-11
I-135	1.13E+05	2.25E+05	8.19E+04	2.01E+07	2.50E+05	0.00E+00	8.13E+04
Cs-134	3.65E+10	6.80E+10	6.87E+09	0.00E+00	1.75E+10	7.18E+09	1.85E+08
Cs-136	1.97E+09	5.80E+09	2.16E+09	0.00E+00	2.31E+09	4.72E+08	8.80E+07
Cs-137	5.15E+10	6.02E+10	4.27E+09	0.00E+00	1.62E+10	6.55E+09	1.88E+08
Cs-138	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-139	4.29E-07	2.84E-10	1.24E-08	0.00E+00	1.71E-10	1.72E-10	2.72E-05
Ba-140	2.41E+08	2.41E+05	1.24E+07	0.00E+00	5.72E+04	1.48E+05	5.92E+07
Ba-141	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La-140	4.06E+01	1.60E+01	4.12E+00	0.00E+00	0.00E+00	0.00E+00	1.88E+05
La-142	1.73E-10	6.35E-11	1.52E-11	0.00E+00	0.00E+00	0.00E+00	1.08E-05
Ce-141	4.34E+04	2.64E+04	3.11E+03	0.00E+00	8.15E+03	0.00E+00	1.37E+07
Ce-143	3.96E+02	2.63E+05	3.00E+01	0.00E+00	7.65E+01	0.00E+00	1.53E+06
Ce-144	2.33E+06	9.52E+05	1.30E+05	0.00E+00	3.85E+05	0.00E+00	1.33E+08
Pr-143	1.49E+03	5.56E+02	7.37E+01	0.00E+00	2.07E+02	0.00E+00	7.84E+05
Pr-144	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd-147	8.88E+02	9.12E+02	5.59E+01	0.00E+00	3.51E+02	0.00E+00	5.78E+05
W-187	6.08E+04	4.23E+04	1.46E+04	0.00E+00	0.00E+00	0.00E+00	2.48E+06
Np-239	3.64E+01	3.26E+00	1.84E+00	0.00E+00	6.50E+00	0.00E+00	9.42E+04

Notes:

1) Units are m^2 mrem/yr per μCi/sec with the exception of H-3.

2) For H-3, the units are mrem/yr per μCi/m^3.

Table 14
Adult Grass-Goat-Milk Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	8.88E+02	8.88E+02	8.88E+02	8.88E+02	8.88E+02	8.88E+02
Na-24	2.95E+05	2.95E+05	2.95E+05	2.95E+05	2.95E+05	2.95E+05	2.95E+05
Cr-51	0.00E+00	0.00E+00	3.43E+03	2.05E+03	7.55E+02	4.55E+03	8.62E+05
Mn-54	0.00E+00	1.01E+06	1.93E+05	0.00E+00	3.00E+05	0.00E+00	3.09E+06
Mn-56	0.00E+00	4.95E-04	8.79E-05	0.00E+00	6.29E-04	0.00E+00	1.58E-02
Fe-55	3.26E+05	2.26E+05	5.26E+04	0.00E+00	0.00E+00	1.26E+05	1.29E+05
Fe-59	3.86E+05	9.07E+05	3.48E+05	0.00E+00	0.00E+00	2.53E+05	3.02E+06
Co-58	0.00E+00	5.66E+05	1.27E+06	0.00E+00	0.00E+00	0.00E+00	1.15E+07
Co-60	0.00E+00	1.97E+06	4.34E+06	0.00E+00	0.00E+00	0.00E+00	3.70E+07
Ni-63	8.07E+08	5.60E+07	2.71E+07	0.00E+00	0.00E+00	0.00E+00	1.17E+07
Ni-65	4.44E-02	5.77E-03	2.63E-03	0.00E+00	0.00E+00	0.00E+00	1.46E-01
Cu-64	0.00E+00	2.63E+03	1.23E+03	0.00E+00	6.63E+03	0.00E+00	2.24E+05
Zn-65	1.65E+08	5.24E+08	2.37E+08	0.00E+00	3.50E+08	0.00E+00	3.30E+08
Zn-69	2.41E-13	4.61E-13	3.21E-14	0.00E+00	3.00E-13	0.00E+00	6.93E-14
Br-83	0.00E+00	0.00E+00	1.16E-02	0.00E+00	0.00E+00	0.00E+00	1.67E-02
Br-84	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	3.12E+08	1.45E+08	0.00E+00	0.00E+00	0.00E+00	6.15E+07
Rb-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-89	3.05E+09	0.00E+00	8.74E+07	0.00E+00	0.00E+00	0.00E+00	4.88E+08
Sr-90	1.13E+11	0.00E+00	2.27E+09	0.00E+00	0.00E+00	0.00E+00	2.84E+09
Sr-91	6.03E+04	0.00E+00	2.44E+03	0.00E+00	0.00E+00	0.00E+00	2.87E+05
Sr-92	1.02E+00	0.00E+00	4.39E-02	0.00E+00	0.00E+00	0.00E+00	2.01E+01
Y-90	8.52E+00	0.00E+00	2.28E-01	0.00E+00	0.00E+00	0.00E+00	9.03E+04
Y-91M	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.26E-20
Y-91	1.03E+03	0.00E+00	2.76E+01	0.00E+00	0.00E+00	0.00E+00	5.67E+05
Y-92	6.68E-06	0.00E+00	1.95E-07	0.00E+00	0.00E+00	0.00E+00	1.17E-01
Y-93	2.66E-02	0.00E+00	7.34E-04	0.00E+00	0.00E+00	0.00E+00	8.43E+02
Zr-95	1.13E+02	3.63E+01	2.46E+01	0.00E+00	5.70E+01	0.00E+00	1.15E+05
Zr-97	5.19E-02	1.05E-02	4.79E-03	0.00E+00	1.58E-02	0.00E+00	3.24E+03
Nb-95	9.92E+03	5.52E+03	2.97E+03	0.00E+00	5.45E+03	0.00E+00	3.35E+07
Mo-99	0.00E+00	2.97E+06	5.65E+05	0.00E+00	6.72E+06	0.00E+00	6.88E+06
Tc- 99M	3.97E-01	1.12E+00	1.43E+01	0.00E+00	1.70E+01	5.50E-01	6.64E+02
Tc-101	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	1.22E+02	0.00E+00	5.26E+01	0.00E+00	4.66E+02	0.00E+00	1.43E+04
Ru-105	1.02E-04	0.00E+00	4.03E-05	0.00E+00	1.32E-03	0.00E+00	6.25E-02
Ru-106	2.45E+03	0.00E+00	3.10E+02	0.00E+00	4.73E+03	0.00E+00	1.58E+05
Ag-110M	6.99E+06	6.46E+06	3.84E+06	0.00E+00	1.27E+07	0.00E+00	2.64E+09

Table 14 (Continued)
Adult Grass-Goat-Milk Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	1.96E+06	7.09E+05	2.62E+05	5.88E+05	7.95E+06	0.00E+00	7.81E+06
Te-127M	5.49E+06	1.96E+06	6.69E+05	1.40E+06	2.23E+07	0.00E+00	1.84E+07
Te-127	8.00E+01	2.87E+01	1.73E+01	5.92E+01	3.26E+02	0.00E+00	6.31E+03
Te-129M	7.22E+06	2.69E+06	1.14E+06	2.48E+06	3.01E+07	0.00E+00	3.64E+07
Te-129	3.39E-11	1.27E-11	8.26E-12	2.60E-11	1.43E-10	0.00E+00	2.56E-11
Te-131M	4.33E+04	2.12E+04	1.76E+04	3.35E+04	2.14E+05	0.00E+00	2.10E+06
Te-131	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-132	2.87E+05	1.86E+05	1.74E+05	2.05E+05	1.79E+06	0.00E+00	8.78E+06
I-130	5.01E+05	1.48E+06	5.84E+05	1.25E+08	2.31E+06	0.00E+00	1.27E+06
I-131	3.55E+08	5.08E+08	2.91E+08	1.67E+11	8.71E+08	0.00E+00	1.34E+08
I-132	1.98E-01	5.29E-01	1.85E-01	1.85E+01	8.42E-01	0.00E+00	9.93E-02
I-133	4.65E+06	8.09E+06	2.47E+06	1.19E+09	1.41E+07	0.00E+00	7.27E+06
I-134	2.27E-12	6.15E-12	2.20E-12	1.07E-10	9.79E-12	0.00E+00	5.36E-15
I-135	1.55E+04	4.06E+04	1.50E+04	2.68E+06	6.51E+04	0.00E+00	4.58E+04
Cs-134	1.70E+10	4.04E+10	3.30E+10	0.00E+00	1.31E+10	4.34E+09	7.06E+08
Cs-136	7.88E+08	3.11E+09	2.24E+09	0.00E+00	1.73E+09	2.37E+08	3.53E+08
Cs-137	2.21E+10	3.03E+10	1.98E+10	0.00E+00	1.03E+10	3.42E+09	5.86E+08
Cs-138	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-139	5.32E-09	3.79E-12	1.56E-10	0.00E+00	3.54E-12	2.15E-12	9.44E-09
Ba-140	3.23E+06	4.05E+03	2.11E+05	0.00E+00	1.38E+03	2.32E+03	6.64E+06
Ba-141	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La-140	5.43E-01	2.74E-01	7.23E-02	0.00E+00	0.00E+00	0.00E+00	2.01E+04
La-142	2.27E-12	1.03E-12	2.57E-13	0.00E+00	0.00E+00	0.00E+00	7.53E-09
Ce-141	5.81E+02	3.93E+02	4.46E+01	0.00E+00	1.83E+02	0.00E+00	1.50E+06
Ce-143	4.98E+00	3.68E+03	4.07E-01	0.00E+00	1.62E+00	0.00E+00	1.38E+05
Ce-144	4.29E+04	1.79E+04	2.30E+03	0.00E+00	1.06E+04	0.00E+00	1.45E+07
Pr-143	1.90E+01	7.60E+00	9.40E-01	0.00E+00	4.39E+00	0.00E+00	8.31E+04
Pr-144	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd-147	1.14E+01	1.32E+01	7.87E-01	0.00E+00	7.69E+00	0.00E+00	6.31E+04
W-187	7.82E+02	6.53E+02	2.28E+02	0.00E+00	0.00E+00	0.00E+00	2.14E+05
Np-239	4.40E-01	4.33E-02	2.39E-02	0.00E+00	1.35E-01	0.00E+00	8.88E+03

Notes:

1) Units are m^2 mrem/yr per μCi/sec with the exception of H-3.

2) For H-3, the units are mrem/yr per $\mu Ci/m^3$.

Table 14a
Teen Grass-Goat-Milk Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	1.16E+03	1.16E+03	1.16E+03	1.16E+03	1.16E+03	1.16E+03
Na-24	5.15E+05	5.15E+05	5.15E+05	5.15E+05	5.15E+05	5.15E+05	5.15E+05
Cr-51	0.00E+00	0.00E+00	5.99E+03	3.33E+03	1.31E+03	8.55E+03	1.01E+06
Mn-54	0.00E+00	1.68E+06	3.34E+05	0.00E+00	5.02E+05	0.00E+00	3.45E+06
Mn-56	0.00E+00	8.78E-04	1.56E-04	0.00E+00	1.11E-03	0.00E+00	5.78E-02
Fe-55	5.79E+05	4.11E+05	9.57E+04	0.00E+00	0.00E+00	2.60E+05	1.78E+05
Fe-59	6.74E+05	1.57E+06	6.07E+05	0.00E+00	0.00E+00	4.96E+05	3.72E+06
Co-58	0.00E+00	9.53E+05	2.20E+06	0.00E+00	0.00E+00	0.00E+00	1.31E+07
Co-60	0.00E+00	3.34E+06	7.52E+06	0.00E+00	0.00E+00	0.00E+00	4.35E+07
Ni-63	1.42E+09	1.00E+08	4.81E+07	0.00E+00	0.00E+00	0.00E+00	1.59E+07
Ni-65	8.13E-02	1.04E-02	4.73E-03	0.00E+00	0.00E+00	0.00E+00	5.63E-01
Cu-64	0.00E+00	4.69E+03	2.20E+03	0.00E+00	1.19E+04	0.00E+00	3.64E+05
Zn-65	2.53E+08	8.78E+08	4.09E+08	0.00E+00	5.62E+08	0.00E+00	3.72E+08
Zn-69	4.44E-13	8.46E-13	5.92E-14	0.00E+00	5.53E-13	0.00E+00	1.56E-12
Br-83	0.00E+00	0.00E+00	2.13E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	5.68E+08	2.67E+08	0.00E+00	0.00E+00	0.00E+00	8.41E+07
Rb-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-89	5.61E+09	0.00E+00	1.61E+08	0.00E+00	0.00E+00	0.00E+00	6.69E+08
Sr-90	1.71E+11	0.00E+00	3.41E+09	0.00E+00	0.00E+00	0.00E+00	3.90E+09
Sr-91	1.11E+05	0.00E+00	4.41E+03	0.00E+00	0.00E+00	0.00E+00	5.02E+05
Sr-92	1.86E+00	0.00E+00	7.92E-02	0.00E+00	0.00E+00	0.00E+00	4.74E+01
Y-90	1.56E+01	0.00E+00	4.21E-01	0.00E+00	0.00E+00	0.00E+00	1.29E+05
Y-91M	1.41E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.66E-19
Y-91	1.90E+03	0.00E+00	5.08E+01	0.00E+00	0.00E+00	0.00E+00	7.77E+05
Y-92	1.23E-05	0.00E+00	3.57E-07	0.00E+00	0.00E+00	0.00E+00	3.39E-01
Y-93	4.90E-02	0.00E+00	1.34E-03	0.00E+00	0.00E+00	0.00E+00	1.50E+03
Zr-95	1.98E+02	6.25E+01	4.30E+01	0.00E+00	9.18E+01	0.00E+00	1.44E+05
Zr-97	9.44E-02	1.87E-02	8.61E-03	0.00E+00	2.83E-02	0.00E+00	5.06E+03
Nb-95	1.69E+04	9.38E+03	5.16E+03	0.00E+00	9.09E+03	0.00E+00	4.01E+07
Mo-99	0.00E+00	5.36E+06	1.02E+06	0.00E+00	1.23E+07	0.00E+00	9.59E+06
Tc- 99M	6.89E-01	1.92E+00	2.49E+01	0.00E+00	2.86E+01	1.07E+00	1.26E+03
Tc-101	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	2.17E+02	0.00E+00	9.29E+01	0.00E+00	7.66E+02	0.00E+00	1.81E+04
Ru-105	1.86E-04	0.00E+00	7.24E-05	0.00E+00	2.35E-03	0.00E+00	1.51E-01
Ru-106	4.50E+03	0.00E+00	5.67E+02	0.00E+00	8.68E+03	0.00E+00	2.16E+05
Ag-110M	1.16E+07	1.09E+07	6.65E+06	0.00E+00	2.09E+07	0.00E+00	3.07E+09

