POINT BEACH NUCLEAR PLANT
UNITS 1 AND 2

OFFSITE DOSE CALCULATION MANUAL

WISCONSIN ELECTRIC POWER COMPANY

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Revision 10 DRAFT

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1.0 OFFSITE DOSE CALCULATION MANUAL ADMINISTRATION

1.1 Purpose

The PBNP Offsite Dose Calculation Manual contains the current methodology and parameters for the calculation of offsite doses due to radioactive gaseous and liquid effluents. This manual describes a methodology for demonstrating compliance with 10 CFR 50, Appendix I dose limits. Compliance with Appendix I is demonstrated by periodic calculation of offsite doses based on actual plant releases and comparison to Appendix I dose limits.

The manual also details the methodology for the determination of gaseous and liquid effluent monitor alarm set points. The PBNP Radiation Monitoring System (RMS) effluent monitor alarm set points are established to ensure that controlled releases of liquid and gaseous radioactive effluents are maintained as low as is reasonably achievable and to ensure releases result in concentrations to unrestricted areas within limits specified in 10 CFR 20.

The manual also details the methodology for evaluating the radiological impact of sewage treatment sludge disposal. This methodology addresses the commitments made to the United States Nuclear Regulatory Commission in our application dated October 8, 1987 (NRC-87-104) and accepted by the USNRC in a letter dated January 13, 1988. This application was submitted in accordance with the provisions of 10 CFR 20.302(a). A copy of the submittal and subsequent modifications is contained in Appendices E,F, and G. Dose limits are established in the application to ensure the health and safety of the maximally exposed member of the general public and the inadvertent intruder. 10 CFR 50, Appendix I dose limits do not apply to sewage treatment sludge disposal.

1.2 General Responsibilities

The primary responsibility for the implementation of the PBNP offsite dose calculation program and for any actions required by the program resides with the Manager and the staff of the Nuclear Industry and Regulatory Services Section (IRSS). IRSS will provide the technical, regulatory, licensing, and administrative support necessary to fulfill the requirements of this manual. The calculation of offsite doses and analysis of data are IRSS responsibilities.

The Manager-PBNP is responsible for assuring that Radiation Monitoring System alarm set points are established and maintained in accordance with the methodologies outlined in this manual. The Manager-PBNP is also responsible for assuring the performance of periodic release summaries for the purpose of demonstrating compliance with PBNP effluent release limits.

1.3 Manual Revisions

This manual describes the current scope of the PBNP offsite dose calculation program. The program and the manual are maintained by IRSS. Program items or procedures may be periodically updated or changed, either to reflect new parameters or to improve program effectiveness. This manual may be revised at the discretion of IRSS with the concurrence of the PBNP Manager's Supervisory Staff (MSS).

2.0 RADIATION MONITORING SYSTEM AND RELEASE ACCOUNTING

A computerized Radiation Monitoring System (RMS) is installed at Point Beach Nuclear Plant (PBNP). The RMS includes area, process, and effluent monitors. A description of those monitors used for liquid and gaseous effluents is presented in Tables 2-1 and 2-2. The liquid and gaseous waste processing flow paths, equipment, and monitoring systems are depicted in Figures 2-1 and 2-2. Calibration of the RMS detectors is accomplished in accordance with procedures contained in the PBNP Health Physics Calibration Manual. The set point methodology is described in Section 3 of this manual.

The RMS is designed to detect and measure liquid and gaseous releases from the plant effluent pathways. The RMS will initiate isolation and control functions on certain effluent streams identified in Tables 2-1 and 2-2. Complete monitoring and accounting of nuclides released in liquid and gaseous effluents is accomplished with the RMS together with the characterization of nuclide distributions by laboratory analysis of grab samples. Sampling frequencies and analysis requirements are described in Tables 6-1 and 6-2 of the Radiological Effluent Control Manual (RECM). The various aspects of grab sampling and release accountability are described in the PBNP Release Accountability Manual.

TABLE 2-1

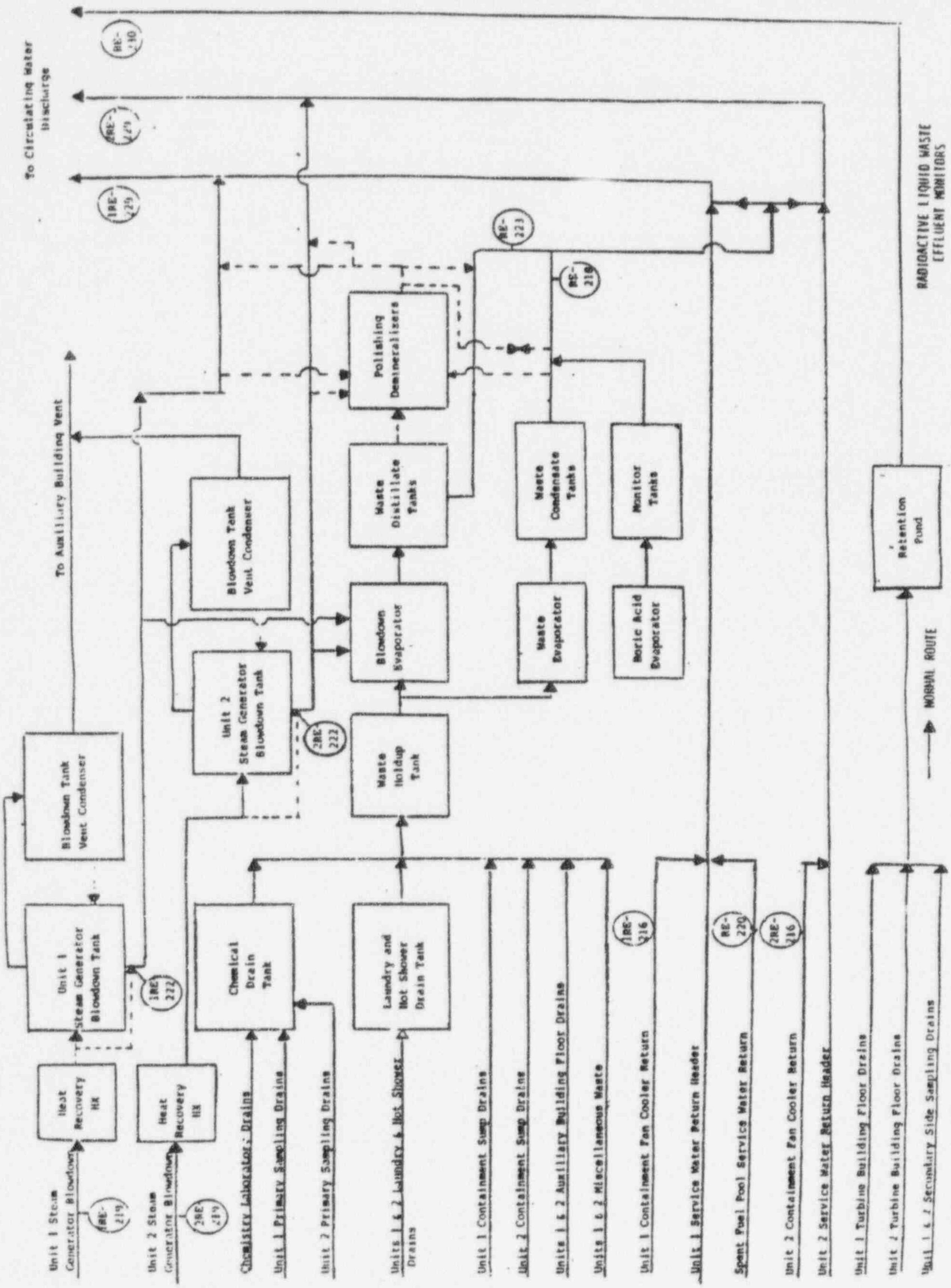
RADIOACTIVE LIQUID WASTE EFFLUENT MONITORS

CHANNEL NUMBER	NAME	CONTROL FUNCTION	DETECTOR TYPE
1 (2) RE-216	Containment Fan Coolers Liquid Monitors	None	Scintillation
RE-218	Waste Disposal System Liquid Monitor	Shuts waste liquid overboard	Scintillation
1 (2) RE-219	Steam Generator Blowdown Liquid Monitors	Shuts steam generator blowdown isolation valves, blowdown tank outlet valves and steam generator sample valves	Scintillation
RE-220	Spent Fuel Pool Liquid Monitor	None	Scintillation
RE-223	Waste Distillate Overboard Liquid Monitor	Shuts waste distillate overboard isolation valve	Scintillation
1 (2) RE-229	Service Water Discharge Monitors	None	Scintillation
RE-230	Retention Pond Discharge Liquid Monitor	None	Scintillation
1 (2) RE-222	Steam Generator Blowdown Tank Outlet Monitor	Shuts steam generator blowdown isolation valves and blowdown tank outlet valves	GM Tube

TABLE 2-2

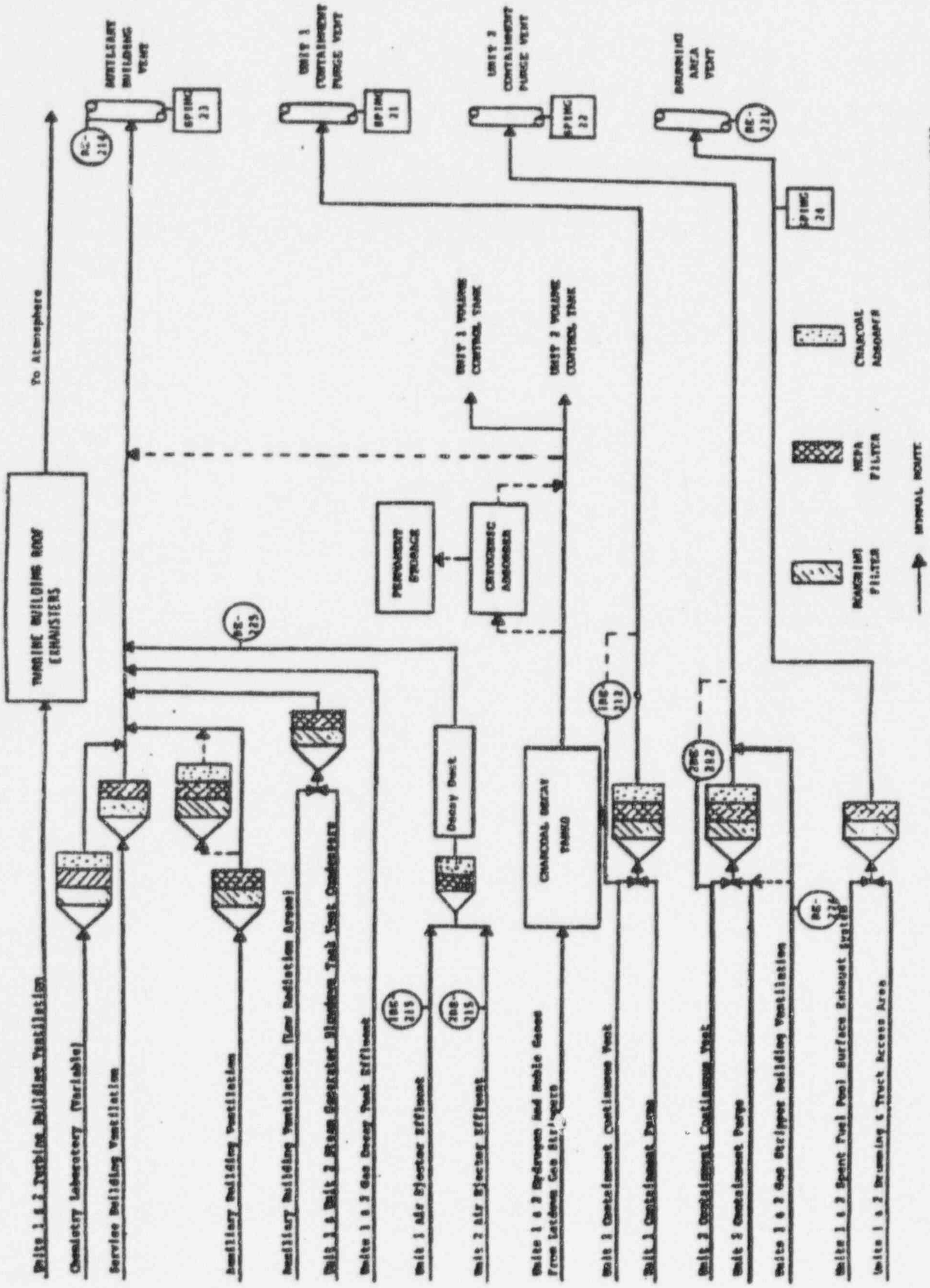
RADIOACTIVE GASEOUS WASTE EFFLUENT MONITORS

CHANNEL NUMBER	NAME	CONTROL FUNCTION	DETECTOR TYPE
1 (2) RE-212	Containment Noble Gas Monitor	Actuates containment ventilation isolation	Scintillation
RE-214	Auxiliary Building Exhaust Ventilation Noble Gas Monitor	Shuts gas release valve and shifts auxiliary building exhaust through carbon filters	Scintillation
1 (2) RE-215	Condenser Air Ejector Noble Gas Monitors	None	Scintillation
RE-225	Combined Air Ejector Low-Range Noble Gas Monitor	None	Scintillation
RE-221	Drumming Area Vent Noble Gas Monitor	None	Scintillation
RE-224	Gas Stripper Building Exhaust Noble Gas Monitor	None	Scintillation
1 (2) RE-305	Unit 1 and 2 Purge Exhaust Noble Gas Monitors (Channel 5 on SPING Units No. 21 and No. 22)	Containment ventilation isolation	Scintillation
RE-315	Auxiliary Building Exhaust Ventilation Noble Gas Monitor (Channel 5 on SPING Unit No. 23)	None	Scintillation
RE-325	Drumming Area Ventilation Noble Gas Monitor (Channel 5 on SPING Unit No. 24)	None	Scintillation



RADIOACTIVE LIQUID WASTE EFFLUENT MONITORS

Figure 2-1



RADIOACTIVE GASEOUS WASTE EFFLUENT MONITORS

Figure 2-2

3.0 METHODOLOGY FOR DETERMINING ALARM SET POINTS

3.1 Introduction

The selection and maintenance of alert and alarm set points for each effluent monitor of the PBNP radiation monitoring system will be accomplished within the guidelines of this section. The computerized PBNP radiation monitoring system permits each effluent radiation monitor to be programmed to alarm at two distinct set points. The alert set point, typically twice the steady-state reading, is intended to delineate a changing plant condition which may warrant corrective action. The high alarm or trip set point either will actuate a control function as applicable or will require corrective action to be initiated.

3.2 Objective

The effluent monitor set points are established to ensure that controlled releases of liquid and gaseous radioactive effluents are maintained as low as is reasonably achievable, to ensure releases result in concentrations to unrestricted areas within limits specified in 10 CFR 20, and to ensure that the dose limits of 10 CFR 50, Appendix I are not exceeded.

3.3 Alert Set Point Guidelines

The alert set point of each effluent monitor generally will be set to alarm at two times the established steady-state reading. The alert set point is normally set at concentrations well below the alarm set point value and is never to be set in excess of the alarm set point. In the course of plant operations, certain situations may require a deviation from the two times steady-state guideline. The intent of the alert set point is to warn of changing plant conditions which may warrant an evaluation of the cause of the increased radiation. If the increased reading is actually due to an increased radiation inventory within the system being monitored, as opposed to an increased background radiation field in the vicinity of the detector, an evaluation should be made to determine the impact of the release. The alert set point may be adjusted with the approval of the Duty Shift Superintendent. Alert set point adjustments are to be made in accordance with the PBNP RMS Alarm Set Point and Response Book.

3.4 Alarm or Trip Set Point Guidelines

In accordance with the requirements of Sections 5.2 and 5.4 of the RECM, the alarm or trip set point for effluent monitors shall be established to annunciate at radiation levels which would result in an unrestricted area concentration equal to or less than the applicable maximum effluent concentration (MEC) specified in 10 CFR 20, Appendix B, for a single radionuclide. However, for a mixture of radionuclides, the set point shall be established so that the summation of fractions, as defined in Appendix B of 10 CFR 20 is less than or equal to one (1). The appropriate detailed response to an effluent alarm is described in the PBNP RMS Alarm Set Point and Response Book.

3.5 Monitor Calibration and Calibration Constant Determination

Calibration of the RMS effluent detectors is accomplished in accordance with procedures contained in the PBNP Health Physics Calibration Manual. Noble gas effluent monitors apply the calibration constant to standardize all gaseous releases to the 1985-1991 average isotopic noble gas distribution. The calibration constants are based on the calculated monitor response to the beta energy distribution in the 1985-1991 average isotopic noble gas distribution.

Noble gas effluent monitor calibration constants are derived from the following formulae:

$$\text{Cal. Constant} = \frac{1}{\text{Sensitivity}}$$

and

$$\text{Sensitivity} = \frac{\text{Monitor Response}}{\Sigma\,(\text{microCi/cc}_i)}$$

where:

Monitor response = the calculated counts per minute registered by monitor exposed to the 1985-1991 average noble gas isotopic distribution

$\Sigma(\mu Ci/cc_i)$ = total concentration of isotopes in the 1985-1991 average noble gas isotopic distribution

The liquid effluent monitors apply the derived calibration constant to standardize all liquid releases to the total concentration in the release path. The calibration constants are based on the monitor response to the 1985-1991 average liquid isotopic distribution. Each liquid monitor channel displays the effluent concentration in terms of a total release concentration.

Liquid effluent monitor calibration constants are derived from the following formulae:

$$\text{Cal. Constant} = \frac{1}{\text{Sensitivity}}$$

and

$$\text{Sensitivity} = \frac{\text{Monitor Response}}{\Sigma\,(\mu Ci/cc_i)}$$

where:

Monitor Response = the counts per minute registered by monitor exposed to calibration source

$\Sigma(\mu Ci/cc_i)$ = total concentration on radionuclides in the 1985-1991 average liquid effluent isotopic distribution

The QAD computer program may be utilized to predict or determine monitor calibration constants. Application of the QAD program may be appropriate for determining monitor response for accident source terms or other instances when the use of a calibration source is impracticable. The methodology for determination of calibration constants using the QAD program is maintained by the staff of the IRSS.

3.6 Determination of the Effective Maximum Effluent Concentration (EMEC) for Liquid Releases

In order to fulfill the requirements of 10 CFR 20, the RMS set point must be a value which will alarm when a liquid effluent would contain enough radionuclides to cause the effluent concentration limit of 10 CFR 20, Appendix B, Table 2, Column 2 for a single radionuclide to be exceeded, or for a mixture of radionuclides, the summation of fractions (SOF), as defined in Appendix B, to exceed one (1). Dividing the average isotopic concentrations for the years 1985-1991 by the SOF scales the total of individual concentrations up to the value where the SOF equals one. This total concentration is called the effective maximum effluent concentration (EMEC) and its calculation is described below. (For a complete discussion of the EMEC derivation, see Appendix A.)

The SOF is calculated using the formula found in 10 CFR 20, Appendix B, Note 4:

$$SOF = \sum C_i/MEC_i$$

where:

C_i = concentration of radionuclide "i" (μCi/ml) in effluent (annual discharge/total volume of discharge)

MEC_i = maximum effluent concentration for unrestricted areas from Appendix B, Table 2, Column 2 of 10 CFR 20.

The SOF for radionuclides in liquid effluent for the years 1985 through 1991 were averaged and applied to the average of the isotopic concentrations for the same years. Na-24 and H-3 were not used in the calculations (see Appendix A for details).

Next, the "effective MEC" or EMEC is calculated using the formula:

$$EMEC = \sum C_i / \sum (C_i/MEC_i) \text{ or } \sum C_i * 1/SOF$$

where the variables are the same as defined above.

The average EMEC, based on 1985-1991 data is 4.29E-06 μCi/cc. This is the maximum non H-3 radionuclide mixture concentration that could be released in liquid effluent without the SOF exceeding one (1).

However, the 10 CFR 20, Appendix B criterion is that the SOF for all radionuclides, including H-3 which cannot be measured by the liquid effluent NaI RMS monitors, be less than or equal to one (1). Therefore, the above equation modified by a factor of 0.70 (see Appendix A) to account for H-3 becomes

$$EMEC = 0.70 \sum C_i / \sum (C_i/MEC_i) \quad \text{or} \quad \sum C_i * 0.70/SOF.$$

The EMEC becomes

$$EMEC = 0.70 * 4.29E\text{-}06 = 3.00E\text{-}06 \ \mu Ci/cc.$$

Only three radionuclides identified in PBNP liquid effluent have a lower MEC (10 CFR 20, Appendix B, Table 2). They are I-131 (1E-06), Cs-134 (9E-07), and Cs-137 (1E-06).

Note that the use of the 0.7 modifying factor sets the SOF for non-tritium radionuclides to 0.7 and allows an SOF of 0.3 for H-3. A SOF of 0.3 limits the discharge concentration of H-3 to 0.3 MEC or 3E-04 μCi/cc. The factor of 0.3 may be changed as needed for releases for which the isotopic mixture and concentrations are known as long as the total SOF ≤1.

3.7 Determination of Liquid Effluent Monitor Alarm Set Point

The alarm set point for each liquid monitor is based upon the 1985-1991 average radionuclide concentration in the effluent discharged to the unrestricted area. The radionuclide concentration in the release is calculated assuming a minimum circulating water flow rate of 206,000 gpm and the maximum flow rate of the individual liquid effluent waste stream. The isotopic distribution of the waste stream is obtained from the historical PBNP release data for the seven years mentioned above. Set points are determined such that the sum of all radionuclides in the mixture, when released into the circulating water system, will be maintained at or below the unrestricted area EMEC.

Set points are calculated using the formula

$$SP = EMEC * \frac{\text{Circ water flow rate (gpm)}}{\text{Waste Discharge Flow Rate (gpm)}}$$

where

SP = RMS alarm set point in μCi/cc

EMEC = effective maximum effluent concentration

Circ water flow rate = total flow from Unit 1 + Unit 2

Waste discharge flow rate = flow rate for effluent line on which the monitor is located

Maximum waste discharge flow rates and monitors associated with each liquid effluent pathway are described in Table 3.7-1.

Default alarm set points normally are established based upon the maximum waste discharge flow rate and the minimum circulation water flow rate. The liquid release monitor default set points are listed in Table 3.7-2. Alarm set points may be adjusted for batch releases, when actual flow rates are known. Alarm set point adjustments which are higher than default values, are to be made in accordance with the provisions and methodologies of this section and requires approval of the MSS. Lower alarm set point values maybe used without MSS approval if the default values lie outside the upper range of the monitor or if compliance with applicable limits will not be compromised.

TABLE 3.7-1

SUMMARY OF LIQUID DILUTION AND EFFLUENT PATHWAY FLOW RATES

LIQUID EFFLUENT PATHWAY	DISCHARGE FLOW RATE (GPM)	PATHWAY MONITOR
RECIRCULATION WATER		None
1 pump, either unit	206,000	
2 pumps, either unit	350,000	
1 pump, each unit	392,000	
1 pump, one unit & 2 pumps, other unit	530,000	
2 pumps, each unit	680,000	
SERVICE WATER RETURN (normal cooldown per pump		1 (2) RE-229
2 pumps @ 7500 gpm	15,900	
3 pumps @ 6300 gpm	18,900	
4 pumps @ 5100 gpm	20,400	
5 pumps @ 4300 gpm	21,500	
6 pumps @ 3700 gpm	22,200	
STEAM GENERATOR BLOWDOWN		1 (2) RE-219 & 1 (2) RE-222
Max flow	200	
RETENTION POND		RE-230
Max Flow Rate (2 pumps)	360	
(sliding gate open)	1670	

TABLE 3.7-1 (continued)

SUMMARY OF LIQUID DILUTION AND EFFLUENT PATHWAY FLOW RATES

LIQUID EFFLUENT PATHWAY	DISCHARGE FLOW RATE (GPM)	PATHWAY MONITOR
SPENT FUEL POOL		RE-220
Max Flow Rate	700	
WASTE DISTILLATE & CONDENSATE TANK DISCHARGE		RE-218 & RE-223
Max Flow Rate	100	
CONTAINMENT FAN COOLER RETURN		1 (2) RE-216
Max Flow Rate per Containment	4000	

TABLE 3.7-2

LIQUID PATHWAY MONITOR

CALCULATED DEFAULT SET POINTS

MONITOR	FLOWRATE (gpm)	SET POINT (μCi/cc)
1 (2) RE-229	6 @ 3700[1]	2.78E-05
1 (2) RE-219 & 1 (2) RE-222	200	3.09E-3
RE-230	1670	3.70E-04
RE-220	700	8.83E-04
RE-218 & RE-223	100	6.18E-03
1 (2) RE-216	4000	1.55E-04

[1] six service water pumps at normal cooldown flow rates

3.8 Determination of EMEC for Atmospheric Releases

The maximum concentration of the mixture of radionuclides that is allowable at the site boundary is called the effective maximum effluent concentration (EMEC). The EMEC for an effluent mixture is defined by the equation

$$EMEC = \sum C_i / \sum (C_i / MEC_i)$$

where

C_i = concentration of radionuclide "i"

MEC_i = maximum effluent concentration for radionuclide i from 10 CFR 20, Appendix B, Table 2

$\Sigma (C_i / MEC_i)$ = summation of fractions (SOF), as discussed in Section 3.6, applied to atmospheric releases

The EMEC is calculated from the reference radionuclide mixture. This mixture is obtained from the 1985 - 1991 average annual atmospheric releases and the corresponding concentrations determined from the highest annual average χ/Q. (Details of the EMEC calculation are found in Appendix B.)

The calculated EMEC, corrected for H-3, of 1.92E-08 µCi/cc was obtained to be used in the set point calculations.

3.9 Determination of Gaseous Effluent Monitor Alarm Set points

The alarm set point for each monitor is based upon maintaining the concentration of the reference radionuclide mixture at or below the EMEC. The set point is calculated using the formula

$$SP = 2.12E{+}03 * EMEC / (\chi/Q * FR)$$

where

SP = set point in µCi/cc

2.12E+03 = conversion factor for ft^3/min to m^3/sec

EMEC = 1.92E-08 µCi/cc

χ/Q = highest site boundary annual average 1.5E-06 sec/m^3

FR = the flow rate in ft^3/min of the effluent pathway being monitored.

Combining the above numerical values yields

$$SP(\mu Ci/cc) = 2.71E{+}01 / FR$$

Gaseous effluent pathway discharge flow rates and monitors associated with each pathway are summarized in Table 3.9-1.

TABLE 3.9-1

SUMMARY OF GASEOUS EFFLUENT PATHWAY DISCHARGE FLOW RATES

GASEOUS EFFLUENT PATHWAY		DISCHARGE FLOW RATE CFM	MONITOR(S) IN EFFLUENT PATHWAY
a.	Auxiliary Building Vent	66,400	RE-214 & SPING 23
b.	Combined Air Ejector	20	RE-225
c.	Unit Air Ejector	10	1 (2) RE-215
d.	Containment Purge Vent		
	1) 1 fan operating	12,500	1 (2) RE-212 &
	2) 2 fans operating	25,000	SPINGS 21 & 22
e.	Gas Stripper Building	13,000	RE-224
f.	Drumming Area Vent	43,100	RE-221 & SPING 24

Alarm set points are to be normally established based upon maximum waste discharge flow rates and the highest annual average χ/Q value at the site boundary. The alarm set points may be adjusted for release periods if actual flow rates are reduced to less than maximum values or actual χ/Q values are calculated. Alarm set point adjustments to higher values are to be made in accordance with the provisions and methodologies of this section and require MSS approval. Default set point values obtained using the flow rates in Table 3.9-1 are presented in Table 3.9-2. An additional reduction factor of 1/4 has been applied to the four release point monitors so that the maximum allowable site boundary concentrations will not be exceeded in the event simultaneous releases from these points occur. Lower set point values may be used for any of the monitors without MSS approval if the default value is outside the upper range of the monitor or if compliance with applicable release limits will not be compromised. The set point values for the SPINGs will be the same as the corresponding release point monitor; RE-214 (SPING 23), 1(2)RE-212 (SPINGS 21 and 22) or RE-221 (SPING 24).

TABLE 3.9-2

ATMOSPHERIC PATHWAY MONITOR

DEFAULT RMS SET POINTS

MONITOR	FLOW RATE (ft^3/min)	SET POINT ($\mu Ci/cc$)
RE-214	66,400	1.02E-04
RE-225	20	1.36E+00
1RE-215	10	2.71E+00
2RE-215	10	2.71E+00
1RE-212	25,000[1]	2.73E-04
2RE-212	38,000[2]	1.78E-04
RE-224	13,000	2.09E-03
RE-221	43,000	1.58E-04

[1] 2 fans (with 1 fan the flow rate is 12,500 cubic feet/minute)

[2] 2 fans + 13,000 cfm from the gas stripper building

4.0 DEMONSTRATING COMPLIANCE WITH 10 CFR 50, APPENDIX I

4.1 Introduction

Maintaining effluents within the dose objectives of Appendix I is demonstrated at PBNP by periodic calculations. Compliance with Appendix I limits is demonstrated by periodically calculating doses to the maximum exposed individual using the methodology set forth in Regulatory Guide 1.109, Rev. 1, October 1977 and in other recognized sources such as ICRP publications.

In order to aid in the dose calculations, the formulae in Reg Guide 1.109 were rearranged to calculate the dose per curie released (mrem/Ci) to the environment. For each pathway given in Reg Guide 1.109, a radionuclide's mrem/Ci values for the whole body and the organs were calculated for each of the two release modes, liquid and atmospheric. All of the pathway doses for a radionuclide via the release mode under consideration were summed to obtain the radionuclide's total mrem/Ci released. These values, called total dose factors (TDFs), are listed in Tables 5.1.1 and 5.1.2. The application of TDFs are given in Section 5; the calculations used to obtain them, in Appendix C.

4.2 Dose Limits

To define the limits and conditions for the controlled release of radioactive materials in liquid and gaseous effluents to the environment, to ensure that these releases are as low as is reasonably achievable in conformance with 10 CFR Parts 50.34a and 50.36a, to ensure that these releases result in concentrations of radioactive materials in liquid and gaseous effluents released to unrestricted areas that are within the limits specified in 10 CFR 20, and to ensure that the releases of radioactive material above background to unrestricted areas are as low as is reasonably achievable, the following design release limits as defined in Appendix I to 10 CFR 50 apply:

4.2.1 The calculated annual total quantity of all radioactive material above background that may be released from each light-water-cooled nuclear power reactor to unrestricted areas should not result in an estimated annual dose or dose commitment from liquid effluents for any individual in an unrestricted area from all pathways of exposure in excess of 3 millirems to the total body or 10 millirems to any organ.

4.2.2 The calculated annual total quantity of all radioactive material above background that may be released from each light-water-cooled nuclear power reactor to the atmosphere should not result in an estimated annual air dose from gaseous effluents at any location near ground level which could be occupied by individuals in unrestricted areas in excess of 10 millirads for gamma radiation or 20 millirads for beta radiation, or that this quantity should not result in an estimated annual external dose from gaseous effluents to any individual in unrestricted areas in excess of 5 millirems to the total body or 15 millirems to the skin.

4.2.3 The calculated annual total quantity of all radioactive iodine and radioactive material in particulate form above background that may be released from each light-water-cooled nuclear power reactor in effluents to the atmosphere should not result in an estimated annual dose or dose commitment from such radioactive iodine and radioactive material in particulate form for any individual in an unrestricted area from all pathways of exposure in excess of 15 millirems to any organ.

4.3 Release Limits

Based on the Appendix I dose limits, Point Beach, being a two (2) unit nuclear plant, may release into the environment the quantities of radionuclides above background that fulfill the criteria listed below.

4.3.1. Pursuant to Section 4.2.1, the estimated doses from radionuclides in the unrestricted area in liquids shall not exceed

a. Six (6) millirem to the whole body, or

b. Twenty (20) millirem to any organ.

4.3.2 Pursuant to Section 4.2.2, the estimated doses from gaseous radionuclides in the unrestricted area shall not exceed

a. Twenty (20) millirads to the air from gamma radiation,

b. Forty (40) millirads to the air from beta radiation,

c. Ten (10) millirem to the whole body, or

d. Thirty (30) millirem to the skin.

4.3.3. Pursuant to Section 4.2.3, the estimated dose from radioiodine and radioactive material in particulate form released to the atmosphere in the unrestricted area shall not exceed thirty (30) millirem to any organ.

4.3.4. Quarterly release limits are defined as ¼ the annual limits.

4.4 EPA Regulations

Compliance with the provisions of Appendix I to 10 CFR 50 is adequate demonstration of conformance to the standards set forth in 40 CFR 190 regarding the dose commitment to individuals from the uranium fuel cycle. For 40 CFR 190 compliance, quarterly dose calculations shall include exposures from effluent pathways and direct radiation contributions from the reactor units and from any outside storage tanks.

The above calculations do not include contributions from the Kewaunee Nuclear Power Plant (KNPP) which is some four miles north of PBNP. Under normal operations using the PBNP annual average χ/Q and assuming that the KNPP source term is identical to either PBNP unit, the greatest KNPP dose contribution occurs at the north sector PBNP boundary. However, the total KNPP-PBNP dose at that point is less than the dose in the highest sector (south boundary) from PBNP alone. The KNPP contribution in this sector adds only 1 percent to 8 percent to the total dose depending upon the release mode. Even in the highly unlikely event that PBNP and KNPP operated for an entire year at twice the Appendix I levels, the small percentage contribution from KNPP would be insufficient to yield doses exceeding 40 CFR 190 limits.

5.0 CALCULATION AND COMPARISON OF EFFLUENT RELEASES TO RELEASE LIMITS

| Sections 5.3, 5.5, and 5.6 of the RECM require that an effluent release summary or dose calculation be performed quarterly. This section describes the methodology for the calculation of doses for comparison to the corresponding dose limits. For Appendix I compliance, the organ and whole body doses shall be calculated for the maximumly exposed individual in each age group using the appropriate total dose factors in mrem/Ci released which were obtained using Regulatory Guide 1.109 and other documented methodologies.

5.1 Appendix I Dose Calculations

5.1.1 Liquid Release Mode

The dose calculations for demonstration of compliance with the 10 CFR 50, Appendix I dose limits will be accomplished by the Radiological Engineering Group of IRSS. These calculations will be done monthly, within fifteen (15) days of receipt of the final effluent curie values from the cognizant IRSS engineer. The doses from each radionuclide will be calculated for each age group and for each organ, including the whole body, and summed over all the identified radionuclides released. The total dose is compared to the corresponding liquid release mode Appendix I dose limit for the organ in question. Noble gases released in liquids are added to the atmospherically released noble gases for Appendix I dose compliance calculations.

The doses are calculated using the following formula:

$$API = \Sigma\, Dose_{aomi} = \Sigma\, (TDF_{aomi} \times C_i) \leq K_{om} \text{ mrem}$$

where

API = the Appendix I dose for compliance evaluation in mrem

$Dose_{aomi}$ = the dose to the specific age group a) and organ (o) via release mode (m) from radionuclide (i)

TDF_{aomi} = total dose factor for the specific age group (a) and organ (o) via release mode (m) from radionuclide (i) from Table 5.1-1 in mrem/Ci

C_i = curies of radionuclide (i) released

K_{om} = the Appendix I dose limit for organ (o) and release mode (m) for which the calculation is being made.

The methodology and the values used to obtain the TDF_{aomi} values are given in Appendix C.

It is recognized that some of the release quantities may not be available at the end of the month because the samples from these release paths are sent to a vendor for analysis. Usually, the only radionuclides affected by these delays are Sr-89 and Sr-90. Because the quantities of these two radionuclides are but a small fraction of the total release, the absence of their dose contributions from the initial monthly dose calculation will not significantly affect the total dose obtained from the remaining radionuclides. The dose for the month will be updated upon the receipt of the vendor isotopic results and upon the receipt of any corrections to previous release quantities.

Instead of using the precalculated total dose factors, the Appendix I dose calculation may be modified to reflect the actual liquid discharge volume during the release period using the methodology in Appendix C.

Table 5.1-1

Liquid Effluent Dose Factor

Summation of dose per curie released factor calculations over the pathways: potable water, aquatic food, shoreline deposit, irrigated foods (milk), and irrigated foods (meat).