Table 14a (Continued)
Teen Grass-Goat-Milk Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	3.61E+06	1.30E+06	4.82E+05	1.01E+06	0.00E+00	0.00E+00	1.06E+07
Te-127M	1.01E+07	3.59E+06	1.20E+06	2.41E+06	4.10E+07	0.00E+00	2.52E+07
Te-127	1.48E+02	5.25E+01	3.19E+01	1.02E+02	6.00E+02	0.00E+00	1.14E+04
Te-129M	1.32E+07	4.90E+06	2.09E+06	4.26E+06	5.53E+07	0.00E+00	4.96E+07
Te-129	6.24E-11	2.33E-11	1.52E-11	4.46E-11	2.62E-10	0.00E+00	3.41E-10
Te-131M	7.88E+04	3.78E+04	3.15E+04	5.68E+04	3.94E+05	0.00E+00	3.03E+06
Te-131	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-132	5.13E+05	3.25E+05	3.06E+05	3.42E+05	3.12E+06	0.00E+00	1.03E+07
I-130	8.82E+05	2.55E+06	1.02E+06	2.08E+08	3.93E+06	0.00E+00	1.96E+06
I-131	6.45E+08	9.02E+08	4.85E+08	2.63E+11	1.55E+09	0.00E+00	1.78E+08
I-132	3.50E-01	9.17E-01	3.29E-01	3.09E+01	1.44E+00	0.00E+00	3.99E-01
I-133	8.50E+06	1.44E+07	4.40E+06	2.01E+09	2.53E+07	0.00E+00	1.09E+07
I-134	4.03E-12	1.07E-11	3.83E-12	1.78E-10	1.68E-11	0.00E+00	1.41E-13
I-135	2.75E+04	7.09E+04	2.63E+04	4.56E+06	1.12E+05	0.00E+00	7.85E+04
Cs-134	2.94E+10	6.93E+10	3.22E+10	0.00E+00	2.20E+10	8.41E+09	8.62E+08
Cs-136	1.34E+09	5.28E+09	3.54E+09	0.00E+00	2.87E+09	4.53E+08	4.25E+08
Cs-137	4.02E+10	5.34E+10	1.86E+10	0.00E+00	1.82E+10	7.06E+09	7.60E+08
Cs-138	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-139	9.84E-09	6.92E-12	2.87E-10	0.00E+00	6.53E-12	4.77E-12	8.78E-08
Ba-140	5.82E+06	7.14E+03	3.75E+05	0.00E+00	2.42E+03	4.80E+03	8.98E+06
Ba-141	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La-140	9.75E-01	4.79E-01	1.27E-01	0.00E+00	0.00E+00	0.00E+00	2.75E+04
La-142	4.09E-12	1.82E-12	4.53E-13	0.00E+00	0.00E+00	0.00E+00	5.53E-08
Ce-141	1.07E+03	7.12E+02	8.17E+01	0.00E+00	3.35E+02	0.00E+00	2.04E+06
Ce-143	9.15E+00	6.66E+03	7.44E-01	0.00E+00	2.99E+00	0.00E+00	2.00E+05
Ce-144	7.90E+04	3.27E+04	4.24E+03	0.00E+00	1.95E+04	0.00E+00	1.99E+07
Pr-143	3.48E+01	1.39E+01	1.73E+00	0.00E+00	8.08E+00	0.00E+00	1.15E+05
Pr-144	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd-147	2.19E+01	2.38E+01	1.43E+00	0.00E+00	1.40E+01	0.00E+00	8.59E+04
W-187	1.43E+03	1.17E+03	4.08E+02	0.00E+00	0.00E+00	0.00E+00	3.15E+05
Np-239	8.40E-01	7.92E-02	4.40E-02	0.00E+00	2.49E-01	0.00E+00	1.27E+04

Notes:

1) *Units are m^2 mrem/yr per μCi/sec with the exception of H-3.*

2) For H-3, the units are mrem/yr per $\mu Ci/m^3$.

Table 14b
Child Grass-Goat-Milk Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	1.83E+03	1.83E+03	1.83E+03	1.83E+03	1.83E+03	1.83E+03
Na-24	1.07E+06	1.07E+06	1.07E+06	1.07E+06	1.07E+06	1.07E+06	1.07E+06
Cr-51	0.00E+00	0.00E+00	1.22E+04	6.78E+03	1.85E+03	1.24E+04	6.47E+05
Mn-54	0.00E+00	2.52E+06	6.70E+05	0.00E+00	7.06E+05	0.00E+00	2.11E+06
Mn-56	0.00E+00	1.53E-03	3.46E-04	0.00E+00	1.85E-03	0.00E+00	2.22E-01
Fe-55	1.45E+06	7.71E+05	2.39E+05	0.00E+00	0.00E+00	4.36E+05	1.43E+05
Fe-59	1.56E+06	2.53E+06	1.26E+06	0.00E+00	0.00E+00	7.33E+05	2.63E+06
Co-58	0.00E+00	1.46E+06	4.46E+06	0.00E+00	0.00E+00	0.00E+00	8.49E+06
Co-60	0.00E+00	5.18E+06	1.53E+07	0.00E+00	0.00E+00	0.00E+00	2.87E+07
Ni-63	3.56E+09	1.90E+08	1.21E+08	0.00E+00	0.00E+00	0.00E+00	1.28E+07
Ni-65	1.99E-01	1.87E-02	1.09E-02	0.00E+00	0.00E+00	0.00E+00	2.29E+00
Cu-64	0.00E+00	8.24E+03	4.98E+03	0.00E+00	1.99E+04	0.00E+00	3.87E+05
Zn-65	4.96E+08	1.32E+09	8.22E+08	0.00E+00	8.33E+08	0.00E+00	2.32E+08
Zn-69	1.09E-12	1.58E-12	1.46E-13	0.00E+00	9.57E-13	0.00E+00	9.95E-11
Br-83	0.00E+00	0.00E+00	5.24E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	1.05E+09	6.48E+08	0.00E+00	0.00E+00	0.00E+00	6.78E+07
Rb-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-89	1.39E+10	0.00E+00	3.97E+08	0.00E+00	0.00E+00	0.00E+00	5.38E+08
Sr-90	3.53E+11	0.00E+00	7.11E+09	0.00E+00	0.00E+00	0.00E+00	3.16E+09
Sr-91	2.72E+05	0.00E+00	1.03E+04	0.00E+00	0.00E+00	0.00E+00	6.00E+05
Sr-92	4.54E+00	0.00E+00	1.82E-01	0.00E+00	0.00E+00	0.00E+00	8.60E+01
Y-90	3.87E+01	0.00E+00	1.04E+00	0.00E+00	0.00E+00	0.00E+00	1.10E+05
Y-91M	3.45E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.75E-17
Y-91	4.68E+03	0.00E+00	1.25E+02	0.00E+00	0.00E+00	0.00E+00	6.24E+05
Y-92	3.03E-05	0.00E+00	8.67E-07	0.00E+00	0.00E+00	0.00E+00	8.75E-01
Y-93	1.20E-01	0.00E+00	3.31E-03	0.00E+00	0.00E+00	0.00E+00	1.80E+03
Zr-95	4.60E+02	1.01E+02	9.00E+01	0.00E+00	1.45E+02	0.00E+00	1.05E+05
Zr-97	2.30E-01	3.32E-02	1.96E-02	0.00E+00	4.77E-02	0.00E+00	5.03E+03
Nb-95	3.82E+04	1.49E+04	1.06E+04	0.00E+00	1.40E+04	0.00E+00	2.75E+07
Mo-99	0.00E+00	9.75E+06	2.41E+06	0.00E+00	2.08E+07	0.00E+00	8.06E+06
Tc- 99M	1.58E+00	3.10E+00	5.14E+01	0.00E+00	4.50E+01	1.57E+00	1.76E+03
Tc-101	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	5.14E+02	0.00E+00	1.97E+02	0.00E+00	1.29E+03	0.00E+00	1.33E+04
Ru-105	4.55E-04	0.00E+00	1.65E-04	0.00E+00	4.00E-03	0.00E+00	2.97E-01
Ru-106	1.11E+04	0.00E+00	1.38E+03	0.00E+00	1.50E+04	0.00E+00	1.72E+05
Ag-110M	2.51E+07	1.69E+07	1.35E+07	0.00E+00	3.15E+07	0.00E+00	2.01E+09

Table 14b (Continued)
Child Grass-Goat-Milk Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	8.86E+06	2.40E+06	1.18E+06	2.49E+06	0.00E+00	0.00E+00	8.55E+06
Te-127M	2.50E+07	6.72E+06	2.96E+06	5.97E+06	7.12E+07	0.00E+00	2.02E+07
Te-127	3.64E+02	9.83E+01	7.82E+01	2.52E+02	1.04E+03	0.00E+00	1.42E+04
Te-129M	3.26E+07	9.09E+06	5.05E+06	1.05E+07	9.56E+07	0.00E+00	3.97E+07
Te-129	1.54E-10	4.30E-11	3.66E-11	1.10E-10	4.51E-10	0.00E+00	9.59E-09
Te-131M	1.92E+05	6.63E+04	7.06E+04	1.36E+05	6.42E+05	0.00E+00	2.69E+06
Te-131	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-132	1.22E+06	5.42E+05	6.55E+05	7.89E+05	5.03E+06	0.00E+00	5.46E+06
I-130	2.06E+06	4.17E+06	2.15E+06	4.59E+08	6.23E+06	0.00E+00	1.95E+06
I-131	1.56E+09	1.57E+09	8.94E+08	5.20E+11	2.58E+09	0.00E+00	1.40E+08
I-132	8.29E-01	1.52E+00	7.00E-01	7.07E+01	2.33E+00	0.00E+00	1.79E+00
I-133	2.06E+07	2.55E+07	9.66E+06	4.74E+09	4.25E+07	0.00E+00	1.03E+07
I-134	9.53E-12	1.77E-11	8.14E-12	4.07E-10	2.71E-11	0.00E+00	1.17E-11
I-135	6.52E+04	1.17E+05	5.55E+04	1.04E+07	1.80E+05	0.00E+00	8.94E+04
Cs-134	6.79E+10	1.11E+11	2.35E+10	0.00E+00	3.45E+10	1.24E+10	6.01E+08
Cs-136	3.03E+09	8.32E+09	5.39E+09	0.00E+00	4.43E+09	6.61E+08	2.92E+08
Cs-137	9.67E+10	9.26E+10	1.37E+10	0.00E+00	3.02E+10	1.09E+10	5.80E+08
Cs-138	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-139	2.42E-08	1.29E-11	7.01E-10	0.00E+00	1.13E-11	7.59E-12	1.40E-06
Ba-140	1.41E+07	1.23E+04	8.21E+05	0.00E+00	4.01E+03	7.34E+03	7.12E+06
Ba-141	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La-140	2.33E+00	8.16E-01	2.75E-01	0.00E+00	0.00E+00	0.00E+00	2.27E+04
La-142	9.88E-12	3.15E-12	9.87E-13	0.00E+00	0.00E+00	0.00E+00	6.24E-07
Ce-141	2.62E+03	1.31E+03	1.94E+02	0.00E+00	5.74E+02	0.00E+00	1.63E+06
Ce-143	2.25E+01	1.22E+04	1.76E+00	0.00E+00	5.11E+00	0.00E+00	1.78E+05
Ce-144	1.95E+05	6.11E+04	1.04E+04	0.00E+00	3.38E+04	0.00E+00	1.59E+07
Pr-143	8.62E+01	2.59E+01	4.28E+00	0.00E+00	1.40E+01	0.00E+00	9.30E+04
Pr-144	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd-147	5.37E+01	4.35E+01	3.37E+00	0.00E+00	2.39E+01	0.00E+00	6.89E+04
W-187	3.47E+03	2.05E+03	9.21E+02	0.00E+00	0.00E+00	0.00E+00	2.88E+05
Np-239	2.07E+00	1.48E-01	1.04E-01	0.00E+00	4.29E-01	0.00E+00	1.10E+04

Notes:

1) Units are m^2 mrem/yr per μCi/sec with the exception of H-3.

2) For H-3, the units are mrem/yr per $\mu Ci/m^3$.

Table 14c
Infant Grass-Goat-Milk Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	2.78E+03	2.78E+03	2.78E+03	2.78E+03	2.78E+03	2.78E+03
Na-24	1.87E+06	1.87E+06	1.87E+06	1.87E+06	1.87E+06	1.87E+06	1.87E+06
Cr-51	0.00E+00	0.00E+00	1.93E+04	1.26E+04	2.76E+03	2.46E+04	5.64E+05
Mn-54	0.00E+00	4.68E+06	1.06E+06	0.00E+00	1.04E+06	0.00E+00	1.72E+06
Mn-56	0.00E+00	3.75E-03	6.47E-04	0.00E+00	3.22E-03	0.00E+00	3.41E-01
Fe-55	1.76E+06	1.13E+06	3.03E+05	0.00E+00	0.00E+00	5.55E+05	1.44E+05
Fe-59	2.92E+06	5.09E+06	2.01E+06	0.00E+00	0.00E+00	1.51E+06	2.43E+06
Co-58	0.00E+00	2.91E+06	7.26E+06	0.00E+00	0.00E+00	0.00E+00	7.25E+06
Co-60	0.00E+00	1.06E+07	2.50E+07	0.00E+00	0.00E+00	0.00E+00	2.52E+07
Ni-63	4.19E+09	2.59E+08	1.45E+08	0.00E+00	0.00E+00	0.00E+00	1.29E+07
Ni-65	4.21E-01	4.77E-02	2.17E-02	0.00E+00	0.00E+00	0.00E+00	3.63E+00
Cu-64	0.00E+00	2.05E+04	9.48E+03	0.00E+00	3.46E+04	0.00E+00	4.20E+05
Zn-65	6.66E+08	2.28E+09	1.05E+09	0.00E+00	1.11E+09	0.00E+00	1.93E+09
Zn-69	2.33E-12	4.19E-12	3.12E-13	0.00E+00	1.74E-12	0.00E+00	3.42E-10
Br-83	0.00E+00	0.00E+00	1.11E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	2.67E+09	1.32E+09	0.00E+00	0.00E+00	0.00E+00	6.84E+07
Rb-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-89	2.64E+10	0.00E+00	7.58E+08	0.00E+00	0.00E+00	0.00E+00	5.43E+08
Sr-90	3.91E+11	0.00E+00	7.92E+09	0.00E+00	0.00E+00	0.00E+00	3.19E+09
Sr-91	5.66E+05	0.00E+00	2.05E+04	0.00E+00	0.00E+00	0.00E+00	6.70E+05
Sr-92	9.65E+00	0.00E+00	3.59E-01	0.00E+00	0.00E+00	0.00E+00	1.04E+02
Y-90	8.19E+01	0.00E+00	2.20E+00	0.00E+00	0.00E+00	0.00E+00	1.13E+05
Y-91M	7.31E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.44E-16
Y-91	8.79E+03	0.00E+00	2.34E+02	0.00E+00	0.00E+00	0.00E+00	6.30E+05
Y-92	6.44E-05	0.00E+00	1.81E-06	0.00E+00	0.00E+00	0.00E+00	1.23E+00
Y-93	2.57E-01	0.00E+00	6.99E-03	0.00E+00	0.00E+00	0.00E+00	2.03E+03
Zr-95	8.17E+02	1.99E+02	1.41E+02	0.00E+00	2.15E+02	0.00E+00	9.91E+04
Zr-97	4.87E-01	8.35E-02	3.81E-02	0.00E+00	8.42E-02	0.00E+00	5.33E+03
Nb-95	7.13E+04	2.94E+04	1.70E+04	0.00E+00	2.10E+04	0.00E+00	2.48E+07
Mo-99	0.00E+00	2.49E+07	4.86E+06	0.00E+00	3.72E+07	0.00E+00	8.21E+06
Tc- 99M	3.29E+00	6.78E+00	8.73E+01	0.00E+00	7.29E+01	3.54E+00	1.97E+03
Tc-101	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	1.04E+03	0.00E+00	3.48E+02	0.00E+00	2.16E+03	0.00E+00	1.27E+04
Ru-105	9.60E-04	0.00E+00	3.23E-04	0.00E+00	7.06E-03	0.00E+00	3.82E-01
Ru-106	2.28E+04	0.00E+00	2.85E+03	0.00E+00	2.70E+04	0.00E+00	1.73E+05
Ag-110M	4.63E+07	3.38E+07	2.24E+07	0.00E+00	4.84E+07	0.00E+00	1.75E+09

Table 14c (Continued)
Infant Grass-Goat-Milk Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	1.81E+07	6.05E+06	2.45E+06	6.09E+06	0.00E+00	0.00E+00	8.62E+06
Te-127M	5.05E+07	1.68E+07	6.12E+06	1.46E+07	1.24E+08	0.00E+00	2.04E+07
Te-127	7.74E+02	2.59E+02	1.66E+02	6.30E+02	1.89E+03	0.00E+00	1.63E+04
Te-129M	6.68E+07	2.29E+07	1.03E+07	2.57E+07	1.67E+08	0.00E+00	3.99E+07
Te-129	3.26E-10	1.13E-10	7.62E-11	2.74E-10	8.13E-10	0.00E+00	2.61E-08
Te-131M	4.05E+05	1.63E+05	1.35E+05	3.30E+05	1.12E+06	0.00E+00	2.74E+06
Te-131	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-132	2.52E+06	1.25E+06	1.17E+06	1.84E+06	7.81E+06	0.00E+00	4.62E+06
I-130	4.24E+06	9.32E+06	3.74E+06	1.04E+09	1.02E+07	0.00E+00	2.00E+06
I-131	3.26E+09	3.85E+09	1.69E+09	1.26E+12	4.49E+09	0.00E+00	1.37E+08
I-132	1.72E+00	3.49E+00	1.24E+00	1.64E+02	3.90E+00	0.00E+00	2.83E+00
I-133	4.36E+07	6.35E+07	1.86E+07	1.15E+10	7.46E+07	0.00E+00	1.07E+07
I-134	1.98E-11	4.05E-11	1.44E-11	9.44E-10	4.53E-11	0.00E+00	4.19E-11
I-135	1.36E+05	2.70E+05	9.83E+04	2.42E+07	3.01E+05	0.00E+00	9.76E+04
Cs-134	1.09E+11	2.04E+11	2.06E+10	0.00E+00	5.25E+10	2.15E+10	5.54E+08
Cs-136	5.91E+09	1.74E+10	6.49E+09	0.00E+00	6.93E+09	1.42E+09	2.64E+08
Cs-137	1.54E+11	1.81E+11	1.28E+10	0.00E+00	4.85E+10	1.96E+10	5.65E+08
Cs-138	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-139	5.14E-08	3.41E-11	1.49E-09	0.00E+00	2.05E-11	2.07E-11	3.26E-06
Ba-140	2.89E+07	2.89E+04	1.49E+06	0.00E+00	6.87E+03	1.78E+04	7.11E+06
Ba-141	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La-140	4.88E+00	1.92E+00	4.95E-01	0.00E+00	0.00E+00	0.00E+00	2.26E+04
La-142	2.08E-11	7.62E-12	1.82E-12	0.00E+00	0.00E+00	0.00E+00	1.29E-06
Ce-141	5.20E+03	3.17E+03	3.73E+02	0.00E+00	9.78E+02	0.00E+00	1.64E+06
Ce-143	4.75E+01	3.15E+04	3.60E+00	0.00E+00	9.19E+00	0.00E+00	1.84E+05
Ce-144	2.79E+05	1.14E+05	1.56E+04	0.00E+00	4.62E+04	0.00E+00	1.60E+07
Pr-143	1.78E+02	6.67E+01	8.84E+00	0.00E+00	2.48E+01	0.00E+00	9.41E+04
Pr-144	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd-147	1.07E+02	1.09E+02	6.70E+00	0.00E+00	4.22E+01	0.00E+00	6.93E+04
W-187	7.29E+03	5.07E+03	1.75E+03	0.00E+00	0.00E+00	0.00E+00	2.98E+05
Np-239	4.37E+00	3.91E-01	2.21E-01	0.00E+00	7.80E-01	0.00E+00	1.13E+04

Notes:

1) Units are m^2 mrem/yr per μCi/sec with the exception of H-3.

2) For H-3, the units are mrem/yr per $\mu Ci/m^3$.

Table 15
Adult Grass-Cow-Meat Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	1.85E+02	1.85E+02	1.85E+02	1.85E+02	1.85E+02	1.85E+02
Na-24	1.45E-03	1.45E-03	1.45E-03	1.45E-03	1.45E-03	1.45E-03	1.45E-03
Cr-51	0.00E+00	0.00E+00	7.04E+03	4.21E+03	1.55E+03	9.34E+03	1.77E+06
Mn-54	0.00E+00	9.18E+06	1.75E+06	0.00E+00	2.73E+06	0.00E+00	2.81E+07
Mn-56	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Fe-55	2.93E+08	2.03E+08	4.72E+07	0.00E+00	0.00E+00	1.13E+08	1.16E+08
Fe-59	2.65E+08	6.24E+08	2.39E+08	0.00E+00	0.00E+00	1.74E+08	2.08E+09
Co-58	0.00E+00	1.82E+07	4.09E+07	0.00E+00	0.00E+00	0.00E+00	3.70E+08
Co-60	0.00E+00	7.52E+07	1.66E+08	0.00E+00	0.00E+00	0.00E+00	1.41E+09
Ni-63	1.89E+10	1.31E+09	6.33E+08	0.00E+00	0.00E+00	0.00E+00	2.73E+08
Ni-65	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cu-64	0.00E+00	2.52E-07	1.18E-07	0.00E+00	6.36E-07	0.00E+00	2.15E-05
Zn-65	3.56E+08	1.13E+09	5.12E+08	0.00E+00	7.57E+08	0.00E+00	7.13E+08
Zn-69	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-83	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	4.88E+08	2.28E+08	0.00E+00	0.00E+00	0.00E+00	9.63E+07
Rb-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-89	3.01E+08	0.00E+00	8.65E+06	0.00E+00	0.00E+00	0.00E+00	4.83E+07
Sr-90	1.43E+10	0.00E+00	2.87E+08	0.00E+00	0.00E+00	0.00E+00	3.59E+08
Sr-91	1.43E-10	0.00E+00	5.79E-12	0.00E+00	0.00E+00	0.00E+00	6.83E-10
Sr-92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y-90	1.08E+02	0.00E+00	2.91E+00	0.00E+00	0.00E+00	0.00E+00	1.15E+06
Y-91M	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y-91	1.13E+06	0.00E+00	3.03E+04	0.00E+00	0.00E+00	0.00E+00	6.23E+08
Y-92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y-93	4.39E-12	0.00E+00	1.21E-13	0.00E+00	0.00E+00	0.00E+00	1.39E-07
Zr-95	1.87E+06	6.01E+05	4.07E+05	0.00E+00	9.43E+05	0.00E+00	1.91E+09
Zr-97	2.04E-05	4.12E-06	1.88E-06	0.00E+00	6.22E-06	0.00E+00	1.28E+00
Nb-95	2.30E+06	1.28E+06	6.89E+05	0.00E+00	1.27E+06	0.00E+00	7.78E+09
Mo-99	0.00E+00	9.93E+04	1.89E+04	0.00E+00	2.25E+05	0.00E+00	2.30E+05
Tc- 99M	0.00E+00	1.22E-20	1.56E-19	0.00E+00	1.85E-19	0.00E+00	7.23E-18
Tc-101	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	1.05E+08	0.00E+00	4.53E+07	0.00E+00	4.01E+08	0.00E+00	1.23E+10
Ru-105	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-106	2.80E+09	0.00E+00	3.54E+08	0.00E+00	5.40E+09	0.00E+00	1.81E+11
Ag-110M	6.68E+06	6.18E+06	3.67E+06	0.00E+00	1.22E+07	0.00E+00	2.52E+09

Table 15 (Continued)
Adult Grass-Cow-Meat Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	3.59E+08	1.30E+08	4.81E+07	1.08E+08	1.46E+09	0.00E+00	1.43E+09
Te-127M	1.12E+09	3.99E+08	1.36E+08	2.85E+08	4.53E+09	0.00E+00	3.74E+09
Te-127	2.50E-10	8.98E-11	5.41E-11	1.85E-10	1.02E-09	0.00E+00	1.97E-08
Te-129M	1.13E+09	4.23E+08	1.79E+08	3.89E+08	4.73E+09	0.00E+00	5.71E+09
Te-129	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-131M	4.49E+02	2.20E+02	1.83E+02	3.48E+02	2.23E+03	0.00E+00	2.18E+04
Te-131	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-132	1.40E+06	9.03E+05	8.48E+05	9.98E+05	8.70E+06	0.00E+00	4.27E+07
I-130	2.03E-06	5.98E-06	2.36E-06	5.07E-04	9.33E-06	0.00E+00	5.15E-06
I-131	1.07E+07	1.54E+07	8.80E+06	5.03E+09	2.63E+07	0.00E+00	4.05E+06
I-132	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-133	3.70E-01	6.43E-01	1.96E-01	9.45E+01	1.12E+00	0.00E+00	5.78E-01
I-134	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-135	4.66E-17	1.22E-16	4.50E-17	8.04E-15	1.95E-16	0.00E+00	1.38E-16
Cs-134	6.58E+08	1.57E+09	1.28E+09	0.00E+00	5.07E+08	1.68E+08	2.74E+07
Cs-136	1.20E+07	4.73E+07	3.40E+07	0.00E+00	2.63E+07	3.61E+06	5.37E+06
Cs-137	8.72E+08	1.19E+09	7.81E+08	0.00E+00	4.05E+08	1.35E+08	2.31E+07
Cs-138	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-139	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-140	2.88E+07	3.61E+04	1.88E+06	0.00E+00	1.23E+04	2.07E+04	5.92E+07
Ba-141	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La-140	3.76E-02	1.90E-02	5.01E-03	0.00E+00	0.00E+00	0.00E+00	1.39E+03
La-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce-141	1.40E+04	9.49E+03	1.08E+03	0.00E+00	4.41E+03	0.00E+00	3.63E+07
Ce-143	1.99E-02	1.47E+01	1.63E-03	0.00E+00	6.47E-03	0.00E+00	5.49E+02
Ce-144	1.46E+06	6.09E+05	7.83E+04	0.00E+00	3.61E+05	0.00E+00	4.93E+08
Pr-143	2.10E+04	8.42E+03	1.04E+03	0.00E+00	4.86E+03	0.00E+00	9.20E+07
Pr-144	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd-147	7.21E+03	8.33E+03	4.98E+02	0.00E+00	4.87E+03	0.00E+00	4.00E+07
W-187	2.07E-02	1.73E-02	6.04E-03	0.00E+00	0.00E+00	0.00E+00	5.66E+00
Np-239	2.57E-01	2.53E-02	1.40E-02	0.00E+00	7.90E-02	0.00E+00	5.19E+03

Notes:

1) Units are m^2 mrem/yr per μCi/sec with the exception of H-3.