Dose factor - liquid release pathway (mrem/Ci released)							
H-3							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	0.00E+00	4.57E-06	4.57E-06	4.57E-06	4.57E-06	4.57E-06	4.57E-06
Teen	0.00E+00	4.11E-06	4.11E-06	4.11E-06	4.11E-06	4.11E-06	4.11E-06
Child	0.00E+00	6.76E-06	6.76E-06	6.76E-06	6.76E-06	6.76E-06	6.76E-06
Infant	0.00E+00	7.80E-06	7.80E-06	7.80E-06	7.80E-06	7.80E-06	7.80E-06

Dose factor - liquid release pathway (mrem/Ci released)							
F-18							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.15E-07	9.12E-89	1.28E-08	0.00E+00	5.14E-89	0.00E+00	3.40E-09
Teen	1.21E-07	7.59E-89	1.35E-08	0.00E+00	4.35E-89	0.00E+00	1.09E-08
Child	1.51E-07	1.08E-88	1.50E-08	0.00E+00	5.74E-89	0.00E+00	4.08E-08
Infant	2.05E-12	0.00E+00	1.75E-13	0.00E+00	0.00E+00	0.00E+00	4.83E-13

Dose factor - liquid release pathway (mrem/Ci released)							
Na-22							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	4.71E-03	4.71E-03	4.82E-03	4.71E-03	4.71E-03	4.71E-03	4.71E-03
Teen	5.48E-03	5.48E-03	6.07E-03	5.48E-03	5.48E-03	5.48E-03	5.48E-03
Child	8.32E-03	8.32E-03	8.45E-03	8.32E-03	8.32E-03	8.32E-03	8.32E-03
Infant	7.21E-03	7.21E-03	7.21E-03	7.21E-03	7.21E-03	7.21E-03	7.21E-03

Table 5.1-1 (continued)

Dose factor - liquid release pathway (mrem/Ci released)

Na-24

	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.85E-04	1.85E-04	1.85E-04	1.85E-04	1.85E-04	1.85E-04	1.85E-04
Teen	1.98E-04	1.98E-04	1.98E-04	1.98E-04	1.98E-04	1.98E-04	1.98E-04
Child	2.40E-04	2.40E-04	2.40E-04	2.40E-04	2.40E-04	2.40E-04	2.40E-04
Infant	8.06E-05	8.06E-05	8.06E-05	8.06E-05	8.06E-05	8.06E-05	8.06E-05

Dose factor - liquid release pathway (mrem/Ci released)

Sc-46

	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.70E-07	3.31E-07	8.92E-06	0.00E+00	3.09E-07	0.00E+00	1.61E-03
Teen	1.52E-07	2.97E-07	4.94E-05	0.00E+00	2.84E-07	0.00E+00	1.01E-03
Child	3.54E-07	4.85E-07	1.05E-05	0.00E+00	4.29E-07	0.00E+00	7.09E-04
Infant	3.42E-07	4.94E-07	1.54E-07	0.00E+00	3.25E-07	0.00E+00	3.22E-04

Dose factor - liquid release pathway (mrem/Ci released)

Mn-54

	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	0.00E+00	3.28E-03	6.34E-04	0.00E+00	9.75E-04	0.00E+00	1.00E-02
Teen	0.00E+00	3.22E-03	6.86E-04	0.00E+00	9.59E-04	0.00E+00	6.60E-03
Child	0.00E+00	2.60E-03	7.04E-04	0.00E+00	7.30E-04	0.00E+00	2.19E-03
Infant	0.00E+00	1.92E-04	4.34E-05	0.00E+00	4.25E-05	0.00E+00	7.04E-05

Table 5.1-1 (continued)

Dose factor - liquid release pathway (mrem/Ci released)							
Cr-51							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	0.00E+00	0.00E+00	1.01E-06	5.84E-07	2.15E-07	1.30E-06	2.46E-04
Teen	0.00E+00	0.00E+00	1.17E-06	5.60E-07	2.21E-07	1.44E-06	1.70E-04
Child	0.00E+00	0.00E+00	1.19E-06	6.44E-07	1.76E-07	1.18E-06	6.15E-05
Infant	0.00E+00	0.00E+00	1.72E-07	1.12E-07	2.45E-08	2.18E-07	5.01E-06

Dose factor - liquid release pathway (mrem/Ci released)							
Mn-56							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	0.00E+00	3.18E-06	5.65E-07	0.00E+00	4.04E-06	0.00E+00	1.02E-04
Teen	0.00E+00	3.33E-06	5.94E-07	0.00E+00	4.22E-06	0.00E+00	2.19E-04
Child	0.00E+00	3.04E-06	6.86E-07	0.00E+00	3.67E-06	0.00E+00	4.40E-04
Infant	0.00E+00	1.97E-11	3.39E-12	0.00E+00	1.69E-11	0.00E+00	1.79E-09

Dose factor - liquid release pathway (mrem/Ci released)							
Fe-55							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	5.98E-04	4.13E-04	9.63E-05	0.00E+00	0.00E+00	2.31E-04	2.37E-04
Teen	6.11E-04	4.33E-04	1.01E-04	0.00E+00	0.00E+00	2.75E-04	1.88E-04
Child	9.35E-04	4.96E-04	1.54E-04	0.00E+00	0.00E+00	2.80E-04	9.19E-05
Infant	1.55E-04	1.00E-04	2.68E-05	0.00E+00	0.00E+00	4.91E-05	1.28E-05

Table 5.1-1 (continued)

Dose factor - liquid release pathway (mrem/Ci released)							
Fe-59							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	9.12E-04	2.14E-03	8.23E-04	0.00E+00	0.00E+00	5.99E-04	7.14E-03
Teen	9.22E-04	2.15E-03	8.40E-04	0.00E+00	0.00E+00	6.79E-04	5.09E-03
Child	1.29E-03	2.09E-03	1.04E-03	0.00E+00	0.00E+00	6.07E-04	2.18E-03
Infant	3.34E-04	5.84E-04	2.30E-04	0.00E+00	0.00E+00	1.73E-04	2.79E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Co-57							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	0.00E+00	2.02E-05	3.57E-05	0.00E+00	0.00E+00	0.00E+00	5.13E-04
Teen	0.00E+00	2.06E-05	4.62E-05	0.00E+00	0.00E+00	0.00E+00	3.83E-04
Child	0.00E+00	2.31E-05	4.93E-05	0.00E+00	0.00E+00	0.00E+00	1.89E-04
Infant	0.00E+00	1.24E-05	2.02E-05	0.00E+00	0.00E+00	0.00E+00	4.24E-05

Dose factor - liquid release pathway (mrem/Ci released)							
Co-58							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	0.00E+00	8.49E-05	1.93E-04	0.00E+00	0.00E+00	0.00E+00	1.72E-03
Teen	0.00E+00	8.30E-05	2.04E-04	0.00E+00	0.00E+00	0.00E+00	1.14E-03
Child	0.00E+00	8.32E-05	2.57E-04	0.00E+00	0.00E+00	0.00E+00	4.85E-04
Infant	0.00E+00	3.84E-05	9.58E-05	0.00E+00	0.00E+00	0.00E+00	9.57E-05

Table 5.1-1 (continued)

Dose factor - liquid release pathway (mrem/Ci released)							
Co-60							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	0.00E+00	2.48E-04	6.82E-04	0.00E+00	0.00E+00	0.00E+00	4.66E-03
Teen	0.00E+00	2.44E-04	1.30E-03	0.00E+00	0.00E+00	0.00E+00	3.17E-03
Child	0.00E+00	2.49E-04	8.92E-04	0.00E+00	0.00E+00	0.00E+00	1.38E-03
Infant	0.00E+00	1.17E-04	2.77E-04	0.00E+00	0.00E+00	0.00E+00	2.79E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Ni-63							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.03E-02	2.10E-03	1.02E-03	0.00E+00	0.00E+00	0.00E+00	4.38E-04
Teen	3.13E-02	2.21E-03	1.06E-03	0.00E+00	0.00E+00	0.00E+00	3.52E-04
Child	5.00E-02	2.67E-03	1.70E-03	0.00E+00	0.00E+00	0.00E+00	1.80E-04
Infant	1.27E-02	7.85E-04	4.41E-04	0.00E+00	0.00E+00	0.00E+00	3.91E-05

Dose factor - liquid release pathway (mrem/Ci released)							
Ni-65							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.39E-06	4.40E-07	2.01E-07	0.00E+00	0.00E+00	0.00E+00	1.12E-05
Teen	3.66E-06	4.68E-07	2.13E-07	0.00E+00	0.00E+00	0.00E+00	2.54E-05
Child	4.68E-06	4.41E-07	2.57E-07	0.00E+00	0.00E+00	0.00E+00	5.40E-05
Infant	1.74E-10	1.97E-11	8.95E-12	0.00E+00	0.00E+00	0.00E+00	1.50E-09

Table 5.1-1 (continued)

Dose factor - liquid release pathway (mrem/Ci released)							
Cu-64							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	0.00E+00	4.02E-06	1.89E-06	0.00E+00	1.01E-05	0.00E+00	3.43E-04
Teen	0.00E+00	4.31E-06	2.04E-06	0.00E+00	1.09E-05	0.00E+00	3.34E-04
Child	0.00E+00	4.30E-06	2.60E-06	0.00E+00	1.04E-05	0.00E+00	2.02E-04
Infant	0.00E+00	1.41E-06	6.52E-07	0.00E+00	2.38E-06	0.00E+00	2.89E-05

Dose factor - liquid release pathway (mrem/Ci released)							
Zn-65							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.73E-02	5.50E-02	2.49E-02	0.00E+00	3.68E-02	0.00E+00	3.46E-02
Teen	1.58E-02	5.50E-02	2.57E-02	0.00E+00	3.52E-02	0.00E+00	2.33E-02
Child	1.68E-02	4.47E-02	2.78E-02	0.00E+00	2.82E-02	0.00E+00	7.85E-03
Infant	1.32E-03	4.51E-03	2.08E-03	0.00E+00	2.19E-03	0.00E+00	3.81E-03

Dose factor - liquid release pathway (mrem/Ci released)							
Zn-69							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.97E-05	3.76E-05	2.62E-06	0.00E+00	2.44E-05	0.00E+00	5.65E-06
Teen	2.14E-05	4.08E-05	2.86E-06	0.00E+00	2.67E-05	0.00E+00	7.52E-05
Child	2.77E-05	4.00E-05	3.70E-06	0.00E+00	2.43E-05	0.00E+00	2.52E-03
Infant	5.98E-07	1.08E-06	8.01E-08	0.00E+00	4.47E-07	0.00E+00	8.78E-05

Table 5.1-1 (continued)

Dose factor - liquid release pathway (mrem/Ci released)							
Zn-69m							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.25E-04	7.79E-04	7.12E-05	0.00E+00	4.72E-04	0.00E+00	4.76E-02
Teen	3.50E-04	8.25E-04	7.57E-05	0.00E+00	5.01E-04	0.00E+00	4.53E-02
Child	4.49E-04	7.65E-04	9.04E-05	0.00E+00	4.44E-04	0.00E+00	2.49E-02
Infant	9.61E-06	1.96E-05	1.79E-06	0.00E+00	7.94E-06	0.00E+00	2.72E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Br-82							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	0.00E+00	0.00E+00	1.39E-03	0.00E+00	0.00E+00	0.00E+00	1.59E-03
Teen	0.00E+00	0.00E+00	1.47E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Child	0.00E+00	0.00E+00	1.71E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Infant	0.00E+00	0.00E+00	4.43E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Dose factor - liquid release pathway (mrem/Ci released)							
Br-83							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	0.00E+00	0.00E+00	9.06E-07	0.00E+00	0.00E+00	0.00E+00	1.30E-06
Teen	0.00E+00	0.00E+00	9.85E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Child	0.00E+00	0.00E+00	1.27E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Infant	0.00E+00	0.00E+00	2.93E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 5.1-1 (continued)

Dose factor - liquid release pathway (mrem/Ci released)							
Br-84							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	0.00E+00	0.00E+00	3.12E-05	0.00E+00	0.00E+00	0.00E+00	2.44E-10
Teen	0.00E+00	0.00E+00	3.43E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Child	0.00E+00	0.00E+00	4.33E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Infant	0.00E+00	0.00E+00	1.20E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Dose factor - liquid release pathway (mrem/Ci released)							
Br-85							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	0.00E+00	0.00E+00	4.24E-82	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Teen	0.00E+00	0.00E+00	4.60E-82	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Child	0.00E+00	0.00E+00	5.94E-82	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Infant	0.00E+00	0.00E+00	9.35E-309	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Dose factor - liquid release pathway (mrem/Ci released)							
Rb-86							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	0.00E+00	7.36E-02	3.43E-02	0.00E+00	0.00E+00	0.00E+00	1.45E-02
Teen	0.00E+00	7.98E-02	3.75E-02	0.00E+00	0.00E+00	0.00E+00	1.18E-02
Child	0.00E+00	7.93E-02	4.88E-02	0.00E+00	0.00E+00	0.00E+00	5.10E-03
Infant	0.00E+00	9.07E-03	4.48E-03	0.00E+00	0.00E+00	0.00E+00	2.32E-04

Table 5.1-1 (continued)

Dose factor - liquid release pathway (mrem/Ci released)

Rb-88

	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	0.00E+00	1.41E-16	7.46E-17	0.00E+00	0.00E+00	0.00E+00	1.94E-27
Teen	0.00E+00	1.51E-16	8.04E-17	0.00E+00	0.00E+00	0.00E+00	1.29E-23
Child	0.00E+00	1.45E-16	1.01E-16	0.00E+00	0.00E+00	0.00E+00	7.12E-18
Infant	0.00E+00	5.68E-54	3.12E-54	0.00E+00	0.00E+00	0.00E+00	5.54E-54

Dose factor - liquid release pathway (mrem/Ci released)

Rb-89

	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	0.00E+00	1.28E-18	8.99E-19	0.00E+00	0.00E+00	0.00E+00	7.42E-32
Teen	0.00E+00	1.34E-18	9.45E-19	0.00E+00	0.00E+00	0.00E+00	2.05E-27
Child	0.00E+00	1.23E-18	1.09E-18	0.00E+00	0.00E+00	0.00E+00	1.07E-20
Infant	0.00E+00	1.15E-61	7.93E-62	0.00E+00	0.00E+00	0.00E+00	3.92E-62

Dose factor - liquid release pathway (mrem/Ci released)

Sr-89

	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	2.26E-02	0.00E+00	6.48E-04	0.00E+00	0.00E+00	0.00E+00	3.62E-03
Teen	2.43E-02	0.00E+00	6.95E-04	0.00E+00	0.00E+00	0.00E+00	2.89E-03
Child	4.27E-02	0.00E+00	1.22E-03	0.00E+00	0.00E+00	0.00E+00	1.65E-03
Infant	2.58E-02	0.00E+00	7.40E-04	0.00E+00	0.00E+00	0.00E+00	5.30E-04

Table 5.1-1 (continued)

Dose factor - liquid release pathway (mrem/Ci released)

Sr-90

	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	5.63E-01	0.00E+00	1.38E-01	0.00E+00	0.00E+00	0.00E+00	1.63E-02
Teen	4.64E-01	0.00E+00	1.15E-01	0.00E+00	0.00E+00	0.00E+00	1.30E-02
Child	5.59E-01	0.00E+00	1.42E-01	0.00E+00	0.00E+00	0.00E+00	7.53E-03
Infant	1.95E-01	0.00E+00	4.97E-02	0.00E+00	0.00E+00	0.00E+00	2.44E-03

Dose factor - liquid release pathway (mrem/Ci released)

Sr-91

	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.27E-04	0.00E+00	5.14E-06	0.00E+00	0.00E+00	0.00E+00	6.05E-04
Teen	1.38E-04	0.00E+00	5.51E-06	0.00E+00	0.00E+00	0.00E+00	6.24E-04
Child	1.83E-04	0.00E+00	6.91E-06	0.00E+00	0.00E+00	0.00E+00	4.04E-04
Infant	1.59E-05	0.00E+00	5.76E-07	0.00E+00	0.00E+00	0.00E+00	1.88E-05

Dose factor - liquid release pathway (mrem/Ci released)

Sr-92

	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	5.21E-06	0.00E+00	2.26E-07	0.00E+00	0.00E+00	0.00E+00	1.03E-04
Teen	5.64E-06	0.00E+00	2.42E-07	0.00E+00	0.00E+00	0.00E+00	1.44E-04
Child	7.20E-06	0.00E+00	2.89E-07	0.00E+00	0.00E+00	0.00E+00	1.36E-04
Infant	9.41E-10	0.00E+00	3.50E-11	0.00E+00	0.00E+00	0.00E+00	1.01E-08

Table 5.1-1 (continued)

Dose factor - liquid release pathway (mrem/Ci released)							
Y-90							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	4.85E-07	0.00E+00	1.30E-08	0.00E+00	0.00E+00	0.00E+00	5.15E-03
Teen	5.16E-07	0.00E+00	1.40E-08	0.00E+00	0.00E+00	0.00E+00	4.26E-03
Child	8.67E-07	0.00E+00	2.32E-08	0.00E+00	0.00E+00	0.00E+00	2.47E-03
Infant	4.80E-07	0.00E+00	1.29E-08	0.00E+00	0.00E+00	0.00E+00	6.63E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Y-91							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	9.20E-06	0.00E+00	2.53E-07	0.00E+00	0.00E+00	0.00E+00	5.06E-03
Teen	9.68E-06	0.00E+00	2.97E-07	0.00E+00	0.00E+00	0.00E+00	3.97E-03
Child	1.74E-05	0.00E+00	4.74E-07	0.00E+00	0.00E+00	0.00E+00	2.32E-03
Infant	1.03E-05	0.00E+00	2.73E-07	0.00E+00	0.00E+00	0.00E+00	7.35E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Y-91m							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.71E-13	0.00E+00	5.10E-14	0.00E+00	0.00E+00	0.00E+00	5.02E-13
Teen	1.85E-13	0.00E+00	2.55E-13	0.00E+00	0.00E+00	0.00E+00	8.72E-12
Child	2.36E-13	0.00E+00	6.04E-14	0.00E+00	0.00E+00	0.00E+00	4.62E-10
Infant	2.62E-26	0.00E+00	8.92E-28	0.00E+00	0.00E+00	0.00E+00	8.72E-23

Table 5.1-1 (continued)

Dose factor - liquid release pathway (mrem/Ci released)							
Y-92							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.51E-09	0.00E+00	2.88E-10	0.00E+00	0.00E+00	0.00E+00	6.15E-05
Teen	3.83E-09	0.00E+00	1.15E-09	0.00E+00	0.00E+00	0.00E+00	1.05E-04
Child	4.92E-09	0.00E+00	3.57E-10	0.00E+00	0.00E+00	0.00E+00	1.42E-04
Infant	5.88E-12	0.00E+00	1.65E-13	0.00E+00	0.00E+00	0.00E+00	1.12E-07

Dose factor - liquid release pathway (mrem/Ci released)							
Y-93							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	5.32E-08	0.00E+00	2.33E-09	0.00E+00	0.00E+00	0.00E+00	1.69E-03
Teen	5.77E-08	0.00E+00	6.38E-09	0.00E+00	0.00E+00	0.00E+00	1.76E-03
Child	7.75E-08	0.00E+00	3.13E-09	0.00E+00	0.00E+00	0.00E+00	1.16E-03
Infant	8.33E-09	0.00E+00	2.27E-10	0.00E+00	0.00E+00	0.00E+00	6.58E-05

Dose factor - liquid release pathway (mrem/Ci released)							
Zr-95							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.23E-06	3.94E-07	1.79E-06	0.00E+00	6.19E-07	0.00E+00	1.25E-03
Teen	1.11E-06	3.52E-07	8.74E-06	0.00E+00	5.17E-07	0.00E+00	8.11E-04
Child	2.48E-06	5.45E-07	2.26E-06	0.00E+00	7.80E-07	0.00E+00	5.69E-04
Infant	1.87E-06	4.56E-07	3.23E-07	0.00E+00	4.91E-07	0.00E+00	2.27E-04

Table 5.1-1 (continued)

Dose factor - liquid release pathway (mrem/Ci released)							
Zr-97							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.07E-08	2.16E-09	1.23E-08	0.00E+00	3.27E-09	0.00E+00	6.70E-04
Teen	1.11E-08	2.19E-09	6.42E-08	0.00E+00	3.33E-09	0.00E+00	5.94E-04
Child	2.21E-08	3.19E-09	1.51E-08	0.00E+00	4.58E-09	0.00E+00	4.83E-04
Infant	1.92E-08	3.29E-09	1.50E-09	0.00E+00	3.32E-09	0.00E+00	2.10E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Nb-95							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.23E-04	1.79E-04	9.73E-05	0.00E+00	1.77E-04	0.00E+00	1.09E+00
Teen	3.25E-04	1.80E-04	1.04E-04	0.00E+00	1.75E-04	0.00E+00	7.70E-01
Child	3.84E-04	1.49E-04	1.08E-04	0.00E+00	1.40E-04	0.00E+00	2.76E-01
Infant	5.36E-07	2.21E-07	1.28E-07	0.00E+00	1.58E-07	0.00E+00	1.86E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Nb-97							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	2.69E-09	6.81E-10	2.51E-10	0.00E+00	7.95E-10	0.00E+00	2.51E-06
Teen	2.90E-09	7.20E-10	2.73E-10	0.00E+00	8.41E-10	0.00E+00	1.72E-05
Child	3.68E-09	6.65E-10	3.12E-10	0.00E+00	7.38E-10	0.00E+00	2.05E-04
Infant	5.81E-21	1.24E-10	4.47E-22	0.00E+00	9.68E-22	0.00E+00	3.91E-16

Table 5.1-1 (continued)

Dose factor - liquid release pathway (mrem/Ci released)							
Mo-99							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	0.00E+00	1.49E-04	2.84E-05	0.00E+00	3.38E-04	0.00E+00	3.46E-04
Teen	0.00E+00	1.76E-04	3.36E-05	0.00E+00	4.03E-04	0.00E+00	3.15E-04
Child	0.00E+00	2.79E-04	6.91E-05	0.00E+00	5.96E-04	0.00E+00	2.31E-04
Infant	0.00E+00	4.38E-04	8.54E-05	0.00E+00	6.54E-04	0.00E+00	1.44E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Tc-99m							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.68E-09	4.74E-09	6.07E-08	0.00E+00	7.20E-08	2.32E-09	2.81E-06
Teen	1.74E-09	4.86E-09	6.46E-08	0.00E+00	7.24E-08	2.70E-09	3.19E-06
Child	2.19E-09	4.29E-09	7.15E-08	0.00E+00	6.24E-08	2.18E-09	2.44E-06
Infant	3.78E-10	7.79E-10	1.00E-08	0.00E+00	8.38E-09	4.07E-10	2.26E-07

Dose factor - liquid release pathway (mrem/Ci released)							
Tc-101							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.60E-24	5.19E-24	5.10E-23	0.00E+00	9.34E-23	2.65E-24	1.56E-35
Teen	3.89E-24	5.53E-24	5.49E-23	0.00E+00	1.00E-22	3.37E-24	9.45E-31
Child	4.98E-24	5.22E-24	6.63E-23	0.00E+00	8.90E-23	2.76E-24	1.66E-23
Infant	9.73E-69	1.23E-68	1.21E-67	0.00E+00	1.46E-67	6.69E-69	2.08E-66

Table 5.1-1 (continued)

Dose factor - liquid release pathway (mrem/Ci released)							
Ru-103							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.47E-05	0.00E+00	1.56E-05	0.00E+00	1.32E-04	0.00E+00	4.05E-03
Teen	2.96E-05	0.00E+00	1.64E-05	0.00E+00	1.04E-04	0.00E+00	2.47E-03
Child	5.53E-05	0.00E+00	2.20E-05	0.00E+00	1.39E-04	0.00E+00	1.43E-03
Infant	1.33E-05	0.00E+00	4.43E-06	0.00E+00	2.76E-05	0.00E+00	1.61E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Ru-105							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	4.13E-08	0.00E+00	1.75E-08	0.00E+00	5.34E-07	0.00E+00	2.53E-05
Teen	4.45E-08	0.00E+00	2.42E-08	0.00E+00	5.62E-07	0.00E+00	3.59E-05
Child	5.71E-08	0.00E+00	2.22E-08	0.00E+00	5.02E-07	0.00E+00	3.73E-05
Infant	6.98E-10	0.00E+00	2.35E-10	0.00E+00	5.13E-09	0.00E+00	2.78E-07

Dose factor - liquid release pathway (mrem/Ci released)							
Ru-106							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	6.71E-04	0.00E+00	8.76E-05	0.00E+00	1.30E-03	0.00E+00	4.34E-02
Teen	5.86E-04	0.00E+00	8.85E-05	0.00E+00	1.13E-03	0.00E+00	2.81E-02
Child	1.13E-03	0.00E+00	1.44E-04	0.00E+00	1.53E-03	0.00E+00	1.76E-02
Infant	2.23E-04	0.00E+00	2.78E-05	0.00E+00	2.63E-04	0.00E+00	1.69E-03

Table 5.1-1 (continued)

Dose factor - liquid release pathway (mrem/Ci released)							
Rh-105							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.35E-06	2.45E-06	1.62E-06	0.00E+00	1.04E-05	0.00E+00	3.90E-04
Teen	4.10E-06	2.96E-06	1.97E-06	0.00E+00	1.26E-05	0.00E+00	3.77E-04
Child	8.43E-06	4.52E-06	3.88E-06	0.00E+00	1.80E-05	0.00E+00	2.80E-04
Infant	1.08E-05	7.05E-06	4.74E-06	0.00E+00	1.96E-05	0.00E+00	1.75E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Ag-110m							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.06E-05	2.83E-05	3.83E-05	0.00E+00	5.56E-05	0.00E+00	1.15E-02
Teen	3.74E-05	3.54E-05	1.41E-04	0.00E+00	6.75E-05	0.00E+00	9.94E-03
Child	6.78E-05	4.58E-05	6.17E-05	0.00E+00	8.53E-05	0.00E+00	5.45E-03
Infant	8.87E-05	6.47E-05	4.28E-05	0.00E+00	9.26E-05	0.00E+00	3.36E-03

Dose factor - liquid release pathway (mrem/Ci released)							
Sb-124							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	5.42E-04	1.02E-05	2.21E-04	1.32E-06	0.00E+00	4.22E-04	1.54E-02
Teen	5.66E-04	1.04E-05	2.53E-04	1.28E-06	0.00E+00	4.94E-04	1.14E-02
Child	7.89E-04	1.02E-05	2.83E-04	1.74E-06	0.00E+00	4.38E-04	4.94E-03
Infant	1.95E-04	2.86E-06	6.03E-05	5.17E-07	0.00E+00	1.22E-04	6.00E-04

Table 5.1-1 (continued)

Dose factor - liquid release pathway (mrem/Ci released)							
Sb-125							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.49E-04	3.90E-06	1.07E-04	3.55E-07	0.00E+00	2.69E-04	3.85E-03
Teen	3.65E-04	3.99E-06	2.19E-04	3.49E-07	0.00E+00	3.21E-04	2.84E-03
Child	5.14E-04	3.96E-06	1.35E-04	4.76E-07	0.00E+00	2.86E-04	1.23E-03
Infant	1.14E-04	1.11E-06	2.35E-05	1.43E-07	0.00E+00	7.17E-05	1.52E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Te-125m							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.30E-04	1.20E-04	4.43E-05	9.93E-05	1.34E-03	0.00E+00	1.32E-03
Teen	3.36E-04	1.21E-04	4.53E-05	9.39E-05	0.00E+00	0.00E+00	9.92E-04
Child	5.74E-04	1.56E-04	7.67E-05	1.61E-04	0.00E+00	0.00E+00	5.54E-04
Infant	2.47E-04	8.27E-05	3.35E-05	8.33E-05	0.00E+00	0.00E+00	1.18E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Te-127							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.15E-05	1.13E-05	6.83E-06	2.34E-05	1.28E-04	0.00E+00	2.49E-03
Teen	3.45E-05	1.22E-05	7.43E-06	2.38E-05	1.40E-04	0.00E+00	2.67E-03
Child	4.45E-05	1.20E-05	9.54E-06	3.08E-05	1.27E-04	0.00E+00	1.74E-03
Infant	3.10E-07	1.04E-07	6.67E-08	2.52E-07	7.56E-07	0.00E+00	6.51E-06

Table 5.1-1 (continued)

Dose factor - liquid release pathway (mrem/Ci released)							
Te-127m							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	8.63E-04	3.08E-04	1.05E-04	2.21E-04	3.51E-03	0.00E+00	2.89E-03
Teen	8.74E-04	3.10E-04	1.04E-04	2.08E-04	3.54E-03	0.00E+00	2.18E-03
Child	1.50E-03	4.05E-04	1.79E-04	3.60E-04	4.29E-03	0.00E+00	1.22E-03
Infant	6.28E-04	2.08E-04	7.61E-05	1.82E-04	1.55E-03	0.00E+00	2.54E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Te-129							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.68E-08	6.32E-09	4.10E-09	1.29E-08	7.07E-08	0.00E+00	1.27E-08
Teen	1.83E-08	6.82E-09	4.45E-09	1.31E-08	7.68E-08	0.00E+00	1.00E-07
Child	2.36E-08	6.58E-09	5.60E-09	1.68E-08	6.90E-08	0.00E+00	1.47E-06
Infant	1.08E-18	3.73E-19	2.53E-19	9.07E-19	2.69E-18	0.00E+00	8.65E-17

Dose factor - liquid release pathway (mrem/Ci released)							
Te-129m							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.35E-03	5.04E-04	2.14E-04	4.64E-04	5.63E-03	0.00E+00	6.80E-03
Teen	1.37E-03	5.10E-04	2.18E-04	4.43E-04	5.75E-03	0.00E+00	5.16E-03
Child	2.34E-03	6.54E-04	3.64E-04	7.55E-04	6.88E-03	0.00E+00	2.86E-03
Infant	1.04E-03	3.58E-04	1.61E-04	4.01E-04	2.61E-03	0.00E+00	6.23E-04

Table 5.1-1 (continued)

Dose factor - liquid release pathway (mrem/Ci released)							
Te-131m							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.04E-04	5.08E-05	4.24E-05	8.05E-05	5.15E-04	0.00E+00	5.05E-03
Teen	1.11E-04	5.34E-05	4.49E-05	8.03E-05	5.56E-04	0.00E+00	4.28E-03
Child	1.63E-04	5.63E-05	6.00E-05	1.16E-04	5.45E-04	0.00E+00	2.28E-03
Infant	5.46E-05	2.20E-05	1.81E-05	4.45E-05	1.51E-04	0.00E+00	3.70E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Te-131							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	2.97E-15	1.24E-15	9.40E-16	2.44E-15	1.30E-14	0.00E+00	4.21E-16
Teen	3.21E-15	1.32E-15	1.01E-15	2.47E-15	1.40E-14	0.00E+00	2.63E-16
Child	4.12E-15	1.25E-15	1.23E-15	3.15E-15	1.24E-14	0.00E+00	2.16E-14
Infant	4.22E-41	1.56E-41	1.18E-41	3.77E-41	1.08E-40	0.00E+00	1.71E-39

Dose factor - liquid release pathway (mrem/Ci released)							
Te-132							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.96E-04	1.26E-04	1.19E-04	1.40E-04	1.22E-03	0.00E+00	5.98E-03
Teen	2.05E-04	1.30E-04	1.22E-04	1.37E-04	[illegible].24E-03	0.00E+00	4.11E-03
Child	3.15E-04	1.39E-04	1.69E-04	2.03E-04	1.29E-03	0.00E+00	1.40E-03
Infant	1.48E-04	7.32E-05	6.83E-05	1.08E-04	4.58E-04	0.00E+00	2.71E-04

Table 5.1-1 (continued)

Dose factor - liquid release pathway (mrem/Ci released)							
I-131							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	2.09E-04	2.99E-04	1.71E-04	9.78E-02	5.12E-04	0.00E+00	7.88E-05
Teen	2.41E-04	3.37E-04	1.81E-04	9.83E-02	5.80E-04	0.00E+00	6.66E-05
Child	4.90E-04	4.93E-04	2.80E-04	1.63E-01	8.09E-04	0.00E+00	4.39E-05
Infant	5.71E-04	6.73E-04	2.96E-04	2.21E-01	7.86E-04	0.00E+00	2.40E-05

Dose factor - liquid release pathway (mrem/Ci released)							
I-132							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.43E-07	3.81E-07	1.34E-07	1.33E-05	6.07E-07	0.00E+00	7.16E-08
Teen	1.49E-07	3.90E-07	1.41E-07	1.32E-05	6.15E-07	0.00E+00	1.70E-07
Child	1.85E-07	3.39E-07	1.56E-07	1.57E-05	5.19E-07	0.00E+00	3.99E-07
Infant	1.64E-11	3.32E-11	1.18E-11	1.56E-09	3.71E-11	0.00E+00	2.69E-11

Dose factor - liquid release pathway (mrem/Ci released)							
I-133							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.33E-05	5.80E-05	1.77E-05	8.52E-03	1.01E-04	0.00E+00	5.21E-05
Teen	3.74E-05	6.34E-05	1.94E-05	8.85E-03	1.11E-04	0.00E+00	4.80E-05
Child	6.27E-05	7.75E-05	2.94E-05	1.44E-02	1.29E-04	0.00E+00	3.13E-05
Infant	4.77E-05	6.95E-05	2.04E-05	1.26E-02	8.17E-05	0.00E+00	1.18E-05

Table 5.1-1 (continued)

Dose factor - liquid release pathway (mrem/Ci released)							
I-134							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	2.09E-10	5.69E-10	2.04E-10	9.85E-09	9.04E-10	0.00E+00	4.96E-13
Teen	2.20E-10	5.82E-10	2.10E-10	9.70E-09	9.18E-10	0.00E+00	7.67E-12
Child	2.72E-10	5.05E-10	2.33E-10	1.16E-08	7.72E-10	0.00E+00	3.35E-10
Infant	5.37E-22	1.10E-21	3.91E-22	2.56E-20	1.23E-21	0.00E+00	1.14E-21

Dose factor - liquid release pathway (mrem/Ci released)							
I-135							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.37E-06	8.83E-06	3.26E-06	5.82E-04	1.42E-05	0.00E+00	9.97E-06
Teen	3.55E-06	9.14E-06	3.41E-06	5.88E-04	1.44E-05	0.00E+00	1.01E-05
Child	4.54E-06	8.17E-06	3.87E-06	7.24E-04	1.25E-05	0.00E+00	6.23E-06
Infant	4.48E-07	8.92E-07	3.25E-07	7.99E-05	9.94E-07	0.00E+00	3.23E-07

Dose factor - liquid release pathway (mrem/Ci released)							
Cs-134							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	2.19E-01	5.21E-01	4.26E-01	0.00E+00	1.69E-01	5.60E-02	9.12E-03
Teen	2.25E-01	5.30E-01	2.46E-01	0.00E+00	1.68E-01	6.43E-02	6.59E-03
Child	2.76E-01	4.52E-01	9.55E-02	0.00E+00	1.40E-01	5.03E-02	2.44E-03
Infant	1.07E-02	2.00E-02	2.02E-03	0.00E+00	5.16E-03	2.11E-03	5.44E-05

Table 5.1-1 (continued)

Dose factor - liquid release pathway (mrem/Ci released)

Cs-134m

	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	4.21E-06	8.85E-06	4.52E-06	0.00E+00	4.80E-06	7.56E-07	3.12E-06
Teen	4.42E-06	9.16E-06	4.71E-06	0.00E+00	5.10E-06	8.95E-07	6.0E-06
Child	5.48E-06	8.11E-06	5.29E-06	0.00E+00	4.28E-06	7.07E-07	1.03E-05
Infant	5.19E-11	8.64E-11	4.37E-11	0.00E+00	3.33E-11	7.67E-12	6.84E-11

Dose factor - liquid release pathway (mrem/Ci released)

Cs-136

	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	2.23E-02	8.81E-02	6.34E-02	0.00E+00	4.90E-02	6.72E-03	1.00E-02
Teen	2.25E-02	8.85E-02	5.95E-02	0.00E+00	4.82E-02	7.59E-03	7.12E-03
Child	2.69E-02	7.40E-02	4.79E-02	0.00E+00	3.94E-02	5.87E-03	2.60E-03
Infant	1.18E-03	3.47E-03	1.29E-03	0.00E+00	1.38E-03	2.83E-04	5.27E-05

Dose factor - liquid release pathway (mrem/Ci released)

Cs-137

	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	2.81E-01	3.84E-01	2.52E-01	0.00E+00	1.30E-01	4.33E-02	7.43E-03
Teen	3.02E-01	4.01E-01	1.40E-01	0.00E+00	1.36E-01	5.30E-02	5.71E-03
Child	3.85E-01	3.69E-01	5.45E-02	0.00E+00	1.20E-01	4.33E-02	2.31E-03
Infant	1.49E-02	1.74E-02	1.24E-03	0.00E+00	4.68E-03	1.89E-03	5.45E-05

Table 5.1-1 (continued)

Dose factor - liquid release pathway (mrem/Ci released)							
Cs-138							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.57E-11	7.04E-11	3.49E-11	0.00E+00	5.18E-11	5.11E-12	3.00E-16
Teen	3.82E-11	7.34E-11	3.67E-11	0.00E+00	5.42E-11	6.30E-12	3.33E-14
Child	4.84E-11	6.73E-11	4.27E-11	0.00E+00	4.73E-11	5.10E-12	3.10E-11
Infant	1.63E-32	2.65E-32	1.28E-32	0.00E+00	1.32E-32	2.06E-33	4.23E-32

Dose factor - liquid release pathway (mrem/Ci released)							
Ba-139							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.67E-09	1.[illegible]-12	4.93E-11	0.00E+00	1.12E-12	6.77E-13	2.97E-09
Teen	1.83E-09	1.[illegible]-12	5.50E-11	0.00E+00	1.21E-12	8.87E-13	1.63E-08
Child	2.35E-09	1.25E-12	6.84E-11	0.00E+00	1.09E-12	7.37E-13	1.36E-07
Infant	3.30E-16	2.19E-19	9.55E-18	0.00E+00	1.31E-19	1.33E-19	2.09E-14

Dose factor - liquid release pathway (mrem/Ci released)							
Ba-140							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	5.34E-04	6.71E-07	3.51E-05	0.00E+00	2.28E-07	3.84E-07	1.10E-03
Teen	5.41E-04	6.63E-07	3.56E-05	0.00E+00	2.25E-07	4.46E-07	8.35E-04
Child	1.32E-03	1.16E-06	7.72E-05	0.00E+00	3.76E-07	6.89E-07	6.69E-04
Infant	1.52E-03	1.52E-06	7.84E-05	0.00E+00	3.61E-07	9.34E-07	3.74E-04

Table 5.1-1 (continued)

Dose factor - liquid release pathway (mrem/Ci released)							
Ba-141							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	4.57E-19	3.45E-22	1.63E-20	0.00E+00	3.21E-22	1.96E-22	2.15E-28
Teen	4.96E-19	3.70E-22	2.14E-20	0.00E+00	3.44E-22	2.53E-22	1.06E-24
Child	6.37E-19	3.57E-22	2.18E-20	0.00E+00	3.09E-22	2.10E-21	3.63E-19
Infant	1.58E-53	1.08E-56	4.99E-55	0.00E+00	6.52E-57	6.60E-57	1.93E-52

Dose factor - liquid release pathway (mrem/Ci released)							
La-140							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.66E-08	1.84E-08	1.03E-07	0.00E+00	0.00E+00	0.00E+00	1.35E-03
Teen	3.68E-08	1.81E-08	5.51E-07	0.00E+00	0.00E+00	0.00E+00	1.04E-03
Child	8.21E-08	2.87E-08	1.24E-07	0.00E+00	0.00E+00	0.00E+00	8.00E-04
Infant	8.56E-08	3.38E-08	8.69E-09	0.00E+00	0.00E+00	0.00E+00	3.97E-04