2) For H-3, the units are mrem/yr per $\mu Ci/m^3$.

Table 15a
Teen Grass-Cow-Meat Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	1.10E+02	1.10E+02	1.10E+02	1.10E+02	1.10E+02	1.10E+02
Na-24	1.16E-03	1.16E-03	1.16E-03	1.16E-03	1.16E-03	1.16E-03	1.16E-03
Cr-51	0.00E+00	0.00E+00	5.63E+03	3.13E+03	1.23E+03	8.04E+03	9.46E+05
Mn-54	0.00E+00	7.00E+06	1.39E+06	0.00E+00	2.09E+06	0.00E+00	1.44E+07
Mn-56	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Fe-55	2.38E+08	1.69E+08	3.94E+07	0.00E+00	0.00E+00	1.07E+08	7.31E+07
Fe-59	2.12E+08	4.95E+08	1.91E+08	0.00E+00	0.00E+00	1.56E+08	1.17E+09
Co-58	0.00E+00	1.41E+07	3.24E+07	0.00E+00	0.00E+00	0.00E+00	1.94E+08
Co-60	0.00E+00	5.83E+07	1.31E+08	0.00E+00	0.00E+00	0.00E+00	7.60E+08
Ni-63	1.52E+10	1.07E+09	5.15E+08	0.00E+00	0.00E+00	0.00E+00	1.71E+08
Ni-65	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cu-64	0.00E+00	2.06E-07	9.68E-08	0.00E+00	5.21E-07	0.00E+00	1.60E-05
Zn-65	2.50E+08	8.69E+08	4.05E+08	0.00E+00	5.56E+08	0.00E+00	3.68E+08
Zn-69	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-83	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	4.08E+08	1.91E+08	0.00E+00	0.00E+00	0.00E+00	6.03E+07
Rb-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-89	2.54E+08	0.00E+00	7.28E+06	0.00E+00	0.00E+00	0.00E+00	3.03E+07
Sr-90	9.89E+09	0.00E+00	1.98E+08	0.00E+00	0.00E+00	0.00E+00	2.26E+08
Sr-91	1.21E-10	0.00E+00	4.80E-12	0.00E+00	0.00E+00	0.00E+00	5.47E-10
Sr-92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y-90	9.13E+01	0.00E+00	2.46E+00	0.00E+00	0.00E+00	0.00E+00	7.53E+05
Y-91M	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y-91	9.54E+05	0.00E+00	2.56E+04	0.00E+00	0.00E+00	0.00E+00	3.91E+08
Y-92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y-93	3.71E-12	0.00E+00	1.02E-13	0.00E+00	0.00E+00	0.00E+00	1.13E-07
Zr-95	1.50E+06	4.74E+05	3.26E+05	0.00E+00	6.96E+05	0.00E+00	1.09E+09
Zr-97	1.70E-05	3.37E-06	1.55E-06	0.00E+00	5.10E-06	0.00E+00	9.11E-01
Nb-95	1.80E+06	9.98E+05	5.49E+05	0.00E+00	9.67E+05	0.00E+00	4.27E+09
Mo-99	0.00E+00	8.21E+04	1.57E+04	0.00E+00	1.88E+05	0.00E+00	1.47E+05
Tc- 99M	0.00E+00	0.00E+00	1.24E-19	0.00E+00	1.43E-19	0.00E+00	6.29E-18
Tc-101	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	8.56E+07	0.00E+00	3.66E+07	0.00E+00	3.02E+08	0.00E+00	7.15E+09
Ru-105	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-106	2.36E+09	0.00E+00	2.97E+08	0.00E+00	4.55E+09	0.00E+00	1.13E+11
Ag-110M	5.06E+06	4.79E+06	2.91E+06	0.00E+00	9.13E+06	0.00E+00	1.35E+09

Table 15a (Continued)
Teen Grass-Cow-Meat Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	3.03E+08	1.09E+08	4.06E+07	8.47E+07	0.00E+00	0.00E+00	8.95E+08
Te-127M	9.41E+08	3.34E+08	1.12E+08	2.24E+08	3.82E+09	0.00E+00	2.35E+09
Te-127	2.12E-10	7.53E-11	4.57E-11	1.46E-10	8.60E-10	0.00E+00	1.64E-08
Te-129M	9.49E+08	3.52E+08	1.50E+08	3.06E+08	3.97E+09	0.00E+00	3.56E+09
Te-129	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-131M	3.75E+02	1.80E+02	1.50E+02	2.70E+02	1.87E+03	0.00E+00	1.44E+04
Te-131	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-132	1.14E+06	7.24E+05	6.81E+05	7.63E+05	6.94E+06	0.00E+00	2.29E+07
I-130	1.63E-06	4.72E-06	1.88E-06	3.85E-04	7.27E-06	0.00E+00	3.63E-06
I-131	8.92E+06	1.25E+07	6.71E+06	3.64E+09	2.15E+07	0.00E+00	2.47E+06
I-132	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-133	3.09E-01	5.25E-01	1.60E-01	7.32E+01	9.20E-01	0.00E+00	3.97E-01
I-134	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-135	3.79E-17	9.75E-17	3.61E-17	6.27E-15	1.54E-16	0.00E+00	1.08E-16
Cs-134	5.23E+08	1.23E+09	5.71E+08	0.00E+00	3.91E+08	1.49E+08	1.53E+07
Cs-136	9.34E+06	3.68E+07	2.47E+07	0.00E+00	2.00E+07	3.15E+06	2.96E+06
Cs-137	7.24E+08	9.63E+08	3.36E+08	0.00E+00	3.28E+08	1.27E+08	1.37E+07
Cs-138	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-139	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-140	2.38E+07	2.91E+04	1.53E+06	0.00E+00	9.88E+03	1.96E+04	3.67E+07
Ba-141	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La-140	3.09E-02	1.52E-02	4.04E-03	0.00E+00	0.00E+00	0.00E+00	8.73E+02
La-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce-141	1.18E+04	7.87E+03	9.04E+02	0.00E+00	3.70E+03	0.00E+00	2.25E+07
Ce-143	1.67E-02	1.22E+01	1.36E-03	0.00E+00	5.46E-03	0.00E+00	3.66E+02
Ce-144	1.23E+06	5.08E+05	6.60E+04	0.00E+00	3.04E+05	0.00E+00	3.09E+08
Pr-143	1.77E+04	7.05E+03	8.79E+02	0.00E+00	4.10E+03	0.00E+00	5.81E+07
Pr-144	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd-147	6.35E+03	6.90E+03	4.14E+02	0.00E+00	4.05E+03	0.00E+00	2.49E+07
W-187	1.73E-02	1.41E-02	4.94E-03	0.00E+00	0.00E+00	0.00E+00	3.82E+00
Np-239	2.25E-01	2.12E-02	1.18E-02	0.00E+00	6.66E-02	0.00E+00	3.41E+03

Notes:

1) Units are m^2 mrem/yr per μCi/sec with the exception of H-3.

2) For H-3, the units are mrem/yr per $\mu Ci/m^3$.

Table 15b
Child Grass-Cow-Meat Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	1.34E+02	1.34E+02	1.34E+02	1.34E+02	1.34E+02	1.34E+02
Na-24	1.84E-03	1.84E-03	1.84E-03	1.84E-03	1.84E-03	1.84E-03	1.84E-03
Cr-51	0.00E+00	0.00E+00	8.78E+03	4.87E+03	1.33E+03	8.90E+03	4.66E+05
Mn-54	0.00E+00	8.01E+06	2.13E+06	0.00E+00	2.25E+06	0.00E+00	6.72E+06
Mn-56	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Fe-55	4.57E+08	2.42E+08	7.51E+07	0.00E+00	0.00E+00	1.37E+08	4.49E+07
Fe-59	3.76E+08	6.08E+08	3.03E+08	0.00E+00	0.00E+00	1.76E+08	6.34E+08
Co-58	0.00E+00	1.64E+07	5.03E+07	0.00E+00	0.00E+00	0.00E+00	9.59E+07
Co-60	0.00E+00	6.93E+07	2.04E+08	0.00E+00	0.00E+00	0.00E+00	3.84E+08
Ni-63	2.91E+10	1.56E+09	9.91E+08	0.00E+00	0.00E+00	0.00E+00	1.05E+08
Ni-65	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cu-64	0.00E+00	2.77E-07	1.67E-07	0.00E+00	6.68E-07	0.00E+00	1.30E-05
Zn-65	3.75E+08	1.00E+09	6.22E+08	0.00E+00	6.30E+08	0.00E+00	1.76E+08
Zn-69	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-83	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-86	0.00E+00	5.78E+08	3.55E+08	0.00E+00	0.00E+00	0.00E+00	3.72E+07
Rb-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-89	4.81E+08	0.00E+00	1.37E+07	0.00E+00	0.00E+00	0.00E+00	1.86E+07
Sr-90	1.57E+10	0.00E+00	3.15E+08	0.00E+00	0.00E+00	0.00E+00	1.40E+08
Sr-91	2.26E-10	0.00E+00	8.54E-12	0.00E+00	0.00E+00	0.00E+00	5.00E-10
Sr-92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y-90	1.73E+02	0.00E+00	4.62E+00	0.00E+00	0.00E+00	0.00E+00	4.92E+05
Y-91M	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y-91	1.80E+06	0.00E+00	4.82E+04	0.00E+00	0.00E+00	0.00E+00	2.40E+08
Y-92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y-93	6.97E-12	0.00E+00	1.91E-13	0.00E+00	0.00E+00	0.00E+00	1.04E-07
Zr-95	2.67E+06	5.86E+05	5.22E+05	0.00E+00	8.39E+05	0.00E+00	6.11E+08
Zr-97	3.16E-05	4.57E-06	2.70E-06	0.00E+00	6.56E-06	0.00E+00	6.93E-01
Nb-95	3.11E+06	1.21E+06	8.64E+05	0.00E+00	1.14E+06	0.00E+00	2.24E+09
Mo-99	0.00E+00	1.14E+05	2.82E+04	0.00E+00	2.44E+05	0.00E+00	9.44E+04
Tc- 99M	0.00E+00	1.18E-20	1.96E-19	0.00E+00	1.72E-19	0.00E+00	6.72E-18
Tc-101	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103	1.55E+08	0.00E+00	5.95E+07	0.00E+00	3.90E+08	0.00E+00	4.00E+09
Ru-105	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-106	4.44E+09	0.00E+00	5.54E+08	0.00E+00	5.99E+09	0.00E+00	6.90E+10
Ag-110M	8.39E+06	5.67E+06	4.53E+06	0.00E+00	1.06E+07	0.00E+00	6.74E+08

Table 15b (Continued)
Child Grass-Cow-Meat Dose Factors

Nuclide	Bone	Liver	T Body	Thyroid	Kidney	Lung	GI-LLI
Te-125M	5.70E+08	1.54E+08	7.59E+07	1.60E+08	0.00E+00	0.00E+00	5.50E+08
Te-127M	1.77E+09	4.78E+08	2.11E+08	4.24E+08	5.06E+09	0.00E+00	1.44E+09
Te-127	3.99E-10	1.08E-10	8.56E-11	2.76E-10	1.14E-09	0.00E+00	1.56E-08
Te-129M	1.79E+09	5.00E+08	2.78E+08	5.77E+08	5.25E+09	0.00E+00	2.18E+09
Te-129	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-131M	6.97E+02	2.41E+02	2.57E+02	4.96E+02	2.33E+03	0.00E+00	9.78E+03
Te-131	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-132	2.09E+06	9.23E+05	1.12E+06	1.34E+06	8.57E+06	0.00E+00	9.30E+06
I-130	2.92E-06	5.89E-06	3.04E-06	6.49E-04	8.81E-06	0.00E+00	2.76E-06
I-131	1.65E+07	1.66E+07	9.45E+06	5.50E+09	2.73E+07	0.00E+00	1.48E+06
I-132	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-133	5.75E-01	7.10E-01	2.69E-01	1.32E+02	1.18E+00	0.00E+00	2.86E-01
I-134	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-135	6.86E-17	1.23E-16	5.84E-17	1.09E-14	1.89E-16	0.00E+00	9.40E-17
Cs-134	9.22E+08	1.51E+09	3.19E+08	0.00E+00	4.69E+08	1.68E+08	8.16E+06
Cs-136	1.61E+07	4.43E+07	2.87E+07	0.00E+00	2.36E+07	3.52E+06	1.56E+06
Cs-137	1.33E+09	1.28E+09	1.88E+08	0.00E+00	4.16E+08	1.50E+08	7.99E+06
Cs-138	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-139	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-140	4.39E+07	3.84E+04	2.56E+06	0.00E+00	1.25E+04	2.29E+04	2.22E+07
Ba-141	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La-140	5.66E-02	1.98E-02	6.67E-03	0.00E+00	0.00E+00	0.00E+00	5.52E+02
La-142	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce-141	2.22E+04	1.11E+04	1.64E+03	0.00E+00	4.85E+03	0.00E+00	1.38E+07
Ce-143	3.14E-02	1.70E+01	2.46E-03	0.00E+00	7.14E-03	0.00E+00	2.49E+02
Ce-144	2.32E+06	7.26E+05	1.24E+05	0.00E+00	4.02E+05	0.00E+00	1.89E+08
Pr-143	3.34E+04	1.00E+04	1.66E+03	0.00E+00	5.44E+03	0.00E+00	3.61E+07
Pr-144	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nd-147	1.19E+04	9.65E+03	7.47E+02	0.00E+00	5.29E+03	0.00E+00	1.53E+07
W-187	3.21E-02	1.90E-02	8.52E-03	0.00E+00	0.00E+00	0.00E+00	2.67E+00
Np-239	4.23E-01	3.04E-02	2.14E-02	0.00E+00	8.79E-02	0.00E+00	2.25E+03

Notes:

1) Units are m^2 mrem/yr per μCi/sec with the exception of H-3.