Dose factor - liquid release pathway (mrem/Ci released)							
La-142							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	2.92E-11	1.33E-11	4.94E-11	0.00E+00	0.00E+00	0.00E+00	9.71E-08
Teen	3.12E-11	1.38E-11	2.61E-10	0.00E+00	0.00E+00	0.00E+00	4.21E-07
Child	3.93E-11	1.25E-11	5.77E-11	0.00E+00	0.00E+00	0.00E+00	2.48E-06
Infant	7.74E-18	2.84E-18	6.81E-19	0.00E+00	0.00E+00	0.00E+00	4.83E-13

Table 5.1-1 (continued)

Dose factor - liquid release pathway (mrem/Ci released)							
Ce-141							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	2.05E-07	1.39E-07	2.42E-07	0.00E+00	6.45E-08	0.00E+00	5.31E-04
Teen	2.06E-07	1.37E-07	4.88E-07	0.00E+00	6.47E-08	0.00E+00	3.93E-04
Child	5.80E-07	2.89E-07	1.42E-07	0.00E+00	1.27E-07	0.00E+00	3.61E-04
Infant	7.11E-07	4.34E-07	5.11E-08	0.00E+00	1.34E-07	0.00E+00	2.24E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Ce-143							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.47E-08	1.09E-05	1.78E-08	0.00E+00	4.78E-09	0.00E+00	4.06E-04
Teen	1.49E-08	1.08E-05	9.40E-08	0.00E+00	4.86E-09	0.00E+00	3.26E-04
Child	4.01E-08	2.17E-05	2.25E-08	0.00E+00	9.12E-09	0.00E+00	3.18E-04
Infant	5.10E-08	3.38E-05	3.86E-09	0.00E+00	9.85E-09	0.00E+00	1.97E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Ce-144							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.12E-05	4.67E-06	1.04E-06	0.00E+00	2.77E-06	0.00E+00	3.78E-03
Teen	1.12E-05	4.65E-06	3.03E-06	0.00E+00	2.78E-06	0.00E+00	2.82E-03
Child	3.17E-05	9.92E-06	2.20E-06	0.00E+00	5.50E-06	0.00E+00	2.59E-03
Infant	2.80E-05	1.15E-05	1.57E-06	0.00E+00	4.63E-06	0.00E+00	1.61E-03

Table 5.1-1 (continued)

Dose factor - liquid release pathway (mrem/Ci released)							
Pr-143							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	5.69E-07	2.28E-07	2.82E-08	0.00E+00	1.32E-07	0.00E+00	2.49E-03
Teen	6.00E-07	2.40E-07	2.99E-08	0.00E+00	1.39E-07	0.00E+00	1.97E-03
Child	1.07E-06	3.21E-07	5.31E-08	0.00E+00	1.74E-07	0.00E+00	1.15E-03
Infant	6.81E-07	2.55E-07	3.38E-08	0.00E+00	9.47E-08	0.00E+00	3.60E-04

Dose factor - liquid release pathway (mrem/Ci released)							
Pr-144							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.76E-22	1.56E-22	2.24E-23	0.00E+00	8.80E-23	0.00E+00	5.41E-29
Teen	4.09E-22	1.67E-22	3.91E-23	0.00E+00	9.61E-23	0.00E+00	4.51E-25
Child	5.29E-22	1.64E-22	3.05E-23	0.00E+00	8.66E-23	0.00E+00	3.52E-19
Infant	1.72E-59	6.66E-60	8.67E-61	0.00E+00	2.41E-60	0.00E+00	3.10E-55

Dose factor - liquid release pathway (mrem/Ci released)							
Nd-147							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.82E-07	4.42E-07	1.13E-07	0.00E+00	2.58E-07	0.00E+00	2.12E-03
Teen	4.23E-07	4.60E-07	5.09E-07	0.00E+00	2.70E-07	0.00E+00	1.66E-03
Child	7.45E-07	6.03E-07	1.47E-07	0.00E+00	3.31E-07	0.00E+00	9.55E-04
Infant	4.53E-07	4.65E-07	2.85E-08	0.00E+00	1.79E-07	0.00E+00	2.95E-04

Table 5.1-1 (continued)

Dose factor - liquid release pathway (mrem/Ci released)							
Eu-152							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.31E-05	2.99E-04	1.63E-04	0.00E+00	1.85E-05	0.00E+00	1.72E-03
Teen	1.21E-05	2.92E-06	9.00E-04	0.00E+00	1.35E-05	0.00E+00	1.07E-03
Child	1.84E-05	3.34E-06	1.91E-04	0.00E+00	1.41E-05	0.00E+00	5.49E-04
Infant	6.27E-06	1.67E-06	1.40E-06	0.00E+00	4.67E-06	0.00E+00	1.48E-04

Dose factor - liquid release pathway (mrem/Ci released)							
W-187							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	1.52E-04	1.27E-04	4.45E-05	0.00E+00	0.00E+00	0.00E+00	4.17E-02
Teen	1.65E-04	1.34E-04	4.71E-05	0.00E+00	0.00E+00	0.00E+00	3.63E-02
Child	2.09E-04	1.24E-04	5.57E-05	0.00E+00	0.00E+00	0.00E+00	1.74E-02
Infant	2.25E-06	1.57E-06	5.41E-07	0.00E+00	0.00E+00	0.00E+00	9.21E-05

Dose factor - liquid release pathway (mrem/Ci released)							
Np-239							
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.15E-08	3.09E-09	2.30E-08	0.00E+00	9.65E-09	0.00E+00	6.34E-04
Teen	3.42E-08	3.22E-09	1.21E-07	0.00E+00	1.01E-08	0.00E+00	5.19E-04
Child	6.77E-08	4.86E-09	2.83E-08	0.00E+00	1.41E-08	0.00E+00	3.60E-04
Infant	5.72E-08	5.12E-09	2.89E-09	0.00E+00	1.02E-08	0.00E+00	1.48E-04

Table 5.1-1 (continued)

Dose factor - liquid release pathway (mrem/Ci released)

U-235

	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	3.05E-02	0.00E+00	1.89E-03	0.00E+00	7.13E-03	0.00E+00	2.98E-03
Teen	3.17E-02	0.00E+00	2.13E-03	0.00E+00	7.43E-03	0.00E+00	2.30E-03
Child	6.92E-02	0.00E+00	4.23E-03	0.00E+00	1.14E-02	0.00E+00	1.63E-03
Infant	4.42E-02	0.00E+00	3.37E-03	0.00E+00	9.40E-03	0.00E+00	7.67E-04

Dose factor - liquid release pathway (mrem/Ci released)

U-238

	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	2.92E-02	0.00E+00	1.73E-03	0.00E+00	6.67E-03	0.00E+00	2.10E-03
Teen	3.03E-02	0.00E+00	1.81E-03	0.00E+00	6.96E-03	0.00E+00	1.62E-03
Child	6.62E-02	0.00E+00	3.93E-03	0.00E+00	1.06E-02	0.00E+00	1.15E-03
Infant	4.23E-02	0.00E+00	3.15E-03	0.00E+00	8.78E-03	0.00E+00	5.41E-04

Dose factor - liquid release pathway (mrem/Ci released)

Am-241

	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI
Adult	5.25E-02	1.85E-02	3.47E-03	0.00E+00	2.61E-02	0.00E+00	4.75E-03
Teen	4.10E-02	1.56E-02	2.77E-03	0.00E+00	2.05E-02	0.00E+00	3.74E-03
Child	4.10E-02	1.83E-02	2.93E-03	0.00E+00	1.79E-02	0.00E+00	2.19E-03
Infant	1.42E-02	6.68E-03	1.01E-03	0.00E+00	6.10E-03	0.00E+00	7.17E-04

5.1.2 Atmospheric Release Mode: Radioiodine, Tritium, and Particulates

The dose calculations for demonstration of compliance with the 10 CFR 50, Appendix I dose limits for radioiodines, tritium, and particulate radionuclides released to the atmosphere will be done in the manner similar to the liquid release dose calculations described in Section 5.1.1. The total dose is compared to the corresponding atmospheric release mode Appendix I dose limit for the organ in question.

The doses are calculated using the following formula:

$$API = \Sigma\ Dose_{aomi} = \Sigma\ (TDF_{aomi} \times C_i) \leq K_{om}\ \text{mrem}$$

Where

API = the Appendix I dose for compliance evaluations in mrem

$Dose_{aomi}$ = the dose to the specific age group (a) and organ (o) via release mode (m) from radionuclide (i)

TDF_{aomi} = total dose factor for the specific age group (a) and organ (o) via release mode (m) from radionuclide (i) from Table 5.1-2 in mrem/Ci

C_i = curies of radionuclide (i) released

K_{om} = the Appendix I dose limit for organ (o) and release mode (m) for which the calculation is being made.

The methodology and the values used to obtain the TDF_{aomi} values are given in Appendix C.

It is recognized that some of the release quantities may not be available at the end of the month because the samples from these release paths are sent to a vendor for analysis. Usually, the only radionuclides affected by these delays are Sr-89 and Sr-90. Because the quantities of these two radionuclides are but a small fraction of the total release, the absence of their dose contributions from the initial monthly dose calculation will not significantly affect the total dose obtained from the remaining radionuclides. The dose for the month will be updated upon the receipt of the vendor isotopic results and upon the receipt of any corrections to previous release quantities.

Instead of using the precalculated total dose factors, the Appendix I dose calculation may be modified to reflect the actual χ/Q during the release period using the methodology of Appendix C.

Table 5.1-2

Airborne Effluent Dose Factor

Summations of dose per curie released were made for calculations over the pathways: ingestion of produce, leafy vegetables, milk, meat; inhalation of airborne radionuclides, and direct exposure to deposited radioactivity.

Dose factor - airborne release pathway (mrem/Ci released)

H-3

	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	0.00E+00	9.78E-05	9.78E-05	9.78E-05	9.78E-05	9.78E-05	9.78E-05	0.00E+00
Teen	0.00E+00	1.03E-04	1.03E-04	1.03E-04	1.03E-04	1.03E-04	1.03E-04	0.00E+00
Child	0.00E+00	1.32E-04	1.32E-04	1.32E-04	1.32E-04	1.32E-04	1.32E-04	0.00E+00
Infant	0.00E+00	2.03E-05	2.03E-05	2.03E-05	2.03E-05	2.03E-05	2.03E-05	0.00E+00

Dose factor - airborne release pathway (mrem/Ci released)

F-18

	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.12E-04	0.00E+00	9.61E-04	0.00E+00	0.00E+00	0.00E+00	2.19E-06	2.23E-03
Teen	1.55E-04	0.00E+00	9.65E-04	0.00E+00	0.00E+00	0.00E+00	9.23E-06	2.23E-03
Child	2.06E-04	0.00E+00	9.69E-04	0.00E+00	0.00E+00	0.00E+00	3.70E-05	2.23E-03
Infant	1.63E-04	0.00E+00	9.62E-04	0.00E+00	0.00E+00	0.00E+00	2.53E-05	2.23E-03

Dose factor - airborne release pathway (mrem/Ci released)

Na-22

	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	4.83E+00	4.83E+00	2.89E+01	4.83E+00	4.83E+00	4.83E+00	4.83E+00	3.79E+01
Teen	7.41E+00	7.41E+00	3.15E+01	7.41E+00	7.41E+00	7.41E+00	7.41E+00	3.79E+01
Child	1.50E+01	1.50E+01	3.90E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01	3.79E+01
Infant	1.81E+01	1.81E+01	4.21E+01	1.81E+01	1.81E+01	1.81E+01	1.81E+01	3.79E+01

Table 5.1-2 (continued)

Dose factor - airborne release pathway (mrem/Ci released)								
Na-24								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	9.48E-04	9.48E-04	1.77E-02	9.48E-04	9.48E-04	9.48E-04	9.48E-04	7.64E-02
Teen	1.36E-03	1.36E-03	1.81E-02	1.36E-03	1.36E-03	1.36E-03	1.36E-03	7.64E-02
Child	2.37E-03	2.37E-03	1.91E-02	2.37E-03	2.37E-03	2.37E-03	2.37E-03	7.64E-02
Infant	3.14E-03	3.14E-03	1.99E-02	3.14E-03	3.14E-03	3.14E-03	3.14E-03	7.64E-02

Dose factor - airborne release pathway (mrem/Ci released)								
Sc-46								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.33E-02	2.59E-02	2.00E+00	0.00E+00	2.42E-02	0.00E+00	2.40E+00	2.69E+00
Teen	1.75E-02	3.41E-02	2.00E+00	0.00E+00	3.26E-02	0.00E+00	2.09E+00	2.69E+00
Child	2.23E-02	3.05E-02	2.00E+00	0.00E+00	2.70E-02	0.00E+00	1.32E+00	2.69E+00
Infant	1.56E-02	2.25E-02	2.00E+00	0.00E+00	1.48E-02	0.00E+00	1.35E-03	2.69E+00

Dose factor - airborne release pathway (mrem/Ci released)								
Mn-54								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	0.00E+00	2.32E-01	1.99E+00	0.00E+00	6.89E-02	4.15E-02	7.08E-01	2.28E+00
Teen	0.00E+00	3.34E-01	2.01E+00	0.00E+00	9.95E-02	5.89E-02	6.83E-01	2.28E+00
Child	0.00E+00	4.86E-01	2.07E+00	0.00E+00	1.36E-01	4.68E-02	4.08E-01	2.28E+00
Infant	0.00E+00	2.03E-02	1.95E+00	0.00E+00	4.47E-03	2.97E-02	7.38E-03	2.28E+00

Table 5.1-2 (continued)

Dose factor - airborne release pathway (mrem/Ci released)								
Cr-51								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	0.00E+00	0.00E+00	6.59E-03	2.68E-05	9.86E-06	4.83E-04	1.07E-02	7.73E-03
Teen	0.00E+00	0.00E+00	6.60E-03	3.39E-05	1.34E-05	7.03E-04	9.66E-03	7.73E-03
Child	0.00E+00	0.00E+00	6.66E-03	6.30E-05	1.72E-05	6.14E-04	5.81E-03	7.73E-03
Infant	0.00E+00	0.00E+00	6.58E-03	2.42E-05	5.31E-06	4.25E-04	1.02E-03	7.73E-03

Dose factor - airborne release pathway (mrem/Ci released)								
Mn-56								
	Bone	Liver	T.Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	0.00E+00	4.81E-08	1.27E-03	0.00E+00	5.31E-08	2.80E-04	6.01E-04	1.50E-03
Teen	0.00E+00	6.05E-08	1.27E-03	0.00E+00	6.61E-08	4.51E-04	1.70E-03	1.50E-03
Child	0.00E+00	6.26E-08	1.27E-03	0.00E+00	6.58E-08	3.90E-04	3.66E-03	1.50E-03
Infant	0.00E+00	4.57E-08	1.27E-03	0.00E+00	3.27E-08	3.72E-04	2.13E-03	1.50E-03

Dose factor - airborne release pathway (mrem/Ci released)								
Fe-55								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	3.20E-01	2.21E-01	5.15E-02	0.00E+00	0.00E+00	1.25E-01	1.27E-01	0.00E+00
Teen	3.80E-01	2.70E-01	6.29E-02	0.00E+00	0.00E+00	1.74E-01	1.17E-01	0.00E+00
Child	8.65E-01	4.59E-01	1.42E-01	0.00E+00	0.00E+00	2.62E-01	8.49E-02	0.00E+00
Infant	7.36E-02	4.75E-02	1.27E-02	0.00E+00	0.00E+00	2.56E-02	6.02E-03	0.00E+00

Table 5.1-2 (continued)

Dose factor - airborne release pathway (mrem/Ci released)								
Fe-59								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	2.01E-01	4.73E-01	5.65E-01	0.00E+00	0.00E+00	1.62E-01	1.58E+00	4.50E-01
Teen	2.25E-01	5.24E-01	5.86E-01	0.00E+00	0.00E+00	2.10E-01	1.24E+00	4.50E-01
Child	4.62E-01	7.48E-01	7.56E-01	0.00E+00	0.00E+00	2.54E-01	7.80E-01	4.50E-01
Infant	6.14E-02	1.07E-01	4.26E-01	0.00E+00	0.00E+00	6.16E-02	5.16E-02	4.50E-01

Dose factor - airborne release pathway (mrem/Ci released)								
Co-57								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	0.00E+00	1.17E-02	4.93E-01	0.00E+00	0.00E+00	1.10E-02	2.97E-01	6.13E-01
Teen	0.00E+00	1.59E-02	5.00E-01	0.00E+00	0.00E+00	1.74E-02	2.97E-01	6.13E-01
Child	0.00E+00	2.57E-02	5.26E-01	0.00E+00	0.00E+00	1.50E-02	2.11E-01	6.13E-01
Infant	0.00E+00	4.38E-03	4.81E-01	0.00E+00	0.00E+00	1.13E-02	1.50E-02	6.13E-01

Dose factor - airborne release pathway (mrem/Ci released)								
Co-58								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	0.00E+00	3.14E-02	6.02E-01	0.00E+00	0.00E+00	2.75E-02	6.38E-01	6.23E-01
Teen	0.00E+00	4.00E-02	6.24E-01	0.00E+00	0.00E+00	3.99E-02	5.53E-01	6.23E-01
Child	0.00E+00	5.73E-02	7.07E-01	0.00E+00	0.00E+00	3.28E-02	3.35E-01	6.23E-01
Infant	0.00E+00	9.90E-03	5.57E-01	0.00E+00	0.00E+00	2.31E-02	2.49E-02	6.23E-01

Table 5.1-2 (continued)

Dose factor - airborne release pathway (mrem/Ci released)								
Co-60								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	0.00E+00	1.68E-01	3.06E+01	0.00E+00	0.00E+00	1.77E-01	3.16E+00	3.56E+01
Teen	0.00E+00	2.23E-01	3.07E+01	0.00E+00	0.00E+00	2.59E-01	2.90E+00	3.56E+01
Child	0.00E+00	3.28E-01	3.12E+01	0.00E+00	0.00E+00	2.10E-01	1.82E+00	3.56E+01
Infant	0.00E+00	5.86E-02	3.04E+01	0.00E+00	0.00E+00	1.34E-01	1.40E-01	3.56E+01

Dose factor - airborne release pathway (mrem/Ci released)								
Ni-63								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	2.39E+01	1.65E+00	8.00E-01	0.00E+00	0.00E+00	5.29E-03	3.45E-01	0.00E+00
Teen	2.93E+01	2.07E+00	9.92E-01	0.00E+00	0.00E+00	9.11E-03	3.29E-01	0.00E+00
Child	6.73E+01	3.60E+00	2.29E+00	0.00E+00	0.00E+00	8.16E-03	2.43E-01	0.00E+00
Infant	2.11E+01	1.30E+00	7.32E-01	0.00E+00	0.00E+00	6.19E-03	6.49E-02	0.00E+00

Dose factor - airborne release pathway (mrem/Ci released)								
Ni-65								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	8.95E-08	1.19E-08	4.17E-04	0.00E+00	0.00E+00	1.66E-04	3.66E-04	4.85E-04
Teen	1.06E-07	1.39E-08	4.17E-04	0.00E+00	0.00E+00	2.78E-04	1.09E-03	4.85E-04
Child	1.64E-07	1.58E-08	4.17E-04	0.00E+00	0.00E+00	2.43E-04	2.49E-03	4.85E-04
Infant	7.17E-08	8.51E-09	4.17E-04	0.00E+00	0.00E+00	2.41E-04	1.49E-03	4.85E-04