2) For H-3, the units are mrem/yr per $\mu Ci/m^3$.

3) The infant age group is assumed to receive no dose through the meat ingestion pathway therefore no dose factors are supplied.

Supplemental Table A
Mixed Mode Joint Frequency Distribution Table Summaries

250 Foot Elevation Data

Summary Table of Percent by Direction and Class

Class	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
A	.267	.504	.349	.248	.243	.315	.542	.409	.247	.214	.336	.440	.648	.737	.705	.400	6.604
B	.068	.110	.085	.055	.079	.069	.118	.117	.067	.050	.090	.105	.143	.138	.143	.152	1.590
C	.104	.162	.121	.059	.098	.087	.142	.139	.071	.065	.104	.132	.139	.141	.183	.146	1.892
D	.745	.992	.685	.498	.544	.536	.741	.887	.552	.603	.978	.933	1.115	1.136	1.361	1.003	13.309
E	1.512	1.507	1.234	1.161	1.021	.924	1.376	1.887	1.597	1.672	2.358	2.073	2.051	2.097	2.238	1.620	26.327
F	.729	.603	.521	.386	.409	.410	.568	.923	1.196	1.133	1.354	.977	.897	.875	.858	.644	12.483
G	.499	.412	.352	.283	.246	.247	.362	.700	1.366	1.480	1.008	.612	.421	.428	.463	.388	9.265
Total	3.924	4.292	3.346	2.689	2.640	2.588	3.848	5.062	5.097	5.217	6.227	5.272	5.414	5.552	5.950	4.353	71.471

Summary Table of Percent by Direction and Speed

Speed	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
.45	.003	.000	.005	.013	.009	.008	.000	.010	.014	.002	.000	.003	.000	.001	.001	.005	.074
1.05	.023	.022	.026	.043	.027	.036	.030	.035	.026	.023	.027	.027	.027	.030	.026	.031	.459
2.05	.194	.172	.200	.239	.270	.267	.262	.260	.224	.187	.189	.158	.159	.217	.213	.180	3.391
3.05	.320	.372	.529	.560	.576	.515	.586	.601	.414	.362	.393	.318	.343	.433	.572	.344	7.238
4.05	.478	.599	.629	.522	.514	.473	.722	.842	.562	.590	.595	.548	.546	.716	.831	.595	9.764
5.05	.649	.720	.650	.456	.374	.392	.753	.898	.886	.895	.937	.813	.809	1.029	1.145	.851	12.256
6.05	.656	.713	.484	.296	.247	.262	.528	.807	.976	.968	1.115	.993	.872	1.215	1.362	.971	12.467
8.05	1.106	1.257	.615	.372	.422	.478	.722	1.237	1.609	1.749	2.243	1.856	1.990	1.651	1.628	1.180	20.116
10.05	.458	.407	.191	.171	.182	.148	.229	.348	.365	.412	.677	.522	.630	.249	.164	.187	5.338
13.05	.037	.029	.016	.017	.020	.012	.017	.023	.022	.029	.048	.034	.037	.011	.007	.010	.369
18.00	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
99.00	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
Total	3.924	4.292	3.346	2.689	2.640	2.588	3.848	5.062	5.097	5.217	6.227	5.272	5.414	5.552	5.950	4.353	71.471

NOTE: Wind directions in tables are presented in "wind from" and not "wind to" direction.

In order to determine the final mixed mode values, 71.471% of the elevated value (presented in the 250 FT Mixed Mode table) and 28.529% of the ground level value (presented in the 30 FT Mixed Mode table) are used to calculate the final values.

Supplemental Table A - Continued
Mixed Mode Joint Frequency Distribution Table Summaries

250 Foot Elevation Data

Summary Table of Percent by Speed and Class

Class Speed	A	B	C	D	E	F	G
.45	.001	.000	.003	.006	.025	.016	.023
1.05	.006	.004	.005	.034	.147	.070	.193
2.05	.119	.048	.074	.456	1.047	.616	1.031
3.05	.564	.166	.196	1.332	2.330	1.167	1.485
4.05	.940	.221	.275	1.932	3.494	1.459	1.443
5.05	1.250	.267	.320	2.204	4.388	2.178	1.647
6.05	1.204	.321	.306	2.176	4.544	2.456	1.460
8.05	1.923	.401	.539	3.884	7.909	3.699	1.760
10.05	.560	.151	.161	1.188	2.279	.784	.215
13.05	.037	.011	.013	.096	.165	.039	.007
18.00	.000	.000	.000	.000	.000	.000	.000
99.00	.000	.000	.000	.000	.000	.000	.000

Supplemental Table A - Continued

Mixed Mode Joint Frequency Distribution Table Summaries

35 Foot Elevation Data

Summary Table of Percent by Direction and Class

Class	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
A	.325	.401	.141	.095	.077	.100	.120	.122	.108	.127	.198	.209	.332	.278	.210	.186	3.029
B	.093	.099	.037	.028	.020	.014	.021	.048	.041	.020	.056	.061	.080	.049	.050	.058	.775
C	.103	.122	.047	.027	.030	.028	.028	.047	.029	.031	.065	.077	.090	.066	.054	.052	.885
D	.708	.607	.317	.291	.266	.182	.186	.283	.281	.283	.607	.505	.664	.413	.442	.396	6.431
E	1.140	.850	.531	.507	.431	.288	.289	.656	.894	.818	1.403	1.177	1.133	.621	.600	.384	11.722
F	.273	.144	.099	.098	.090	.066	.109	.165	.557	.449	.569	.436	.349	.232	.175	.109	3.919
G	.059	.029	.027	.018	.031	.038	.039	.063	.412	.289	.247	.159	.119	.114	.081	.042	1.768
Total	2.700	2.252	1.199	1.066	.946	.717	.792	1.384	2.322	2.017	3.144	2.823	2.766	1.764	1.611	1.227	28.529

Summary Table of Percent by Direction and Speed

Speed	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
.45	.001	.002	.001	.000	.001	.001	.001	.003	.002	.003	.002	.002	.000	.002	.003	.001	.025
1.05	.007	.006	.007	.008	.005	.008	.008	.009	.019	.020	.021	.012	.011	.011	.015	.011	.178
2.05	.082	.053	.034	.027	.033	.042	.058	.047	.162	.250	.218	.167	.120	.167	.218	.098	1.775
3.05	.170	.146	.103	.076	.075	.093	.180	.148	.483	.360	.315	.312	.327	.349	.356	.205	3.699
4.05	.214	.250	.157	.090	.086	.095	.183	.255	.614	.260	.350	.379	.389	.291	.350	.230	4.182
5.05	.273	.311	.149	.084	.090	.066	.127	.245	.469	.225	.369	.382	.391	.255	.251	.192	3.878
6.05	.438	.386	.181	.091	.107	.080	.083	.214	.278	.292	.470	.403	.450	.224	.211	.173	4.080
8.05	.892	.607	.268	.225	.208	.161	.118	.323	.219	.473	1.001	.677	.762	.388	.190	.262	6.175
10.05	.413	.313	.208	.333	.213	.118	.032	.114	.061	.128	.317	.209	.219	.061	.019	.046	2.80[illegible]
13.05	.178	.155	.088	.117	.102	.050	.003	.025	.015	.014	.075	.079	.085	.014	.000	.009	1.007
18.00	.032	.023	.004	.013	.025	.003	.000	.000	.000	.001	.005	.003	.012	.003	.000	.000	.123
99.00	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
Total	2.700	2.252	1.199	1.065	.946	.717	.792	1.384	2.322	2.017	3.144	2.623	2.766	1.764	1.611	1.227	28.529

NOTE: Wind directions in tables are presented in "wind from" and not "wind to" direction.

Supplemental Table A - Continued

Mixed Mode Joint Frequency Distribution Table Summaries

35 Foot Elevation Data

Summary Table of Percent by Speed and Class

Class Speed	A	B	C	D	E	F	G
.45	.000	.000	.000	.001	.003	.007	.015
1.05	.001	.000	.002	.004	.032	.048	.091
2.05	.028	.010	.010	.104	.421	.544	.658
3.05	.198	.055	.062	.486	1.333	1.014	.551
4.05	.445	.098	.104	.786	1.701	.818	.230
5.05	.424	.093	.118	.830	1.701	.582	.129
6.05	.429	.120	.146	.999	1.918	.404	.063
8.05	.937	.259	.275	1.985	2.893	.403	.023
10.05	.405	.098	.103	.845	1.270	.078	.007
13.05	.147	.039	.054	.348	.401	.019	.001
18.00	.014	.004	.012	.043	.049	.001	.000
99.00	.000	.000	.000	.000	.000	.000	.000

Supplemental Table B
Ground Level Joint Frequency Distribution Table Summaries

Summary Table of Percent by Direction and Class

Class	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
A	.573	.881	.500	.366	.343	.440	.582	.503	.397	.324	.509	.640	.941	.989	.950	.666	9.605
B	.175	.211	.131	.089	.087	.086	.113	.157	.131	.058	.139	.176	.219	.171	.215	.206	2.363
C	.213	.281	.165	.113	.103	.120	.152	.171	.115	.089	.168	.207	.235	.182	.250	.209	2.771
D	1.488	1.629	1.012	.801	.756	.681	.797	.971	1.036	.783	1.610	1.454	1.820	1.478	1.967	1.433	19.716
E	2.801	2.521	1.683	1.537	1.317	1.065	1.255	2.107	2.835	2.531	3.911	3.300	3.293	2.756	3.239	1.907	38.058
F	1.155	.710	.463	.384	.389	.313	.509	.692	1.908	1.815	1.987	1.547	1.385	1.331	1.143	.707	16.439
G	.472	.253	.176	.132	.127	.192	.258	.353	1.603	1.642	1.448	.987	1.028	1.192	.770	.416	11.049
Total	6.877	6.486	4.130	3.421	3.122	2.898	3.667	4.954	8.025	7.241	9.772	8.311	8.921	8.097	8.534	5.543	100.000

Summary Table of Percent by Direction and Speed

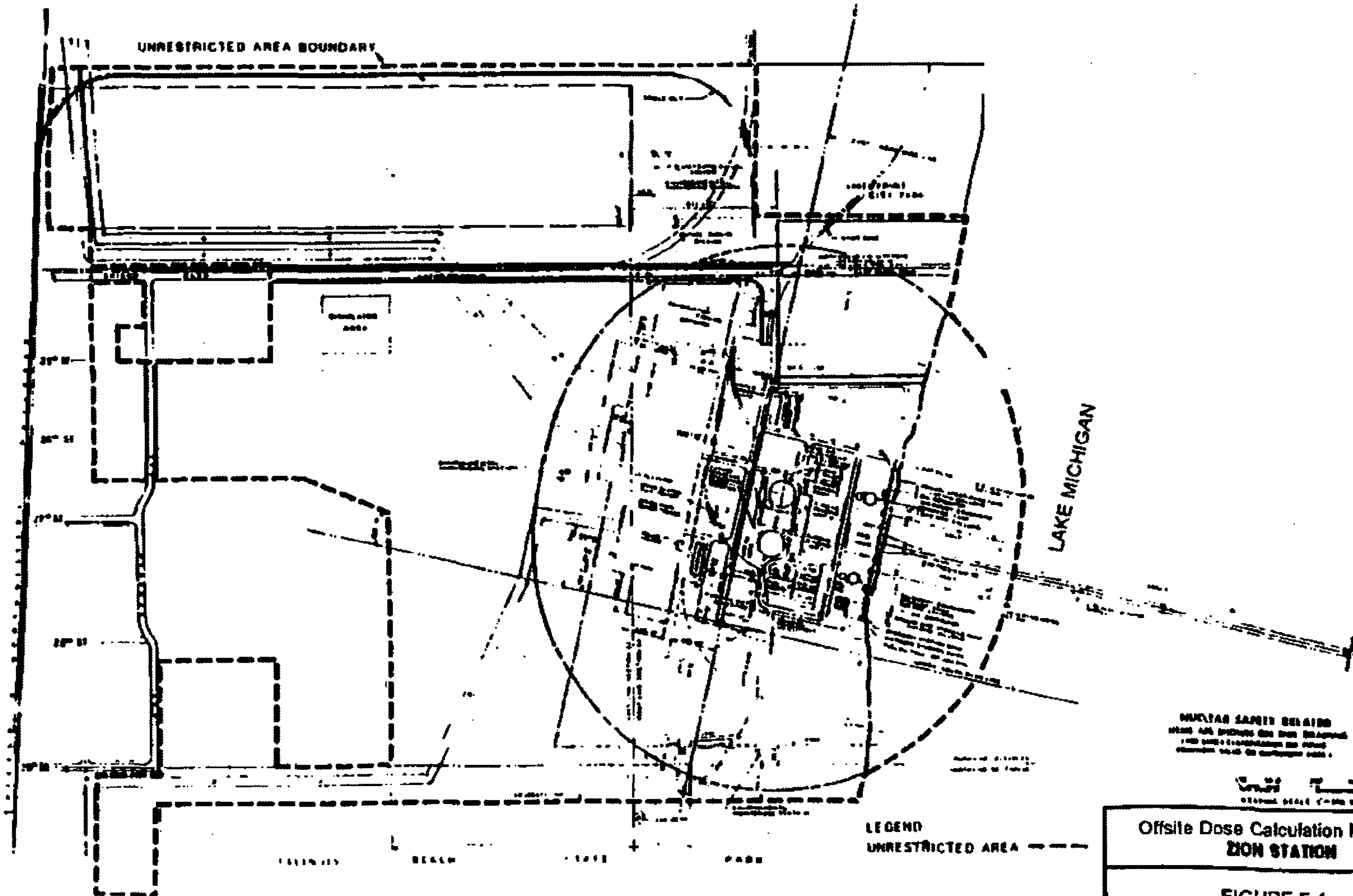
Speed	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
.45	.048	.065	.058	.009	.022	.012	.018	.037	.027	.042	.027	.052	.042	.043	.075	.054	.631
1.05	.206	.168	.156	.118	.121	.118	.135	.134	.216	.238	.271	.197	.233	.204	.350	.234	3.158
2.05	.903	.674	.518	.467	.458	.558	.636	.534	1.254	1.834	1.675	1.396	1.326	1.837	2.043	.990	17.102
3.05	1.089	1.031	.861	.743	.683	.806	1.309	1.075	2.528	1.993	1.781	1.670	1.944	2.220	2.304	1.333	23.474
4.05	1.054	1.309	.883	.554	.456	.478	.846	1.269	2.134	1.088	1.655	1.639	1.715	1.534	1.873	1.234	19.724
5.05	.931	1.129	.586	.346	.338	.230	.369	.797	1.005	.755	1.450	1.328	1.404	1.079	1.079	.836	13.661
6.05	.906	.841	.409	.273	.279	.231	.161	.477	.418	.573	1.176	.894	1.007	.550	.537	.468	9.201
8.05	1.119	.779	.354	.415	.393	.283	.158	.482	.265	.575	1.338	.845	.936	.489	.253	.338	9.022
10.05	.411	.312	.213	.366	.246	.127	.032	.123	.063	.129	.318	.208	.219	.062	.019	.046	2.896
13.05	.177	.154	.087	.118	.102	.050	.003	.026	.015	.014	.075	.078	.085	.014	.000	.009	1.008
18.00	.032	.023	.004	.013	.024	.003	.000	.000	.000	.001	.005	.003	.012	.003	.000	.000	.122
99.00	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
Total	6.877	6.486	4.130	3.421	3.122	2.898	3.667	4.854	8.025	7.241	9.772	8.311	8.921	8.097	8.534	5.543	100.000