Table 5.1-2 (continued)

Dose factor - airborne release pathway (mrem/Ci released)								
Cu-64								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	0.00E+00	1.12E-05	8.57E-04	0.00E+00	2.82E-05	2.01E-04	2.40E-03	9.65E-04
Teen	0.00E+00	1.40E-05	8.58E-04	0.00E+00	3.54E-05	3.30E-04	2.90E-03	9.65E-04
Child	0.00E+00	2.19E-05	8.65E-04	0.00E+00	5.28E-05	2.84E-04	2.11E-03	9.65E-04
Infant	0.00E+00	3.42E-05	8.68E-04	0.00E+00	5.79E-05	2.76E-04	1.15E-03	9.65E-04

Dose factor - airborne release pathway (mrem/Ci released)								
Zn-65								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.21E+00	3.85E+00	2.79E+00	0.00E+00	2.57E+00	2.56E-02	2.42E+00	1.21E+00
Teen	1.63E+00	5.67E+00	3.69E+00	0.00E+00	3.63E+00	3.68E-02	2.40E+00	1.21E+00
Child	3.12E+00	8.31E+00	6.22E+00	0.00E+00	5.24E+00	2.95E-02	1.46E+00	1.21E+00
Infant	2.95E+00	1.01E+01	5.71E+00	0.00E+00	4.91E+00	1.92E-02	8.54E+00	1.21E+00

Dose factor - airborne release pathway (mrem/Ci released)								
Zn-69								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	3.01E-06	5.76E-06	4.01E-07	0.00E+00	3.74E-06	2.73E-05	1.35E-06	0.00E+00
Teen	4.64E-06	8.83E-06	6.18E-07	0.00E+00	5.77E-06	4.70E-05	2.47E-05	0.00E+00
Child	1.08E-05	1.56E-05	1.45E-06	0.00E+00	9.49E-06	4.22E-05	1.29E-03	0.00E+00
Infant	1.93E-05	3.48E-05	2.59E-06	0.00E+00	1.45E-05	4.36E-05	3.23E-03	0.00E+00

Table 5.1-2 (continued)

Dose factor - airborne release pathway (mrem/Ci released)								
Zn-69m								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	4.99E-05	1.20E-04	3.07E-03	0.00E+00	7.26E-05	5.65E-04	1.13E-02	5.74E-03
Teen	7.60E-05	1.79E-04	3.07E-03	0.00E+00	1.09E-04	9.30E-04	1.49E-02	5.74E-03
Child	1.76E-04	3.00E-04	3.09E-03	0.00E+00	1.74E-04	8.08E-04	1.27E-02	5.74E-03
Infant	3.11E-04	6.35E-04	3.12E-03	0.00E+00	2.57E-04	7.93E-04	1.00E-02	5.74E-03

Dose factor - airborne release pathway (mrem/Ci released)								
Br-82								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	0.00E+00	0.00E+00	5.44E-02	0.00E+00	0.00E+00	0.00E+00	8.47E-03	6.41E-02
Teen	0.00E+00	0.00E+00	5.89E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.41E-02
Child	0.00E+00	0.00E+00	7.04E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.41E-02
Infant	0.00E+00	0.00E+00	8.32E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.41E-02

Dose factor - airborne release pathway (mrem/Ci released)								
Br-83								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	0.00E+00	0.00E+00	1.65E-05	0.00E+00	0.00E+00	0.00E+00	6.89E-06	2.84E-03
Teen	0.00E+00	0.00E+00	1.96E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.84E-03
Child	0.00E+00	0.00E+00	2.34E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.84E-03
Infant	0.00E+00	0.00E+00	2.07E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.84E-03

Table 5.1-2 (continued)

Dose factor - airborne release pathway (mrem/Ci released)								
Br-84								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	0.00E+00	0.00E+00	2.59E-02	0.00E+00	0.00E+00	0.00E+00	1.11E-09	2.49E-01
Teen	0.00E+00	0.00E+00	2.60E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.49E-01
Child	0.00E+00	0.00E+00	2.63E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.49E-01
Infant	0.00E+00	0.00E+00	2.66E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.49E-01

Dose factor - airborne release pathway (mrem/Ci released)								
Br-85								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	0.00E+00	0.00E+00	4.95E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.63E-04
Teen	0.00E+00	0.00E+00	7.06E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.63E-04
Child	0.00E+00	0.00E+00	2.02E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.63E-04
Infant	0.00E+00	0.00E+00	4.21E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.63E-04

Dose factor - airborne release pathway (mrem/Ci released)								
Rb-86								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	0.00E+00	8.21E-01	3.95E-01	0.00E+00	0.00E+00	0.00E+00	1.61E-01	1.44E-02
Teen	0.00E+00	1.23E+00	5.92E-01	0.00E+00	0.00E+00	0.00E+00	1.82E-01	1.44E-02
Child	0.00E+00	2.18E+00	1.35E+00	0.00E+00	0.00E+00	0.00E+00	1.40E-01	1.44E-02
Infant	0.00E+00	4.17E+00	2.07E+00	0.00E+00	0.00E+00	0.00E+00	1.07E-01	1.44E-02

Table 5.1-2 (continued)

Dose factor - airborne release pathway (mrem/Ci released)								
Rb-88								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	0.00E+00	1.15E-05	5.22E-05	0.00E+00	0.00E+00	0.00E+00	9.92E-17	5.31E-05
Teen	0.00E+00	1.62E-05	5.45E-05	0.00E+00	0.00E+00	0.00E+00	8.66E-13	5.31E-05
Child	0.00E+00	1.67E-05	5.73E-05	0.00E+00	0.00E+00	0.00E+00	5.12E-07	5.31E-05
Infant	0.00E+00	1.65E-05	5.50E-05	0.00E+00	0.00E+00	0.00E+00	1.01E-05	5.31E-05

Dose factor - airborne release pathway (mrem/Ci released)								
Rb-89								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	0.00E+00	7.60E-06	1.78E-04	0.00E+00	0.00E+00	0.00E+00	2.75E-19	2.07E-04
Teen	0.00E+00	1.04E-05	1.80E-04	0.00E+00	0.00E+00	0.00E+00	1.00E-14	2.07E-04
Child	0.00E+00	1.02E-05	1.81E-04	0.00E+00	0.00E+00	0.00E+00	5.61E-08	2.07E-04
Infant	0.00E+00	9.51E-06	1.79E-04	0.00E+00	0.00E+00	0.00E+00	2.02E-06	2.07E-04

Dose factor - airborne release pathway (mrem/Ci released)								
Sr-89								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	7.63E+00	0.00E+00	2.19E-01	0.00E+00	0.00E+00	4.15E-02	1.23E+00	3.53E-05
Teen	1.16E+01	0.00E+00	3.34E-01	0.00E+00	0.00E+00	7.17E-02	1.40E+00	3.53E-05
Child	2.77E+01	0.00E+00	7.90E-01	0.00E+00	0.00E+00	6.40E-02	1.08E+00	3.53E-05
Infant	3.66E+00	0.00E+00	1.05E-01	0.00E+00	0.00E+00	6.02E-02	7.69E-02	3.53E-05

Table 5.1-2 (continued)

Dose factor - airborne release pathway (mrem/Ci released)

Sr-90

	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	5.10E+02	0.00E+00	1.25E+02	0.00E+00	0.00E+00	2.85E-01	1.47E+01	0.00E+00
Teen	6.33E+02	0.00E+00	1.56E+02	0.00E+00	0.00E+00	4.89E-01	1.77E+01	0.00E+00
Child	1.05E+03	0.00E+00	2.65E+02	0.00E+00	0.00E+00	4.38E-01	1.41E+01	0.00E+00
Infant	7.33E+01	0.00E+00	1.84E+01	0.00E+00	0.00E+00	3.34E-01	9.04E-01	0.00E+00

Dose factor - airborne release pathway (mrem/Ci released)

Sr-91

	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	2.29E-04	0.00E+00	3.03E-03	0.00E+00	0.00E+00	1.08E-03	6.76E-03	3.53E-03
Teen	2.20E-04	0.00E+00	3.03E-03	0.00E+00	0.00E+00	1.80E-03	8.68E-03	3.53E-03
Child	4.09E-04	0.00E+00	3.03E-03	0.00E+00	0.00E+00	1.58E-03	6.06E-03	3.53E-03
Infant	5.29E-05	0.00E+00	3.02E-03	0.00E+00	0.00E+00	1.56E-03	2.24E-03	3.53E-03

Dose factor - airborne release pathway (mrem/Ci released)

Sr-92

	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	5.04E-07	0.00E+00	1.65E-03	0.00E+00	0.00E+00	4.89E-04	1.28E-03	3.15E-03
Teen	5.66E-07	0.00E+00	1.65E-03	0.00E+00	0.00E+00	8.14E-04	3.54E-03	3.15E-03
Child	9.08E-07	0.00E+00	1.65E-03	0.00E+00	0.00E+00	7.12E-04	7.20E-03	3.15E-03
Infant	3.12E-07	0.00E+00	1.65E-03	0.00E+00	0.00E+00	7.06E-04	4.15E-03	3.15E-03

Table 5.1-2 (continued)

Dose factor - airborne release pathway (mrem/Ci released)								
Y-90								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	7.17E-05	0.00E+00	8.23E-06	0.00E+00	0.00E+00	5.03E-03	1.19E-01	7.45E-06
Teen	9.77E-05	0.00E+00	8.93E-06	0.00E+00	0.00E+00	8.69E-03	9.20E-02	7.45E-06
Child	1.39E-04	0.00E+00	1.00E-05	0.00E+00	0.00E+00	7.76E-03	5.63E-02	7.45E-06
Infant	9.77E-05	0.00E+00	8.93E-06	0.00E+00	0.00E+00	7.98E-03	3.26E-03	7.45E-06

Dose factor - airborne release pathway (mrem/Ci released)								
Y-91								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.78E-02	0.00E+00	1.98E-03	0.00E+00	0.00E+00	5.06E-02	2.26E+00	1.70E-03
Teen	2.55E-02	0.00E+00	2.19E-03	0.00E+00	0.00E+00	8.71E-02	2.44E+00	1.70E-03
Child	4.10E-02	0.00E+00	2.60E-03	0.00E+00	0.00E+00	7.79E-02	1.86E+00	1.70E-03
Infant	1.75E-02	0.00E+00	1.97E-03	0.00E+00	0.00E+00	7.27E-02	3.72E-03	1.70E-03

Dose factor - airborne release pathway (mrem/Ci released)								
Y-91m								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	3.58E-06	0.00E+00	2.31E-04	0.00E+00	0.00E+00	5.70E-05	1.05E-05	4.33E-04
Teen	6.15E-06	0.00E+00	2.31E-04	0.00E+00	0.00E+00	9.49E-05	2.91E-04	4.33E-04
Child	1.50E-05	0.00E+00	2.31E-04	0.00E+00	0.00E+00	8.34E-05	2.94E-02	4.33E-04
Infant	1.21E-08	0.00E+00	2.31E-04	0.00E+00	0.00E+00	8.27E-05	6.98E-05	4.33E-04

Table 5.1-2 (continued)

Dose factor - airborne release pathway (mrem/Ci released)

Y-92

	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	3.35E-05	0.00E+00	4.38E-04	0.00E+00	0.00E+00	4.65E-04	5.83E-01	2.90E-02
Teen	5.80E-05	0.00E+00	4.39E-04	0.00E+00	0.00E+00	7.95E-04	1.58E+00	2.90E-02
Child	1.42E-04	0.00E+00	4.41E-04	0.00E+00	0.00E+00	7.09E-04	4.09E+00	2.90E-02
Infant	4.86E-07	0.00E+00	4.37E-04	0.00E+00	0.00E+00	7.27E-04	3.76E-03	2.90E-02

Dose factor - airborne release pathway (mrem/Ci released)

Y-93

Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin	
Adult	1.08E-04	0.00E+00	4.43E-04	0.00E+00	0.00E+00	1.44E-03	3.35E+00	6.58E-02
Teen	1.86E-04	0.00E+00	4.45E-04	0.00E+00	0.00E+00	2.47E-03	5.59E+00	6.58E-02
Child	4.53E-04	0.00E+00	4.52E-04	0.00E+00	0.00E+00	2.21E-03	6.69E+00	6.58E-02
Infant	4.45E-06	0.00E+00	4.40E-04	0.00E+00	0.00E+00	2.27E-03	4.95E-03	6.58E-02

Dose factor - airborne release pathway (mrem/Ci released)

Zr-95

	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	4.79E-03	1.54E-03	3.45E-01	0.00E+00	2.42E-03	5.25E-02	1.64E+00	3.98E-01
Teen	6.16E-03	1.94E-03	3.45E-01	0.00E+00	2.85E-03	7.98E-02	1.35E+00	3.98E-01
Child	9.47E-03	2.08E-03	3.45E-01	0.00E+00	2.97E-03	6.62E-02	8.81E-01	3.98E-01
Infant	3.43E-03	8.27E-04	3.44E-01	0.00E+00	9.23E-04	5.19E-02	9.12E-04	3.98E-01

Table 5.1-2 (continued)

Dose factor - airborne release pathway (mrem/Ci released)								
Zr-97								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	3.12E-06	6.31E-07	4.16E-03	0.00E+00	9.56E-07	2.34E-03	3.09E-02	4.84E-03
Teen	4.31E-06	8.52E-07	4.16E-03	0.00E+00	1.29E-06	3.85E-03	3.09E-02	4.84E-03
Child	5.98E-06	8.66E-07	4.16E-03	0.00E+00	1.24E-06	3.36E-03	1.95E-02	4.84E-03
Infant	4.45E-06	7.60E-07	4.16E-03	0.00E+00	7.69E-07	3.27E-03	4.16E-03	4.84E-03

Dose factor - airborne release pathway (mrem/Ci released)								
Nb-95								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.39E-03	7.75E-04	1.92E-01	0.00E+00	7.67E-04	1.50E-02	3.30E+00	2.26E-01
Teen	1.39E-03	7.72E-04	1.92E-01	0.00E+00	7.48E-04	2.23E-02	1.99E+00	2.26E-01
Child	2.22E-03	8.65E-04	1.93E-01	0.00E+00	8.13E-04	1.82E-02	1.10E+00	2.26E-01
Infant	6.08E-04	2.49E-04	1.92E-01	0.00E+00	1.82E-04	1.42E-02	4.99E-02	2.26E-01

Dose factor - airborne release pathway (mrem/Ci released)								
Nb-97								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	2.05E-06	5.17E-07	4.17E-04	0.00E+00	6.03E-07	7.12E-05	1.91E-03	3.20E-03
Teen	3.50E-06	8.68E-07	4.17E-04	0.00E+00	1.02E-06	1.17E-04	2.07E-02	3.20E-03
Child	8.49E-06	1.53E-06	4.17E-04	0.00E+00	1.70E-06	1.01E-04	4.73E-01	3.20E-03
Infant	1.01E-08	2.16E-09	4.17E-04	0.00E+00	1.69E-09	9.84E-05	7.98E-04	3.20E-03

Table 5.1-2 (continued)

Dose factor - airborne release pathway (mrem/Ci released)								
Mo-99								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	0.00E+00	9.10E-03	7.34E-03	0.00E+00	2.06E-02	2.71E-03	2.85E-02	6.50E-03
Teen	0.00E+00	1.24E-02	7.97E-03	0.00E+00	2.84E-02	4.56E-03	3.02E-02	6.50E-03
Child	0.00E+00	2.06E-02	1.07E-02	0.00E+00	4.41E-02	4.02E-03	2.08E-02	6.50E-03
Infant	0.00E+00	3.82E-02	1.31E-02	0.00E+00	5.70E-02	4.00E-03	1.40E-02	6.50E-03

Dose factor - airborne release pathway (mrem/Ci released)								
Tc-99m								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	2.92E-09	8.24E-09	2.59E-04	0.00E+00	1.25E-07	2.27E-05	1.28E-04	2.96E-04
Teen	3.11E-09	8.68E-09	2.59E-04	0.00E+00	1.29E-07	3.42E-05	1.87E-04	2.96E-04
Child	5.95E-09	1.17E-08	2.59E-04	0.00E+00	1.69E-07	2.82E-05	1.49E-04	2.96E-04
Infant	5.14E-09	1.06E-08	2.59E-04	0.00E+00	1.14E-07	2.41E-05	6.33E-05	2.96E-04

Dose factor - airborne release pathway (mrem/Ci released)								
Tc-101								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.16E-05	1.67E-05	2.08E-04	0.00E+00	3.01E-04	2.04E-05	5.06E-17	5.80E-04
Teen	1.99E-05	2.83E-05	3.23E-04	0.00E+00	5.12E-04	3.71E-05	4.87E-12	5.80E-04
Child	4.89E-05	5.12E-05	6.93E-04	0.00E+00	8.72E-04	4.44E-05	1.63E-04	5.80E-04
Infant	1.93E-12	2.44E-12	4.44E-05	0.00E+00	2.90E-11	1.73E-05	2.50E-05	5.80E-04

Table 5.1-2 (continued)

Dose factor - airborne release pathway (mrem/Ci released)								
Ru-103								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	4.36E-02	0.00E+00	1.71E-01	0.00E+00	1.66E-01	1.50E-02	5.08E+00	1.77E-01
Teen	3.76E-02	0.00E+00	1.68E-01	0.00E+00	1.33E-01	2.32E-02	3.14E+00	1.77E-01
Child	7.01E-02	0.00E+00	1.79E-01	0.00E+00	1.77E-01	1.97E-02	1.81E+00	1.77E-01
Infant	6.20E-05	0.00E+00	1.52E-01	0.00E+00	1.30E-04	1.64E-02	5.05E-04	1.77E-01

Dose factor - airborne release pathway (mrem/Ci released)								
Ru-105								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	6.19E-04	0.00E+00	2.07E-03	0.00E+00	7.99E-03	3.25E-04	3.80E-01	1.02E-02
Teen	1.06E-03	0.00E+00	2.23E-03	0.00E+00	1.34E-02	5.39E-04	8.59E-01	1.02E-02
Child	2.59E-03	0.00E+00	2.76E-03	0.00E+00	2.28E-02	4.72E-04	1.69E+00	1.02E-02
Infant	3.63E-08	0.00E+00	1.82E-03	0.00E+00	2.67E-08	4.65E-04	1.44E-03	1.02E-02

Dose factor - airborne release pathway (mrem/Ci released)								
Ru-106								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.65E+00	0.00E+00	8.01E-01	0.00E+00	3.18E+00	2.78E-01	1.06E+02	7.11E-01
Teen	1.49E+00	0.00E+00	7.81E-01	0.00E+00	2.88E+00	4.77E-01	7.16E+01	7.11E-01
Child	2.93E+00	0.00E+00	9.58E-01	0.00E+00	3.96E+00	4.25E-01	4.55E+01	7.11E-01
Infant	2.67E-03	0.00E+00	5.93E-01	0.00E+00	3.28E-03	3.43E-01	5.60E-03	7.11E-01

Table 5.1-2 (continued)

Dose factor - airborne release pathway (mrem/Ci released)								
Rh-105								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	4.81E-02	3.52E-02	2.47E-02	0.00E+00	1.50E-01	5.72E-04	5.61E+00	7.74E-03
Teen	8.33E-02	6.02E-02	4.10E-02	0.00E+00	2.56E-01	9.71E-04	7.66E+00	7.74E-03
Child	2.04E-01	1.10E-01	9.53E-02	0.00E+00	4.37E-01	8.59E-04	6.80E+00	7.74E-03
Infant	7.15E-04	4.68E-04	1.83E-03	0.00E+00	1.30E-03	8.64E-04	1.22E-02	7.74E-03

Dose factor - airborne release pathway (mrem/Ci released)								
Ag-110m								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	4.10E-02	3.80E-02	4.85E+00	0.00E+00	7.47E-02	1.37E-01	1.54E+01	5.63E+00
Teen	6.28E-02	5.94E-02	4.86E+00	0.00E+00	1.13E-01	2.00E-01	1.66E+01	5.63E+00
Child	1.34E-01	9.04E-02	4.90E+00	0.00E+00	1.68E-01	1.62E-01	1.07E+01	5.63E+00
Infant	1.93E-01	1.41E-01	4.92E+00	0.00E+00	2.02E-01	1.09E-01	7.31E+00	5.63E+00

Dose factor - airborne release pathway (mrem/Ci released)								
Sb-124								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.44E-01	2.73E-03	1.36E+00	3.50E-04	0.00E+00	1.85E-01	4.09E+00	4.02E+00
Teen	2.22E-01	4.09E-03	1.39E+00	5.03E-04	0.00E+00	3.07E-01	4.46E+00	4.02E+00
Child	5.11E-01	6.63E-03	1.48E+00	1.13E-03	0.00E+00	3.79E-01	3.19E+00	4.02E+00
Infant	6.72E-02	9.90E-04	1.32E+00	1.78E-04	0.00E+00	1.20E-01	2.06E-01	4.02E+00

Table 5.1-2 (continued)

Dose factor - airborne release pathway (mrem/Ci released)								
Sb-125								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.07E-01	1.20E-03	5.38E+00	1.09E-04	0.00E+00	1.33E-01	1.17E+00	9.11E+00
Teen	1.61E-01	1.76E-03	5.39E+00	1.54E-04	0.00E+00	2.21E-01	1.24E+00	9.11E+00
Child	3.69E-01	2.84E-03	5.43E+00	3.42E-04	0.00E+00	2.73E-01	8.75E-01	9.11E+00
Infant	8.33E-02	8.05E-04	5.37E+00	1.04E-04	0.00E+00	9.99E-02	1.09E-01	9.11E+00

Dose factor - airborne release pathway (mrem/Ci released)								
Te-125m								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	3.87E-01	1.40E-01	6.67E-02	1.16E-01	1.57E+00	9.30E-03	1.55E+00	3.96E-02
Teen	5.11E-01	1.84E-01	8.32E-02	1.43E-01	0.00E+00	1.59E-02	1.51E+00	3.96E-02
Child	1.17E+00	3.16E-01	1.70E-01	3.27E-01	0.00E+00	1.42E-02	1.13E+00	3.96E-02
Infant	5.10E-02	1.71E-02	2.18E-02	1.72E-02	0.00E+00	1.33E-02	2.46E-02	3.96E-02

Dose factor - airborne release pathway (mrem/Ci released)								
Te-127								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	4.47E-06	1.61E-06	5.15E-06	3.31E-06	1.82E-05	1.93E-04	2.05E-03	4.60E-06
Teen	4.34E-06	1.55E-06	5.12E-06	3.00E-06	1.76E-05	3.32E-04	2.73E-03	4.60E-06
Child	8.13E-06	2.20E-06	5.93E-06	5.63E-06	2.31E-05	2.98E-04	1.98E-03	4.60E-06
Infant	1.25E-06	4.25E-07	4.45E-06	1.02E-06	3.03E-06	3.07E-04	7.48E-04	4.60E-06

Table 5.1-2 (continued)

Dose factor - airborne release pathway (mrem/Ci released)								
Te-127m								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.19E+00	4.26E-01	1.54E-01	3.05E-01	4.84E+00	2.85E-02	4.00E+00	6.16E-02
Teen	1.48E+00	5.26E-01	1.85E-01	3.52E-01	6.01E+00	4.91E-02	3.70E+00	6.16E-02
Child	3.32E+00	8.94E-01	4.03E-01	7.94E-01	9.47E+00	4.39E-02	2.69E+00	6.16E-02
Infant	1.96E-01	6.50E-02	3.26E-02	5.66E-02	4.82E-01	3.89E-02	7.96E-02	6.16E-02

Dose factor - airborne release pathway (mrem/Ci released)								
Te-129								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.48E-09	7.10E-10	3.68E-05	1.16E-09	5.56E-09	5.74E-05	4.65E-06	4.36E-05
Teen	2.11E-09	1.00E-09	3.68E-05	1.54E-09	7.88E-09	9.78E-05	4.79E-05	4.36E-05
Child	2.90E-09	1.04E-09	3.68E-05	2.12E-09	7.62E-09	8.71E-05	7.56E-04	4.36E-05
Infant	2.34E-09	1.03E-09	3.68E-05	2.00E-09	5.19E-09	8.89E-05	7.81E-04	4.36E-05

Dose factor - airborne release pathway (mrem/Ci released)								
Te-129m								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.39E+00	5.19E-01	2.35E-01	4.78E-01	5.80E+00	3.44E-02	7.01E+00	9.07E-01
Teen	1.94E+00	7.20E-01	3.22E-01	6.26E-01	8.12E+00	5.86E-02	7.30E+00	9.07E-01
Child	4.53E+00	1.26E+00	7.18E-01	1.46E+00	1.33E+01	5.23E-02	5.53E+00	9.07E-01
Infant	1.39E-01	4.77E-02	3.66E-02	5.34E-02	3.48E-01	4.98E-02	8.46E-02	9.07E-01

Table 5.1-2 (continued)

Dose factor - airborne release pathway (mrem/Ci released)								
Te-131								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.47E-03	6.14E-04	5.56E-04	1.21E-03	6.43E-03	4.13E-05	2.09E-04	1.63E-03
Teen	2.52E-03	1.04E-03	8.80E-04	1.94E-03	1.10E-02	6.93E-05	2.07E-04	1.63E-03
Child	6.19E-03	1.89E-03	1.93E-03	4.73E-03	1.87E-02	6.09E-05	3.25E-02	1.63E-03
Infant	5.15E-10	2.44E-10	9.27E-05	4.69E-10	1.18E-09	6.11E-05	2.44E-04	1.63E-03

Dose factor - airborne release pathway (mrem/Ci released)								
Te-131m								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.30E-01	6.34E-02	7.45E-02	1.00E-01	6.43E-01	4.32E-03	6.32E+00	3.77E-02
Teen	2.21E-01	1.06E-01	1.10E-01	1.60E-01	1.11E+00	7.05E-03	8.53E+00	3.77E-02
Child	5.38E-01	1.86E-01	2.20E-01	3.83E-01	1.80E+00	6.10E-03	7.56E+00	3.77E-02
Infant	6.34E-04	2.56E-04	2.18E-02	5.18E-04	1.76E-03	5.90E-03	7.81E-03	3.77E-02

Dose factor - airborne release pathway (mrem/Ci released)								
Te-132								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.92E-01	1.24E-01	1.27E-01	1.37E-01	1.20E+00	8.55E-03	5.89E+00	1.32E-02
Teen	3.19E-01	2.02E-01	2.00E-01	2.13E-01	1.94E+00	1.33E-02	6.42E+00	1.32E-02
Child	7.61E-01	3.37E-01	4.17E-01	4.91E-01	3.13E+00	1.12E-02	3.39E+00	1.32E-02
Infant	3.94E-03	1.95E-03	1.17E-02	2.88E-03	1.22E-02	1.01E-02	8.50E-03	1.32E-02

Table 5.1-2 (continued)

Dose factor - airborne release pathway (mrem/Ci released)								
I-131								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	7.16E-02	1.02E-01	8.29E-02	3.36E+01	1.76E-01	0.00E+00	2.69E-02	2.93E-02
Teen	6.57E-02	9.19E-02	7.35E-02	2.68E+01	1.58E-01	0.00E+00	1.81E-02	2.93E-02
Child	1.44E-01	1.45E-01	1.07E-01	4.80E+01	2.38E-01	0.00E+00	1.29E-02	2.93E-02
Infant	2.04E-01	2.40E-01	1.30E-01	7.89E+01	2.80E-01	0.00E+00	8.56E-03	2.93E-02

Dose factor - airborne release pathway (mrem/Ci released)								
I-132								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	3.44E-05	9.67E-05	1.78E-03	3.40E-03	1.54E-04	0.00E+00	1.21E-05	2.06E-03
Teen	4.73E-05	1.30E-04	1.80E-03	4.49E-03	2.05E-04	0.00E+00	3.78E-05	2.06E-03
Child	6.28E-05	1.21E-04	1.80E-03	5.74E-03	1.86E-04	0.00E+00	9.50E-05	2.06E-03
Infant	5.03E-05	1.05E-04	1.79E-03	5.03E-03	1.17E-04	0.00E+00	5.65E-05	2.06E-03

Dose factor - airborne release pathway (mrem/Ci released)								
I-133								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.46E-03	2.53E-03	4.21E-03	3.71E-01	4.41E-03	0.00E+00	2.14E-03	4.19E-03
Teen	1.49E-03	2.52E-03	4.21E-03	3.53E-01	4.42E-03	0.00E+00	1.75E-03	4.19E-03
Child	2.87E-03	3.55E-03	4.78E-03	6.61E-01	5.91E-03	0.00E+00	1.35E-03	4.19E-03
Infant	3.16E-03	4.59E-03	4.79E-03	8.37E-01	5.40E-03	0.00E+00	7.45E-04	4.19E-03

Table 5.1-2 (continued)

Dose factor - airborne release pathway (mrem/Ci released)								
I-134								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.91E-05	5.13E-05	6.45E-04	8.85E-04	8.17E-05	0.00E+00	2.99E-08	7.45E-04
Teen	2.63E-05	6.88E-05	6.52E-04	1.17E-03	1.09E-04	0.00E+00	6.05E-07	7.45E-04
Child	3.48E-05	6.41E-05	6.57E-04	1.50E-03	9.79E-05	0.00E+00	2.83E-05	7.45E-04
Infant	2.73E-05	5.57E-05	6.47E-04	1.32E-03	6.19E-05	0.00E+00	3.83E-05	7.45E-04

Dose factor - airborne release pathway (mrem/Ci released)								
I-135								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	9.31E-05	2.43E-04	3.64E-03	1.56E-02	3.87E-04	0.00E+00	1.96E-04	4.14E-03
Teen	1.22E-04	3.12E-04	3.66E-03	2.05E-02	4.92E-04	0.00E+00	2.41E-04	4.14E-03
Child	1.69E-04	3.00E-04	3.69E-03	2.72E-02	4.61E-04	0.00E+00	1.63E-04	4.14E-03
Infant	1.23E-04	2.43E-04	3.64E-03	2.22E-02	2.70E-04	0.00E+00	6.06E-05	4.14E-03

Dose factor - airborne release pathway (mrem/Ci released)								
Cs-134								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	6.68E+00	1.59E+01	2.26E+01	0.00E+00	5.15E+00	1.71E+00	2.78E-01	1.12E+01
Teen	1.06E+01	2.49E+01	2.12E+01	0.00E+00	7.90E+00	3.02E+00	3.09E-01	1.12E+01
Child	2.39E+01	3.93E+01	1.79E+01	0.00E+00	1.22E+01	4.37E+00	2.12E-01	1.12E+01
Infant	1.96E+01	3.66E+01	1.33E+01	0.00E+00	9.42E+00	3.86E+00	9.94E-02	1.12E+01

Table 5.1-2 (continued)

Dose factor - airborne release pathway (mrem/Ci released)								
Cs-134m								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	8.36E-04	1.76E-03	9.41E-04	0.00E+00	9.54E-04	1.50E-04	6.19E-04	6.90E-05
Teen	1.40E-03	2.89E-03	1.53E-03	0.00E+00	1.61E-03	2.83E-04	1.92E-03	6.90E-05
Child	3.30E-03	4.89E-03	3.24E-03	0.00E+00	2.58E-03	4.27E-04	6.18E-03	6.90E-05
Infant	5.48E-06	8.72E-06	4.70E-05	0.00E+00	3.53E-06	8.31E-07	4.82E-06	6.90E-05

Dose factor - airborne release pathway (mrem/Ci released)								
Cs-136								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	3.31E-01	1.31E+00	1.28E+00	0.00E+00	7.27E-01	9.97E-02	1.48E-01	4.73E-01
Teen	5.12E-01	2.02E+00	1.70E+00	0.00E+00	1.10E+00	1.73E-01	1.62E-01	4.73E-01
Child	1.14E+00	3.14E+00	2.38E+00	0.00E+00	1.67E+00	2.49E-01	1.10E-01	4.73E-01
Infant	3.54E-01	1.04E+00	7.33E-01	0.00E+00	4.15E-01	8.48E-02	1.58E-02	4.73E-01

Dose factor - airborne release pathway (mrem/Ci released)								
Cs-137								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	9.52E+00	1.30E+01	2.30E+01	0.00E+00	4.42E+00	1.47E+00	2.52E-01	1.69E+01
Teen	1.57E+01	2.09E+01	2.18E+01	0.00E+00	7.12E+00	2.77E+00	2.97E-01	1.69E+01
Child	3.73E+01	3.57E+01	1.97E+01	0.00E+00	1.16E+01	4.18E+00	2.23E-01	1.69E+01
Infant	2.99E+01	3.49E+01	1.70E+01	0.00E+00	9.38E+00	3.80E+00	1.09E-01	1.69E+01

Table 5.1-2 (continued)

Dose factor - airborne release pathway (mrem/Ci released)								
Cs-138								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	2.17E-03	4.28E-03	2.70E-03	0.00E+00	3.14E-03	3.10E-04	1.82E-08	4.39E-03
Teen	3.69E-03	7.08E-03	4.13E-03	0.00E+00	5.23E-03	6.08E-04	3.21E-06	4.39E-03
Child	8.93E-03	1.24E-02	8.46E-03	0.00E+00	8.73E-03	9.40E-04	5.71E-03	4.39E-03
Infant	1.50E-05	2.32E-05	5.97E-04	0.00E+00	1.22E-05	1.94E-06	2.60E-05	4.39E-03

Dose factor - airborne release pathway (mrem/Ci released)								
Ba-139								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	3.78E-03	2.69E-06	1.38E-04	0.00E+00	2.52E-06	4.62E-05	6.71E-03	6.76E-03
Teen	6.56E-03	4.61E-06	2.18E-04	0.00E+00	4.35E-06	8.00E-05	5.86E-02	6.76E-03
Child	1.61E-02	8.60E-06	4.95E-04	0.00E+00	7.51E-06	7.37E-05	9.31E-01	6.76E-03
Infant	1.76E-08	1.17E-11	2.75E-05	0.00E+00	7.04E-12	7.07E-05	6.06E-04	6.76E-03

Dose factor - airborne release pathway (mrem/Ci released)								
Ba-140								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.09E-01	1.37E-04	3.60E-02	0.00E+00	4.67E-05	3.78E-02	2.29E-01	3.29E-02
Teen	1.19E-01	1.46E-04	3.65E-02	0.00E+00	4.94E-05	6.04E-02	1.88E-01	3.29E-02
Child	2.39E-01	2.10E-04	4.28E-02	0.00E+00	6.83E-05	5.18E-02	1.23E-01	3.29E-02
Infant	4.46E-02	4.46E-05	3.11E-02	0.00E+00	1.06E-05	4.74E-02	1.17E-02	3.29E-02

Table 5.1-2 (continued)

Dose factor - airborne release pathway (mrem/Ci released)								
Ba-141								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.83E-03	1.39E-06	2.01E-04	0.00E+00	1.29E-06	2.38E-05	8.66E-13	1.55E-03
Teen	3.16E-03	2.36E-06	2.45E-04	0.00E+00	2.19E-06	4.07E-05	6.75E-09	1.55E-03
Child	7.79E-03	4.36E-06	3.92E-04	0.00E+00	3.77E-06	6.03E-05	4.44E-03	1.55E-03
Infant	1.86E-09	1.28E-12	1.39E-04	0.00E+00	7.72E-13	3.53E-05	5.64E-05	1.55E-03

Dose factor - airborne release pathway (mrem/Ci released)								
La-140								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.17E-05	5.91E-06	2.70E-02	0.00E+00	0.00E+00	4.04E-03	6.96E-02	3.06E-02
Teen	1.57E-05	7.71E-06	2.70E-02	0.00E+00	0.00E+00	6.36E-03	5.51E-02	3.06E-02
Child	2.18E-05	7.60E-06	2.70E-02	0.00E+00	0.00E+00	5.42E-03	3.26E-02	3.06E-02
Infant	1.56E-05	6.17E-06	2.70E-02	0.00E+00	0.00E+00	4.98E-03	5.27E-03	3.06E-02

Dose factor - airborne release pathway (mrem/Ci released)								
La-142								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	4.98E-06	2.27E-06	1.97E-03	0.00E+00	0.00E+00	7.52E-05	1.65E-02	9.71E-03
Teen	8.44E-06	3.75E-06	1.97E-03	0.00E+00	0.00E+00	1.21E-04	1.14E-01	9.71E-03
Child	2.04E-05	6.50E-06	1.97E-03	0.00E+00	0.00E+00	1.03E-04	1.29E+00	9.71E-03
Infant	1.22E-08	4.48E-09	1.97E-03	0.00E+00	0.00E+00	9.77E-05	7.07E-04	9.71E-03

Table 5.1-2 (continued)

Dose factor - airborne release pathway (mrem/Ci released)								
Ce-141								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	7.38E-04	5.01E-04	1.93E-02	0.00E+00	2.32E-04	1.07E-02	3.84E-01	2.16E-02
Teen	1.05E-03	7.02E-04	1.93E-02	0.00E+00	3.29E-04	1.82E-02	4.02E-01	2.16E-02
Child	1.65E-03	8.20E-04	1.93E-02	0.00E+00	3.59E-04	1.61E-02	3.02E-01	2.16E-02
Infant	8.32E-04	5.00E-04	1.92E-02	0.00E+00	1.58E-04	1.53E-02	3.79E-03	2.16E-02

Dose factor - airborne release pathway (mrem/Ci released)								
Ce-143								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	6.71E-05	4.80E-02	4.80E-03	0.00E+00	2.18E-05	9.48E-04	1.80E+00	6.60E-02
Teen	1.15E-04	8.10E-02	4.81E-03	0.00E+00	3.74E-05	1.55E-03	2.44E+00	6.60E-02
Child	2.77E-04	1.48E-01	4.82E-03	0.00E+00	6.31E-05	1.37E-03	2.17E+00	6.60E-02
Infant	3.55E-06	5.06E-05	4.80E-03	0.00E+00	6.85E-07	1.38E-03	8.73E-04	6.60E-02