NOTE: Wind directions in tables are presented in "wind from" and not "wind to" direction.

Supplemental Table B -Continued
Ground Level Joint Frequency Distribution Table Summaries

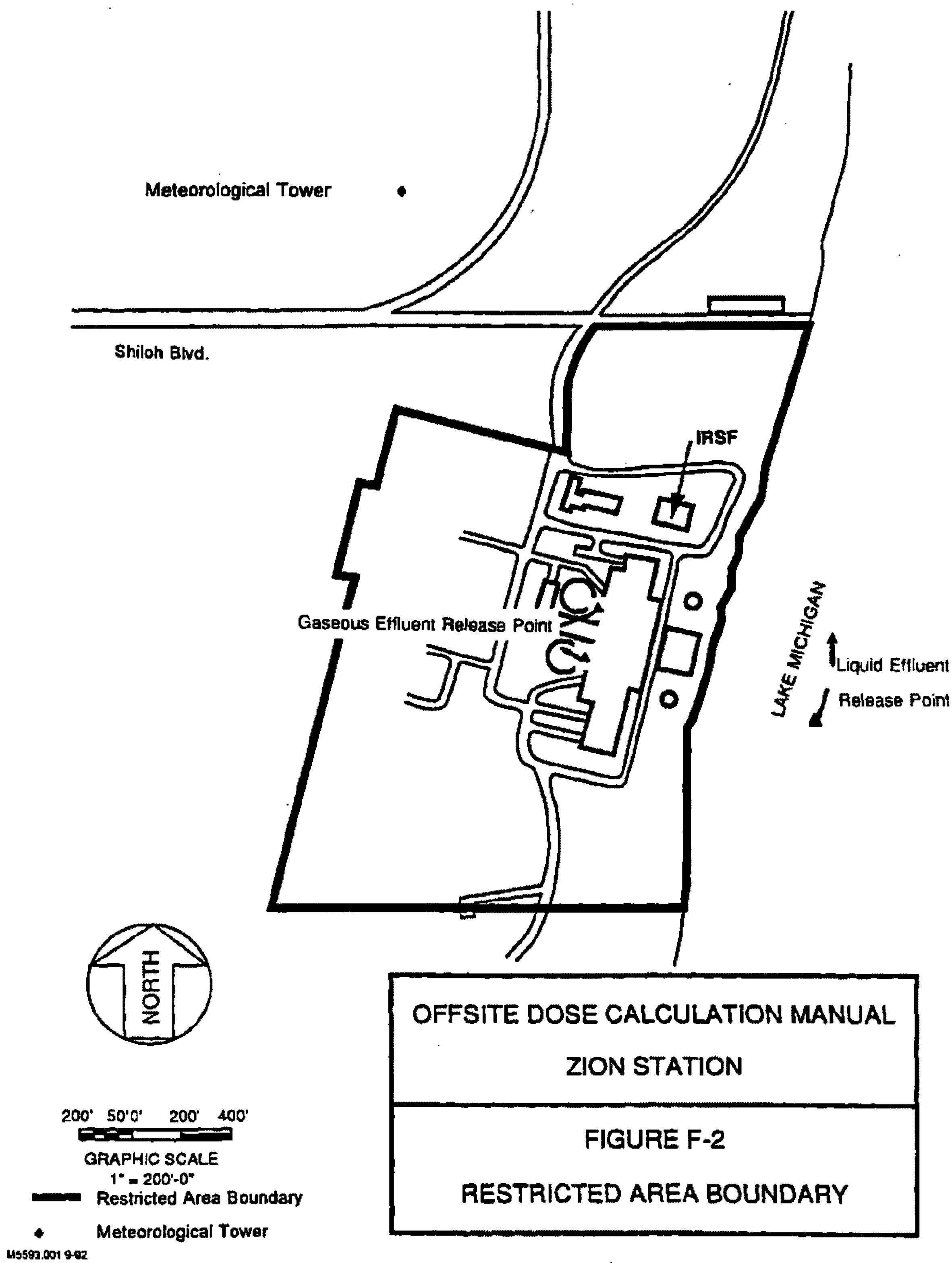
Summary Table of Percent by Speed and Class

Class Speed	A	B	C	D	E	F	G
.45	.006	.004	.005	.040	.172	.154	.249
1.05	.036	.013	.024	.121	.797	.823	1.344
2.05	.464	.141	.194	1.591	4.805	4.405	5.502
3.05	1.606	.433	.507	3.810	8.847	5.409	2.862
4.05	2.520	.563	.613	4.211	8.107	2.995	.715
5.05	1.909	.419	.509	3.384	5.795	1.394	.251
6.05	1.211	.306	.368	2.527	4.023	.681	.085
8.05	1.281	.342	.381	2.766	3.745	.478	.030
10.05	.410	.099	.104	.877	1.317	.078	.010
13.05	.147	.039	.054	.348	.400	.019	.001
18.00	.014	.004	.012	.042	.049	.001	.000
99.00	.000	.000	.000	.000	.000	.000	.000



Offsite Dose Calculation Manual
ZION STATION

FIGURE F-1
UNRESTRICTED AREA BOUNDARY



OFFSITE DOSE CALCULATION MANUAL ZION STATION
FIGURE F-2 RESTRICTED AREA BOUNDARY

Zion*Solutions*, LLC
ZS-2014-0100: Attachment 8

Process Control Program Requirements Procedure

ZS-WM-123
Revision 2
Information Use

Process Control Program Requirements

March 5, 2013

Zion*Solutions* Project

STOP THINK ACT REVIEW

Summary of Changes in this Revision:

- Rev. 2- Updated list of references to revision of regulatory guide revisions as described in ODCM. Updated references to reflect new procedural guidance. Edited wording of reporting requirements to reflect requirements of Rev 1 of Regulatory Guide 1.21. Two minor editorial changes.

1. PURPOSE AND SCOPE

1.1. PURPOSE

This procedure provides the requirements to ensure the Zion*Solutions* PROCESS CONTROL PROGRAM process parameters are established to provide reasonable assurance that all low-level radioactive waste (LLRW) processed at Zion*Solutions* will meet or exceed any and all acceptance criteria for processing, packaging, shipment, and burial of LLRW in licensed burial facilities and as required by 10CFR Parts 20, 61, 71.

1.2. SCOPE

This procedure is applicable to all low-level radioactive waste processed at Zion*Solutions*. This criterion includes all Department of Transportation (DOT), Nuclear Regulatory Commission (NRC), State, and licensed burial facilities rules and regulations for the processing, packaging, shipping, and burial of LLRW.

2. RESPONSIBILITIES

2.1. Waste Operations Manager – is responsible for:

- Maintaining the Process Control Program and its overall implementation.
- Ensure that waste is processed and packaged in accordance with procedures that implement this program.

2.2. Quality Assurance Manager - is responsible for:

- Implements Quality Control hold points and independent verifications in implementing procedures to assure that regulatory requirements and disposal site criteria are satisfied.
- QA/QC Requirements.

2.3. Energy*Solutions* Waste Processor/Operator – is responsible for:

- Providing documentation of satisfactory processing by documenting completed Energy*Solutions* procedures and check sheets.

2.4. Broker/Shipper's - are responsible for:

- Implementation of this procedure.

3. DEFINITIONS

3.1. **Batch** - A fixed volume of wet waste with essentially uniform physical, chemical, and radiological properties. A single batch of wet waste maybe dewatered in several containers. An isolated tank of agitated wet waste is an example of a batch.

3.2. **Disposal Facility** - An off-site facility for the disposal of radioactive waste which is licensed for that purpose by the host state and/or the NRC.

3.3. **Dewatering** - The process in which excess water is removed from the waste to meet the burial site acceptance criteria.

3.4. **Dry Active Waste (DAW)** - Radioactive Waste that is typically paper, wood, plastic, trash, air filters, metal, soil, concrete, asphalt, and used plant components, which without processing, contains essentially no free liquid.

3.5. **Irradiated Hardware** - Neutron activated non-fuel-bearing components.

3.6. **Item** - Any level of unit assembly, including structures, systems, subsystems, and subassemblies, components, part, or material.

3.7. **Mishap** - The misuse or failure of Class B or C waste forms or high integrity containers that require evaluation for reportability in accordance with NRCs Technical Position on Waste Form, Rev.1, January 1999 and NRC Generic Letter 91-02.

3.8. **Process Control Program (PCP)** - Shall contain the approved formulas, sampling, analyses, tests and determinations to be made to ensure that the processing and packaging of solid radioactive wastes based on demonstrated processing of actual or simulated wet solid wastes will be accomplished in such a way as to assure compliance with:

- 10CFR Parts 20, 61 and 71
- 49CFR Parts171-178
- State regulations
- Burial ground requirements
- Other requirements governing the shipping and disposal of radioactive waste

The majority of PCP scope deals with, but is not limited to, wet wastes. Documents listed in the References Section of this procedure may be useful in providing more detailed clarification of the PCP program.

3.9. **Radioactive Waste Package** - The packaging together with its radioactive contents as presented for transport.

3.10. **Radioactive Waste Packaging** - The assembly of components necessary to ensure compliance with the packaging requirements of 49CFR and 10CFR71. It may consist of one or more containers, absorbent materials, spacing structures, thermal insulation, radiation shielding, and devices for cooling or absorbing mechanical shocks. The vehicle, tie-down system, and auxiliary equipment may be designated as part of the packaging.

3.11. **Radioactive Material** - Byproduct material, source material, special nuclear material, and technologically enhanced naturally occurring radioactive material (NORM) as defined in regulation. This includes, but is not limited to: station generated radioactive waste, radioactive material to be shipped to another licensee, and spent fuel.

3.12. **Radioactive Material (for shipping purposes only)** - Material having a specific and total activity as defined in 49CFR §173.436. If the material is not radioactive for the purposes of hazardous material Class 7 transport, it is not subject to the requirements of 49CFR173. However, this is not considered free release criteria or considered non-radioactive under the provisions of 10CFR20.

3.13. **Radioactive Waste (Radwaste or Waste)** - Radioactive Material that has no further economic value and is to be shipped to a decontamination, volume reduction, or disposal facility.

3.14. **Radioactive Waste System(s)** - Radioactive waste systems begin at the interface valve(s) in each line from other systems provided for collecting wastes that may contain radioactive materials and include related instrumentation and control systems. The radioactive waste system terminates at the point of controlled discharge to the environment, at the point of recycle to the primary or secondary water storage, or at the point of packaged solid wastes prior to shipment offsite to a licensed disposal facility.

3.15. **Stabilized** - The use of an approved container or process to provide an acceptable waste form. Some waste forms themselves are inherently stable.

3.16. **Temporary System** - Systems intended for short-term duration and subsequent removal once they have completed their specific task or tasks. This does not include permanent systems, consumables, or vehicles and casks used to pick up/delivery service. Mobile radioactive waste processing systems to support decommissioning activities are examples of temporary systems.

3.17. **Waste Stream** - An individual, specific type or source of radioactive waste and its associated process that exhibit similar radionuclide distributions.

3.18. **Wet Waste** - Radioactive Waste containing free standing liquids or packaged underwater. Wet waste is usually solidified, encapsulated, or dewatered before shipping for disposal. Wet waste being sent to a processor may still contain water. Examples include radioactively spent resin, liquid filters, sludge oil, decontamination fluids, and irradiated hardware packaged underwater.

4. MAIN BODY

4.1. Limitations

4.1.1 Zion*Solutions* does not plan to solidify waste for direct transfer to a disposal facility. If on-site solidification is required, an outside vendor will perform that function under the vendor's PCP, which will be reviewed and approved by Waste Operations prior to commencing any solidification activities:

1.) Any proposed solidification process shall be evaluated for acceptability and applicability to the waste stream intended for solidification on a case-by-case basis.

2.) The vendor PCP will be evaluated by Waste Operations Management prior to implementation and receive review and approval in accordance with applicable Zion*Solutions* procedures. The review will identify that there is sufficient supporting documentation of the vendor's PCP to give assurance that the final product will meet or exceed all requirements for transport and disposal, and that sufficient procedural controls exist to assure safe operations.

3.) Solidification procedures shall be reviewed and approved in accordance with Zion*Solutions* procedures.

4.1.2 The content of a High Integrity Container (HIC) containing resins or dewatered wet wastes shall not contain greater than or equal to 500 curies. (Reference 5.12)

4.1.3 Radioactive Waste Requirements: The basis for the functionality of the radioactive waste system is to ensure the system will be available for use whenever radioactive waste requires processing and packaging prior to being shipped offsite. These radioactive waste requirements implement the requirements of 10CFR §50.36a and General Design Criteria 60 of Appendix A to 10CFRPart 50. The process parameters included in establishing the PROCESS CONTROL PROGRAM may include, but are not limited to waste type, waste pH, waste/liquid/solidification agent/catalyst ratios, waste oil content, waste principal chemical constituents, mixing and curing times.

4.1.4 Liquid LLRW Requirements for Vendors: Zion*Solutions* requires that all vendors who process liquid LLRW meet all Energy*Solutions* quality standards and shall use an NRC approved PROCESS CONTROL PROGRAM Topical report. Furthermore, the vendor solidification/stabilization media must be approved by the licensed burial sites.

4.1.5 The process control activities described in this program and the high integrity containers (HICs) and liners referenced in the NRCs radioactive waste packaging Certificate of Compliance (C of C) are QA approved. Process or equipment failures are subject to the requirements of 10CFR21, "Reporting of Deficiencies and Noncompliance."

4.1.6 During the processing or dewatering of Class B or C waste, deviations from the process control parameters or acceptable waste form properties shall be evaluated for reportability as "mishaps". Failures during qualification testing are not considered "mishaps" and are not reportable events. Mishaps shall be reported to the NRC within 30 days of knowledge of the event and approval from the disposal site shall be obtained prior to shipment.

4.1.7 Liquid wastes will be solidified in accordance with the NRC Technical Position on Waste Form, Rev. 1, January 1999; Waste Form Technical Position, Rev. 1, and the applicable disposal site criteria prior to disposal. (See Attachment 2 for details).

4.1.8 Containers, shipping casks, and methods of packaging will meet applicable federal regulations, e.g., 10CFR71 and 49CFR173, Subpart I.

4.1.9 Waste classification will meet the requirements of 10CFR61 and disposal site criteria.

4.1.10 Procedures or other administrative controls/documents shall assure that the radioactivity content transferred to any one liner or HIC will not result in exceeding the design basis site boundary dose calculated in Reference 5.16.

4.2. Procedure

4.2.1 Review and Qualification of Solidification Processes

1.) Zion*Solutions* does not plan to solidify or encapsulate waste for direct transfer to a disposal facility. If on-site solidification or encapsulation is required, an outside vendor will perform that function under the vendor's PCP, which will be reviewed and approved as follows:

A. Any proposed solidification process shall be evaluated for acceptability and applicability to the waste stream intended for solidification on a case by case basis

B. The vendor PCP will be evaluated by Waste Operations Management prior to implementation and receive review and approval in accordance with applicable Zion*Solutions* procedures. The review shall identify that there is sufficient supporting documentation of the vendor's PCP to give assurance that the final product will meet all requirements for transport and disposal, and that sufficient procedural controls exist to assure safe operations.

C. Solidification procedures shall be reviewed and approved in accordance with applicable Zion*Solutions* procedures.

4.2.2 High Integrity Containers (HICs)

1.) A HIC may be used to provide stability in lieu of the requirement for waste form stability. HICs must meet applicable regulatory and disposal site requirements and procedures for their use shall be reviewed and approved by Waste Operations Management prior to their use

2.) The qualification criteria for HICs include:

A. The container design shall be qualified in accordance with the NRC Branch Technical Position on Waste Form, (Rev. 1, 1991) and the requirements of the disposal facility. If applicable, the regulatory agency for the disposal facility shall issue a Certificate of Compliance (C of C) or otherwise approve the design.

B. Plant and vendor procedures shall meet the fabrication, testing, inspection, and maintenance, preparation for use, filling, storage, handling, and transportation and disposal requirements of the applicable certificate of compliance.

C. Waste processed in HICs may utilize the HIC as the stable waste form to meet the stability and free liquid requirements of 10 CFR §61.56 and the disposal facility. However, the process control parameters for the waste processing shall be controlled to within the limitations of the C of C on the HIC (typically temperature or chemical limitations in the C of C may require additional controls in the process).

3.) Approved procedures support the control of materials that are prohibited in HICs containing radioactive waste. Prohibited materials are specific to the HIC qualification and certification but Attachment 4, "Prohibited Materials" provides a typical listing.

4.2.3 Reportable Events

1.) Mishaps involving the container or solidification process shall be evaluated for reportability under 10 CFR 21. Also, mishaps involving the HIC during or after processing and deviation from prescribed process control parameters for solidification shall be evaluated for reportability. In Generic Letter 91-02, the NRC expressed specific interest in reporting the following circumstances:

A. Failure of a High Integrity Container used to ensure a stable waste form. Changed container dimensions, cracking or damage from mishandling can be evidence of container failure.

B. The presence of free liquids in excess of 1% of the waste volume or excessive void space within the container. Such misuse is prohibited by 10 CFR §61.56 (b) (2).

C. A solidified Class B or C waste form that has any of the following characteristics:

- Contains free liquids in quantities exceeding 0.5% of the volume of the waste.
- Contains waste with radionuclides in concentrations exceeding those considered during waste form qualification testing accepted by the regulatory agency, which could lead to errors in assessment of waste class.
- Contains significantly different waste loading than was used in the qualification testing accepted by the regulatory agency.
- Contains chemical ingredients not present in qualification testing accepted by the regulatory agency, and those quantities are sufficient to unacceptably degrade the waste product.
- Shows instability evidenced by crumbling, cracking, spalling, voids, softening, disintegration, non-homogeneity, or dimensional changes.

- Evidence of processing phenomenon that exceed the limiting processing conditions identified in the applicable topical reports on process control plans, e.g., foaming, temperature extremes, premature or slow hardening, and production of volatile material.

D. Mishaps shall be documented using the station corrective action process.

E. Mishaps may be subject to a 30 day reporting criteria and require approval of the disposal facility prior to transport.

4.2.4 **Cartridge Filter Elements**

A. Cartridge filter elements may be shipped for off-site processing and disposal. The vendor's processes should be reviewed to ensure compliance with the applicable disposal site criteria and 10 CFR 61 requirements.

B. Cartridge filter elements may be processed on-site for direct disposal. Cartridge filter elements shall be processed using an approved dewatering system in accordance with approved procedures. The dewatering process shall be tested and the methodology accepted as meeting the applicable burial site criteria and 10 CFR 61 requirements.

C. The processing procedures for filters dewatered on-site for direct disposal shall be reviewed and approved in accordance with applicable procedures.

D. Class A filters requiring stabilization and Class B and Class C filters shall be disposed of in an approved HIC or a solidified matrix that satisfies the stabilized waste form criteria of 10 CFR §61.56(b).

E. The packaging of cartridge filters for disposal shall be in accordance with the Reference 5.12.

4.2.5 **Demineralizer Resins**

A. Depleted resins may be shipped for off-site processing and disposal. The vendor's processes should be reviewed to ensure compliance with the applicable disposal site criteria and 10 CFR 61 requirements.

B. Depleted resins may be processed on-site for direct disposal. Depleted resins shall be processed using an approved dewatering system in accordance with approved procedures. The dewatering process shall be tested and the methodology accepted as meeting the applicable burial site criteria and 10 CFR 61 requirements.

C. The processing procedures for depleted resins dewatered on-site for direct disposal shall be reviewed and approved in accordance with applicable procedures.

D. Acceptable waste types suitable for processing and dewatering on-site are listed in Attachment C. Resin types or waste forms not specifically listed shall be reviewed and approved by Waste Operations Management prior to use.

E. A valid 10 CFR 61 analysis will be used to determine the radionuclide distribution. This information along with waste volume per package, weight per package, and package size will be used to determine the liner's specific activity.

F. The package's total activity may be based on a dose rate to curie conversion factor or extrapolation of the sample analysis consistent with the waste classification methodology explained later in this procedure.

G. Class A waste resins requiring stabilization and Class B and Class C waste resins shall be disposed of in an approved HIC or a solidified matrix that satisfies the stabilized waste form criteria of 10 CFR §61.56(b).

H. Other methods of processing resins shall be reviewed and approved by Waste Operations Management prior to implementation.

4.2.6 **Dry Active Waste (DAW)**

A. DAW is typically packaged into boxes, gondola railcars, intermodal containers, or C-vans and shipped to a licensed vendor that processes the DAW for final disposal or shipped directly to a licensed disposal facility.

B. DAW is examined prior to packaging to screen out items that may conflict with a vendor's ability to process the material or the disposal site criteria.

C. Removal of prohibitive items such as liquids or items found in DAW that would compromise the integrity of the package are removed and separated for special handling.

D. Controls and/or inspection criteria are established for the receipt and prior-to-use inspections of transport containers and disposal containers for DAW packages shipped directly for disposal.

4.2.7 **Irradiated Metal/Hardware**

A. Verification of suitability for disposal shall be determined through collaboration with the processing or disposal facility. Special characterization methodology may be required for components and a review and approval by the disposal facility prior to shipment is likely. The packaging of irradiated object(s) for direct disposal may be limited by the package or cask used for transport. Shipping and disposal documentation shall be reviewed by Waste Operations Management and deemed acceptable by the processing or disposal facility prior to shipment.

B. IF the material is recycled or processed prior to disposal, the material will be packaged for transport in accordance with 49 CFR, 10 CFR, and any limitations of the package or transport cask. Disposal is based on the vendor's process control program.

4.2.8 **Incinerable Fluids**

A. Fluids that are capable of being incinerated (e.g. hydraulic fluids, lubricating oils, etc.) may be shipped to a processor that is licensed to perform that activity.

B. The vendor will be evaluated and approved by Waste Operations Management prior to implementation. Disposal is based on the vendor's process control program.

C. In the process, the fluid is typically consumed and the resultant activity captured for disposal or released under the vendor's license. The vendor may return any material that cannot be processed for disposal to Zion*Solutions*.

4.2.9 **Sludges/Bottoms**

A. Wet wastes that are not capable of being incinerated may be processed by a vendor licensed to process, concentrate and/or solidify wet wastes. Processing resulting in on-site solidification is subject to the process controls for solidification discussed earlier.

B. The vendor may return any material that cannot be processed for disposal to Zion*Solutions*.

4.2.10 **Prohibited Waste Constituents**

1.) No radioactive waste capable of detonation or of explosive decomposition or reaction will be shipped for disposal per 10 CFR §61.56 (a) (4). Components containing explosive materials, such as some automatic valves (e.g. fire protection valves on Halon and/or CO_2 systems), should be identified and the removal or disposal of these valves controlled by the work control process.

2.) No radioactive waste capable of generating toxic gases, vapors, or fumes will be shipped for disposal per 10 CFR §61.56 (a) (5).

3.) No radioactive waste that is pyrophoric will be shipped for disposal per 10 CFR §61.56 (a) (6).

4.) Control of the generation of these types of waste is provided through the use of approved Zion*Solutions* procedures.

4.2.11 **Mixed Waste**

1.) No mixed waste will be submitted for disposal per 10 CFR §61.56 (a) (8) unless properly treated.

2.) Zion*Solutions* will ship its mixed waste inventory to licensed and permitted facilities for processing prior to disposal.

3.) The vendor will be evaluated by Waste Operations Management prior to implementation. Disposal is based on the vendor's process control program.

4.) The vendor's processes will also be reviewed to ensure compliance with 40 CFR requirements.

5.) Control of the generation of mixed waste is provided through approved Zion*Solutions* procedures.

6.) Material safety data sheets (MSDS) on consumable materials are maintained for chemicals used on site.

4.2.12 **Waste Characterization**

Approved Zion*Solutions* procedures shall specify the method of waste classification to meet the requirements of 10 CFR §61.55. These procedures shall include the collection of data, computational methods, computer codes, etc. The following is a synopsis of the methodology employed and required elements of the procedures.

1.) Individuals performing the calculations described in this section and the reviewer of those calculations shall be specifically approved to perform that function by the Waste Operations Manager/Designee and/or otherwise qualified through an approved qualification program in accordance with station procedures. Approval, in lieu of specific qualification, should be based on experience at other nuclear facilities and/or demonstrated proficiency with the types of calculations or computer codes required.

2.) Radioactive waste streams are sampled and/or assessed biannually, prior to shipment, or after any evolution that may affect the distribution of radionuclides by a factor of ten (10) in waste streams for Class A, B, and C waste as defined in 10 CFR §61.55. An assay of beta, gamma and alpha emitting radionuclides will be performed.

3.) An approved outside laboratory is used by Zion*Solutions* to analyze waste streams to determine the distribution and activity of radionuclides listed in Tables 1 and 2 of 10 CFR 61.

4.) For resin wastes, isotopic analysis is normally performed on samples of resin obtained prior to or during processing. Representative resin samples are analyzed for gamma components and appropriate scaling factors are applied to key gamma radionuclides (such as Co-60 or Cs-137) to determine the specific activity of difficult to measure radionuclides expected in the waste stream based on a prior laboratory analysis. The total activity present in a container is calculated based on the specific activity and the volume or weight of the waste in the container or dose rate to curie conversion calculations.

5.) For containers of cartridge filters, dose rate to curie conversion calculations are performed on each filter or batch of filters to determine the total gamma activity present. Scaling factors are applied to key gamma radionuclide curie content to determine the activity of those radionuclides not measured by gamma analysis or dose rate measurement.

6.) For DAW, dose rate to curie conversion calculations are performed to determine the total gamma emitter activity present in a container.

7.) Computational methods (including computer codes used to perform waste classification) shall be verified and validated by an individual as described in 4.2.12.1 as follows:

A. An individual shall review the computational methods basis document or manual.

B. The reviewer shall ensure technical accuracy, technical adequacy, reasonableness of assumptions, and traceability of data.

C. Calculation results shall be benchmarked against other verified methods to prove reasonable agreement.

D. Initial reviews and benchmark results shall be documented.

E. The verification / validation shall be reviewed and approved prior to implementation of the method.

8.) Calculations to determine curie content and waste classification of radioactive waste performed by means other than computer codes (i.e. manual calculations, etc.) shall be checked by a qualified individual as defined in 4.2.12.1, other than the originator, who shall be responsible to check and document the following:

A. Check the appropriateness of the application of the computational method;

B. Check assumptions and input data for reasonableness;

C. Perform a sufficient number of checks of the calculations to reasonably test accuracy and consistency of the results, OR,

D. Perform a check of the results by comparison with other similar calculations,

9.) Calculation methodology to assess the concentration of radionuclides for waste disposal shall incorporate the guidance provided in the NRC's "Final Branch Technical Position on Concentration Averaging and Encapsulation", January 1995.

4.2.13 **PCP Document and Procedure Control**

1.) Changes to the Process Control Program:

A. SHALL be documented and records of reviews performed shall be retained as required by Permanently Defueled Technical Specifications (PDTS) 5.9.1 (Qualified Technical Review). The documentation shall contain:

i. Sufficient information to support the change together with the appropriate analyses or evaluations justifying change(s).

ii. A determination that the change will maintain the overall conformance of the solidified waste product to existing requirements of Federal, State, or other applicable regulations.

B. SHALL become effective after review and acceptance by:

i. Waste Operations Management will control revision of this PCP. Changes to the program that may result from changes in vendor processes or plant activities should be identified to and reviewed by Waste Operations Management. Waste Operations Management and an Independent Safety Reviewer must review and approve changes to this procedure prior to submittal to the Zion*Solutions* Decommissioning Plant Manager.

ii. The Zion*Solutions* Decommissioning Plant Manager provides final document approval prior to issue and implementation.

2.) New process qualifications or changes in an existing process may be implemented prior to updating this procedure, provided the technical evaluation and approvals for that process are documented.

3.) Radiation Protection Management and Waste Operations Management should ensure that required changes are incorporated to this procedure as appropriate for planned activities.

4.) Waste shipment manifests and supporting documentation shall be retained until license termination plus 10 years. Support documents may include the analysis or a reference to the analysis used in the determination of the total activity contained in the disposal package.

5.) SHALL be submitted to the NRC in the Annual Radioactive Effluent Release Report for the period in which the change was made (including change in vendor).

4.2.14 The Radioactive Waste System shall be verified:

1.) At least annually by verification the Solid Radioactive Waste System has been operated in accordance with the Process Control Program, **<u>OR</u>**

2.) At least once annually by verification of the existence of a valid contract for solidification, dewatering, or processing is to be performed by a contractor in accordance with a Process Control Program specifying:

A. The method and frequency of analyses to verify solidification of radioactive waste.

B. The actions to be taken if solidification **<u>IS NOT</u>** verified.

C. Document by completing Attachment 1, "Verification of Existing Valid Contract for Solidification and Dewatering."

4.2.15 The Solid Radioactive Waste System shall be used, as applicable, in accordance with a PROCESS CONTROL PROGRAM for the solidification and packaging of wet radioactive wastes to meet shipping and burial ground requirements.

1.) These requirements shall be applicable at all times.

2.) **<u>IF</u>** the provisions of the Process Control Program **<u>ARE NOT</u>** satisfied, **<u>THEN</u>** shipments of potentially defective processed or packaged solid radioactive wastes from the site shall be suspended.

<u>CAUTION:</u>
Do **<u>NOT</u>** lift a HIC that contains greater than or equal to 500 curies.

4.2.16 To ensure compliance with offsite dose limits during a design basis HIC handling accident, ENSURE each HIC containing resins or dewatered wet waste contains less than 500 curies. (Reference 5.16)

1.) **<u>IF</u>** a HIC is determined to contain greater than or equal to 500 curies, **<u>THEN</u>** ENSURE activity is processed to another HIC BEFORE any handling or lifting activities.

4.2.17 The Process Control Program shall consist of: (reference 5.14 and 5.15)

1.) PCP-FO-AD-022, Ecodex Precoat/Powdex/Solka-Floc/Diatomaceous Earth/Zeolite Dewatering Procedure.

2.) PCP-FO-OP-023, Bead Resin / Activated Carbon Dewatering Procedure for CNSI 14-195 or Smaller Liners.

4.2.18 The Annual Radioactive Effluent Release Report:

1.) SHALL be submitted prior to May 1st of each year in accordance with T.S. 5.7.3.

2.) SHALL be in the format of Regulatory Guide 1.21, Revision 1- (Table 3). Also shown in reference 5.10 (Attachment 3.)

3.) SHALL be summarized on an annual basis.

4.) SHALL include the following information for each type of solid waste and irradiated fuel shipped offsite during the report period:

A. Spent resins, filter sludges, evaporator bottoms.

B. Dry compressible waste, contaminated equipment etc.

C. Irradiated components.

D. Other (furnish description).

i. Indicate the following information for each type of waste listed above (A – D):

- Total Volume in cubic meters.
- Total Radioactivity in Curies (specify whether determined by measurement or estimate)
- Principal radionuclide's (specify whether determined by measurement or estimate).
- Type of container (e.g., LSA, Type A, Type B).
- Solidification Agent (e.g., cement, urea formaldehyde).
- Dates of shipment and disposition. Identify the number of shipments, the mode of transport, and the destination.
- The disposition of irradiated fuel shipments. Identify the number of shipments, the mode of transport, and the destination.
- Estimates of the total error associated with certain total values. (See Table 3 of reference 5.9 or Attachment 3 of reference 5.10).

5. REFERENCES

5.1. Code of Federal Regulations, Title 10, "Energy", Appendix G to Part 20, "Requirements for Transfers of Low-Level Radioactive Waste Intended for Disposal at Licensed Land Disposal Facilities and Manifests."

5.2. Code of Federal Regulations, Title 10, "Energy", Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste."

5.3. Code of Federal Regulations, Title 10, "Energy", Part 71, "Packaging and Transfer of Radioactive Material."

5.4. Code of Federal Regulations, Title 49, "Transportation", Sub Chapter C – Hazardous Materials Regulations, Part 173, "Shippers – General Requirements for Shipments."

5.5. NRC Regulatory Guide 1.143, "Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants.

5.6. NRC Generic Letter 91-02, "Reporting Mishaps Involving LLW Forms Prepared for Disposal."

5.7. Permanently Defueled Technical Specifications (PDTS).

5.8. 10CFR20, 10CFR50.36a, General Design Criteria 60 of Appendix A to 10CFR50, 10CFR61, and 10CFR71.

5.9. Regulatory Guide 1.21, Measuring, Evaluating, and Reporting Radioactivity in Solid Wastes and Releases of Radioactive Materials in Liquid and Gaseous Effluents from Light-Water-Cooled Nuclear Power Plants, Revision 1 (June 1974).

5.10. ZS-RP-109-001-002, "Generation of the Annual Radioactive Effluent Release Report (ARERR)."

5.11. NRC Branch Technical Position On Concentration Averaging and Encapsulation, dated January 1995.

5.12. NRC Branch Technical Position On Waste Form, Rev.1, dated January 1991.

5.13. Zion Station Calculation No. 22N-0-119M-0001, Rev. 1, "Dose Effects on Radwaste Handling Accident Involving a HIC."

5.14. PCP-FO-AD-022, Ecodex Precoat/Powdex/Solka-Floc/Diatomaceous/Earth/Zeolite Dewatering Procedure."

5.15. PCP-FO-OP-023, Bead Resin/ Activated Carbon Dewatering Procedure for CNSI 14-195 or Smaller Liners.

5.16. 295-201-97-CAQD-121605 (Zion Corrective Action).

6. RECORDS

None

7. ATTACHMENTS

7.1. Attachment 1 - Verification of Existing Valid Contract for Solidification and Dewatering

7.2. Attachment 2 - Minimum Review Criteria for Solidification Processes

7.3. Attachment 3 - Waste Types Suitable for Dewatering

7.4. Attachment 4 - Prohibited Materials.

8. FORMS

None

ATTACHMENT 1
Verification of Existing Valid Contract for Solidification and Dewatering
Page 1 of 1

I ____________________ on ______________, have verified the existence of a valid
(Broker/Shipper) (Date)

contract to solidify or dewater waste by a Contractor at Zion*Solutions*. The contract expires on ____________________.
(Date)

Note: When completed this document is to go to Zion*Solutions* File for filing with ZS-WM-123 package.

ATTACHMENT 2
Minimum Review Criteria for Solidification Processes

*Qualification of the solidification matrix shall be by test of non-radioactive simulated samples or actual samples of wet waste in accordance with the NRC Technical Position on Waste Form, Rev. 1, dated January, 1991. Successful qualification test results of physically and chemically similar wet waste (i.e. type tests) are acceptable. The qualification criteria shall include:

- A description of the acceptable waste form properties (free liquid, stability. etc.) determined by 10 CFR 61.56 and the applicable disposal facility requirements;

- Provisions for waste characterization;

- A discussion of the process control parameters important for assuring that the process will result in an acceptable waste form such as solidification agents, chemical additions, mixing ratios, mixing time, drying time and temperature. Acceptable ranges or boundary conditions for each parameter should be identified;

- Identification of measurement and test instrumentation and QC hold points required to monitor the process or verify that the process is operating within the acceptable range of the process control parameters specified above. The instrumentation shall be periodically calibrated with calibrations traceable to NIST;

- A procedure for sampling of the solidification process that will verify for each batch of wet wastes that the process control parameters result in complete solidification with no free liquids. If the sample fails to verify solidification, the procedure shall specify what actions are to be taken. Samples shall be clearly labeled and retrievable either up to the time of disposal or for long term storage and testing (6 and 12 months) as required for problem waste streams identified in Appendix A of the NRC's Technical Position on Waste Form;

- Identification of QC provisions to verify the absence of free liquid in each container processed. If free liquid is detected, the procedure shall ensure that free liquid is eliminated prior to shipment to a disposal facility. The presence of greater than 0.5 percent by volume of free liquid after the solidification of Class B or C waste forms shall be reviewed for reportability;

- For exothermic processes, a description of the process control parameters that must be satisfied prior to capping the container.

ATTACHMENT 3
Waste Types Suitable for Dewatering

1.0 Any common polystyrene-based bead ion exchange resins not included in the listing above are acceptable for dewatering subject to the following conditions:

* The resin shall have a moisture content of less than or equal to 57 percent when shipped from the supplier to the plant.

  * Mixtures of resins shall have a weighted average of "as shipped" moisture contents less than or equal to 57 percent.

2.0 The bead ion exchange resins qualified above shall also satisfy the following criteria to be acceptable for dewatering:

  * If oil or grease is detected in the media, the spent resin will be evaluated to quantify that the media contains less than 1% oil or grease by container volume.
  * The media shall not contain significant quantities of corrosion products that could inhibit dewatering capabilities.
  * The media shall not contain significant amounts of organic contaminants that could inhibit dewatering capabilities.
  * Physical degradation of the media shall be limited to that due to routine water demineralization and resin transfer operations.

3.0 Miscellaneous metals and irradiated hardware are acceptable for dewatering as long as the shape does not create the potential to trap water.

ATTACHMENT 4
Prohibited Materials

Material Not Compatible with Polyethylene HIC

Acetone	Ethyl Butyrate	Nitrobenzene
Amyl Acetate	Ethyl Chloride	Octyl Cresol
Amyl Chloride	Ethyl Ether	Oleic Acid
Aqua Regia	Ethylene Chloride	Oleum
Benzene	Ethylene Chlorohydrin	Petroleum Ether
Bromine Liquid	Ethylene Dichloride	Phenol
Camphor Oil	Fluorine	Propylene Dichloride
Carbon Disulfide	Furfural	Sulfuric Acid (60%)
Carbon Tetrachloride	Furfuryl Alcohol	Tetrahydrofurane
Chloride Liquid	Fuel Oil	Tetralin
Moist Chlorine Gas	Gasoline	Titanium Tetrachloride
Chlorobenzene	Hydrofluoric Acid (conc.)	Toluene
Chloroform	Methyl Bromide	Trichloroethylene
Chlorosulfonic Acid	Methyl Chloride	Turpentine
Cyclohexanone	Methyl Ethyl Ketone (MEK)	Xylene
Dimethylamine	Methylene Chloride	
Ethyl Acetate	Nitric Acid (conc.)	

NOTE: High integrity containers shall not be subjected to concentrated free standing oil. However, this does not prohibit the materials in the HIC from containing incidental or trace amounts of oil or petroleum based materials which have been absorbed in the waste materials, provided that the amount of absorbed oil and petroleum based materials does not exceed one percent (1%) by waste volume in the container.