Dose factor - airborne release pathway (mrem/Ci released)								
Ce-144								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.26E-01	5.24E-02	1.04E-01	0.00E+00	3.10E-02	2.31E-01	8.05E+00	1.13E-01
Teen	1.83E-01	7.56E-02	1.07E-01	0.00E+00	4.51E-02	3.96E-01	9.46E+00	1.13E-01
Child	2.91E-01	9.10E-02	1.13E-01	0.00E+00	5.04E-02	3.55E-01	7.37E+00	1.13E-01
Infant	9.58E-02	3.64E-02	1.03E-01	0.00E+00	1.61E-02	2.92E-01	6.97E-02	1.13E-01

Table 5.1-2 (continued)

Dose factor - airborne release pathway (mrem/Ci released)								
Pr-143								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	5.11E-04	2.05E-04	2.53E-05	0.00E+00	1.18E-04	3.34E-03	1.75E+00	3.77E-01
Teen	8.14E-04	3.25E-04	4.05E-05	0.00E+00	1.89E-04	5.74E-03	2.16E+00	3.77E-01
Child	1.82E-03	5.46E-04	9.02E-05	0.00E+00	2.96E-04	5.15E-03	1.73E+00	3.77E-01
Infant	1.67E-04	6.23E-05	8.32E-06	0.00E+00	2.35E-05	5.14E-03	5.83E-04	3.77E-01

Dose factor - airborne release pathway (mrem/Ci released)								
Pr-144								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	8.93E-10	3.70E-10	2.58E-06	0.00E+00	2.09E-10	3.01E-05	6.39E-16	2.96E-06
Teen	1.27E-09	5.22E-10	2.58E-06	0.00E+00	2.99E-10	5.20E-05	6.98E-12	2.96E-06
Child	1.77E-09	5.48E-10	2.58E-06	0.00E+00	2.90E-10	4.64E-05	5.84E-06	2.96E-06
Infant	1.42E-09	5.48E-10	2.58E-06	0.00E+00	1.99E-10	4.78E-05	1.27E-04	2.96E-06

Dose factor - airborne release pathway (mrem/Ci released)								
Nd-147								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	8.95E-05	1.03E-04	2.00E-02	0.00E+00	6.04E-05	2.62E-03	1.51E-01	2.00E-01
Teen	1.22E-04	1.33E-04	2.00E-02	0.00E+00	7.80E-05	4.42E-03	1.15E-01	2.00E-01
Child	1.85E-04	1.49E-04	2.00E-02	0.00E+00	8.22E-05	3.90E-03	7.33E-02	2.00E-01
Infant	9.45E-05	9.69E-05	2.00E-02	0.00E+00	3.75E-05	3.83E-03	4.73E-04	2.00E-01

Table 5.1-2 (continued)

Dose factor - airborne release pathway (mrem/Ci released)								
Eu-152								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	3.32E-02	2.45E-01	3.62E+01	0.00E+00	4.67E-02	3.26E-02	1.38E+00	6.86E+01
Teen	4.20E-02	1.02E-02	3.62E+01	0.00E+00	4.73E-02	4.76E-02	1.23E+00	6.86E+01
Child	6.02E-02	1.10E-02	3.62E+01	0.00E+00	4.64E-02	3.96E-02	8.25E-01	6.86E+01
Infant	1.30E-02	2.95E-03	3.62E+01	0.00E+00	9.90E-03	2.46E-02	5.31E-04	6.86E+01

Dose factor - airborne release pathway (mrem/Ci released)								
W-187								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	4.08E-03	3.41E-03	7.22E-03	0.00E+00	0.00E+00	3.45E-04	1.12E+00	2.79E-02
Teen	6.98E-03	5.69E-03	8.03E-03	0.00E+00	0.00E+00	5.63E-04	1.54E+00	2.79E-02
Child	1.69E-02	1.00E-02	1.05E-02	0.00E+00	0.00E+00	4.88E-04	1.41E+00	2.79E-02
Infant	1.13E-05	7.88E-06	6.04E-03	0.00E+00	0.00E+00	4.71E-04	8.79E-04	2.79E-02

Dose factor - airborne release pathway (mrem/Ci released)								
U-235								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	4.06E+01	0.00E+00	1.04E+01	0.00E+00	9.47E+00	4.66E+00	3.87E+00	1.06E+01
Teen	6.45E+01	0.00E+00	1.19E+01	0.00E+00	1.51E+01	8.03E+00	4.59E+00	1.06E+01
Child	1.54E+02	0.00E+00	1.73E+01	0.00E+00	2.53E+01	7.17E+00	3.58E+00	1.06E+01
Infant	1.17E+01	0.00E+00	8.84E+00	0.00E+00	2.49E+00	5.46E+00	1.90E-01	1.06E+01

Table 5.1-2 (continued)

Dose factor - airborne release pathway (mrem/Ci released)								
U-238								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	3.88E+01	0.00E+00	2.33E+00	0.00E+00	8.86E+00	4.36E+00	2.72E+00	2.47E-01
Teen	6.17E+01	0.00E+00	3.70E+00	0.00E+00	1.41E+01	7.50E+00	3.23E+00	2.47E-01
Child	1.48E+02	0.00E+00	8.79E+00	0.00E+00	2.37E+01	6.73E+00	2.53E+00	2.47E-01
Infant	1.12E+01	0.00E+00	8.63E-01	0.00E+00	2.33E+00	5.09E+00	1.34E-01	2.47E-01

Dose factor - airborne release pathway (mrem/Ci released)								
Np-239								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	5.00E-05	4.92E-06	5.54E-03	0.00E+00	1.53E-05	4.47E-04	9.55E-01	9.52E-03
Teen	8.79E-05	8.29E-06	5.55E-03	0.00E+00	2.60E-05	7.71E-04	1.27E+00	9.52E-03
Child	2.11E-04	1.52E-05	5.55E-03	0.00E+00	4.39E-05	6.91E-04	1.10E+00	9.52E-03
Infant	4.42E-06	3.95E-07	5.54E-03	0.00E+00	7.88E-07	7.07E-04	3.14E-04	9.52E-03

Dose factor - airborne release pathway (mrem/Ci released)								
Am-241								
	Bone	Liver	T. Body	Thyroid	Kidney	Lungs	GI-LLI	Skin
Adult	1.34E+02	4.76E+01	1.03E+01	0.00E+00	6.70E+01	5.76E+00	3.48E+00	2.94E+00
Teen	1.46E+02	5.59E+01	1.11E+01	0.00E+00	7.31E+01	9.99E+00	4.12E+00	2.94E+00
Child	1.37E+02	6.14E+01	1.11E+01	0.00E+00	5.98E+01	8.88E+00	3.22E+00	2.94E+00
Infant	3.07E+01	1.41E+01	3.56E+00	0.00E+00	1.32E+01	6.76E+00	2.58E-03	2.94E+00

5.1.3 Atmospheric Release Mode: Noble Gases

The dose calculations for demonstration of compliance with the 10 CFR 50, Appendix I dose limits for noble gases released to the atmosphere will be done in the manner similar to the liquid release dose calculations described in Section 5.1.1. The total doses to the air, skin, and whole body resulting from the release of noble gases is compared to the corresponding Appendix limits. Noble gases released in liquids are to be added to the atmospherically released noble gases for Appendix I dose compliance calculations.

The doses are calculated using the following formula:

$$API = \Sigma \ Dose_{ti} = \Sigma \ (TDF_{ti} \times C_i) \leq K_t \text{ mrem}$$

where

API = the Appendix I dose for compliance evaluation in mrem

$Dose_{ti}$ = the dose to the applicable target (t) from radionuclide (i)

TDF_{ti} = total dose factor from Table 5.1-3 in mrem/Ci for the specific target (t) from radionuclide (i) based on the maximum annual average χ/Q at the site boundary

C_i = curies of radionuclide (i) released

K_t = the noble gas Appendix I dose limit for target (t)

The methodology used to obtain the TDF values are given in Appendix C.

Instead of using the precalculated total dose factors, the Appendix I dose calculation may be modified to reflect actual χ/Q values during the release using the methodology of Appendix C.

Table 5.1-3

Activity to Dose Conversion Factors for Noble Gases (Highest Annual Average χ/Q)				
Nuclide	Beta Air (mrad/Ci)	Gamma Air (mrad/Ci)	Skin (mrem/Ci)	Whole Body (mrem/Ci)
AR-41	1.56E-04	4.42E-04	2.94E-04	4.72E-04
KR-83M	1.37E-05	9.18E-07	2.52E-09	7.13E-07
KR-85M	9.37E-05	5.85E-05	3.89E-05	1.15E-04
KR-85	9.27E-05	8.18E-07	5.36E-07	6.44E-05
KR-87	4.90E-04	2.93E-04	1.97E-04	6.91E-04
KR-88	1.39E-04	7.23E-04	4.89E-04	6.74E-04
KR-89	5.04E-04	8.23E-04	5.53E-04	1.12E-03
KR-90	3.72E-04	7.75E-04	5.19E-04	9.49E-04
XE-131M	5.28E-05	7.42E-06	3.05E-06	2.84E-05
XE-133M	7.04E-05	1.55E-05	8.35E-06	5.93E-05
XE-133	4.99E-05	1.68E-05	9.79E-06	2.76E-05
XE-135M	3.51E-05	1.60E-04	1.04E-04	1.58E-04
XE-135	1.17E-04	9.13E-05	6.02E-05	1.59E-04
XE-137	6.04E-04	7.18E-05	4.73E-05	6.36E-04
XE-138	2.26E-04	4.38E-04	2.94E-04	5.37E-04

6.0 RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

A complete description of the PBNP radiological environmental monitoring program, including procedures and responsibilities, is contained in the PBNP Environmental Manual.

7.0 RADIOLOGICAL IMPACT EVALUATION OF SEWAGE TREATMENT SLUDGE DISPOSAL

The methodology for determining the radiological impact of sewage treatment sludge disposal is presented in this section. The radiological impact evaluation must be performed for each sewage treatment sludge disposal prior to land application.

7.1 Basis

Wisconsin Electric's commitment with the United States Nuclear Regulatory Commission in a letter dated October 8, 1987 (VPNPD-87-430, NRC-87-104) requires Wisconsin Electric to measure the concentrations of radionuclides in the sewage treatment sludge and compare them to concentration limits prior to disposal. In addition, the appropriate exposure pathways will be evaluated prior to each application of sludge to insure that the dose to the maximally exposed member of the general public is maintained less than 1 mrem/year and the dose to the inadvertent intruder is maintained less than 5 mrem/year.

The exposure pathways evaluated for the maximally exposed individual are the following:

1. External whole body exposure due to a ground plane source of radionuclides.
2. Milk ingestion pathway from cows fed alfalfa grown on plot.
3. Meat ingestion pathway from cows fed alfalfa grown on plot.
4. Vegetable ingestion pathway from vegetables grown on plot.
5. Inhalation of radioactivity resuspended in air above plot.
6. Pathways associated with a release to Lake Michigan. These pathways are ingestion of potable water at the Two Rivers, Wisconsin municipal water supply, ingestion of fish from edge of initial mixing zone of radionuclide release, ingestion of fresh and stored vegetables irrigated with water from Lake Michigan, ingestion of milk and meat from cows utilizing Lake Michigan as drinking water source, swimming and boating activities at the edge of the initial mixing zone, and shoreline deposits.

The exposure pathways evaluated for the inadvertent intruder are the same as items 1, 4, 5, and 6 identified above for the maximally exposed individual.

7.2 Procedure

The following steps are to be performed by the Responsible Engineer - IRSS for each sewage treatment sludge disposal:

7.2.1 Obtain from PBNP - Chemistry the radionuclide concentrations in each representative sewage treatment sludge sample. The minimum number of representative samples required is three from each sludge storage tank. The average of all statistically valid concentration determinations will be utilized in determining the sludge storage tank concentration values.

7.2.2 Verify that the concentration of each radionuclide meets the concentration and activity limit criteria. The methodology for determining compliance with the concentration and activity limit criteria are contained in Appendix E.

7.2.3 Verify that the proposed disposal of the sewage treatment sludge will maintain doses within the applicable limits. This calculation will include radionuclides disposed of in previous sludge applications. The activity from these prior disposals will be corrected for radiological decay prior to performing dose calculations for the meat, milk, and vegetable ingestion pathways, the inhalation of resuspended radionuclides, and all pathways associated with a potential release to Lake Michigan. The residual radioactivity will be corrected, if applicable, for the mixing of radionuclides in the soil prior to performing external exposure calculations.

Wisconsin Electric utilizes QAD, a nationally recognized computer code, to perform shielding and dose rate analyses. QAD will be used to calculate the dose rate due to standing on a plot of land utilized for sludge disposal in which the radionuclides from prior disposals have been incorporated into the plot by plowing. This calculated dose rate will be used to assess the radiological consequences from prior disposals with the consequences of proposed future disposals. The total radiological dose consequence of the past and the proposed disposal will be compared to the applicable limits to insure the dose is maintained at or below the limits.

The methodology for calculating the radiological impact of the sewage treatment sludge disposal is contained in Appendix E.

7.2.4 Inform PBNP - Chemistry that the sewage treatment sludge disposal may proceed after verifying that the sewage treatment sludge meets the concentration, activity, and dose limits.

7.2.5 Forward all calculations to PBNP - Chemistry to be included with the sewage treatment sludge disposal record.

7.3 Administrative Requirements

7.3.1 Complete records of each disposal shall be kept as follows:

a. Radionuclide concentration of the sludge.

b. Total volume of sludge disposed.

c. The identity of the plot used for the disposal.

d. Dose calculation results.

e. Results of annual chemical composition determination.

7.3.2 Modifications to the October 8, 1987, NRC submittal

a. Modification 1 - Appendix F

Section 3.2 of Attachment II of the submittal states that physical and chemical properties of the sludge would be determined prior the each land application. Pursuant to a change in the PBNP WPDES Permit, non-radiological properties are now determined annually instead of per application. The frequency for radiological characterization did not change.

b. Modification 2 - Appendix G

In Section 3.3 of Attachment II of the submittal letter, the annual disposal rate was "...limited to 4,000 gallons/acre, provided WDNR chemical composition, NRC dose guidelines and activity limits are maintained...." Modification 2 removes the 4,000 gallon limit and makes the application unlimited provided the WDNR and NRC constraints are met.

APPENDIX A

DERIVATION OF LIQUID RELEASE PATHWAY EFFECTIVE MAXIMUM EFFLUENT CONCENTRATION

A1.0 DERIVATION OF LIQUID RELEASE EFFECTIVE MAXIMUM EFFLUENT CONCENTRATION

A1.1 Source Term

The effective maximum effluent concentration is calculated from the annual releases via liquids for the years 1985 - 1991 (Table A-1). Although Na-24 was discharged in 1985, it was excluded from the isotopic mixture because it is not a radionuclide which would be normally found in PBNP effluent. Na-24 appears in the effluent because it was used for tests run on the steam system. Tritium also was omitted from the initial calculation because its production is largely independent from the appearance of the fission products in the effluent.

A1.2 Effective Maximum Effluent Concentration

The effective maximum effluent concentration (EMEC) was calculated using the formula given in Section 3.6

$$EMEC = \sum C_i / \sum (C_i/MEC_i) \text{ or } \sum C_i * 1/SOF$$

where:

SOF = $\sum C_i/MEC_i$ is the summation of fractions for the annual effluent isotopic release

C_i = concentration of radionuclide "i" (μCi/ml) in effluent (annual discharge/total volume of discharge)

MEC_i = maximum effluent concentration for unrestricted areas from Appendix B, Table 2, Column 2 of 10 CFR 20.

| The SOF for radionuclides in liquid effluent for the years 1985 through 1991 were calculated with and without H-3 and used to calculate the EMEC for the same years (Table A-2). The average EMEC without H-3 is 4.29E-06 μCi/cc. This is the maximum concentration of non H-3 radionuclides in a mixture that could be released in liquid effluent without the SOF exceeding one (1).

However, the 10 CFR 20 Appendix B criterion is that the SOF for all radionuclides, including H-3 which can not be measured by the liquid effluent NaI RMS monitors, be less than or equal to one (1). Therefore, the above equation, modified by a factor of 0.70 to account for H-3, becomes

$$EMEC = 0.70 \sum C_i / \sum (C_i/MEC_i) \text{ or } \sum C_i * 0.70/SOF.$$

The EMEC becomes

$$EMEC = 0.70 * 4.29E\text{-}06 = 3.00E\text{-}06 \ \mu Ci/cc.$$

Only three radionuclides identified in PBNP liquid effluent have a lower MEC (10 CFR 20, Appendix B, Table 2). They are I-131 (1E-06), Cs-134 (9E-07), and Cs-137 (1E-06).

By restricting the non-tritium radionuclides to 70% of their calculated EMEC, the H-3 concentration can be discharged at 30% of its MEC or 3.00E-04 μCi/cc without exceeding the SOF criterion of 10 CFR 20, Appendix B for the total liquid effluent isotopic mixture.

TABLE A-1
CURIES RELEASED IN LIQUIDS

LIQUID RELEASES								
NUCLIDE	MEC uCi/cc	1985	1986	1987	1988	1989	1990	1991
H-3	1.00E-03	8.05E+02	8.11E+02	7.09E+02	3.57E+02	5.59E+02	8.72E+02	7.87E+02
I-131	1.00E-06	1.02E-01	3.74E-02	1.04E-02	1.40E-03	1.77E-03	1.53E-04	1.83E-03
I-132	1.00E-04	6.15E-02	7.25E-02	5.82E-02	1.03E-03	8.15E-04	4.45E-05	9.41E-03
I-133	7.00E-06	1.27E-01	1.49E-01	1.04E-01	1.21E-02	8.11E-03	3.01E-03	1.01E-02
I-134	4.00E-04	3.18E-02	4.39E-02	3.97E-02	2.29E-04			6.83E-04
I-135	3.00E-05	1.04E-01	1.34E-01	1.23E-01	4.48E-04			8.21E-04
AG-110M	6.00E-06	2.55E-05	2.84E-04	3.09E-03	9.85E-04	4.70E-04	1.71E-04	4.06E-04
BA-133	2.00E-05							
BA-139	2.00E-04			8.63E-06	2.47E-04			
BA-140	8.00E-06	6.90E-06		4.45E-05	6.13E-05			
CD-109	6.00E-06		6.33E-05	1.31E-04				
CE-139	7.00E-05							
CE-141	3.00E-05	1.31E-03		7.50E-04				
CE-144	3.00E-06		1.37E-03	2.08E-03	4.76E-04	1.59E-04	9.47E-06	9.64E-06
CO-56	6.00E-06							
CO-57	6.00E-05	2.52E-03	1.33E-04	3.21E-04	5.07E-05	6.90E-07	4.08E-06	
CO-58	2.00E-05	4.05E-01	9.02E-03	3.36E-02	6.81E-03	3.12E-03	3.25E-04	2.93E-03
CO-60	3.00E-06	2.88E-01	2.85E-02	6.34E-02	2.04E-02	1.54E-02	1.41E-03	5.53E-03
CR-51	5.00E-04	2.71E-02	3.16E-04	1.58E-02	5.31E-05	4.44E-04	8.71E-05	
CS-134	9.00E-07	4.76E-02	6.92E-03	1.18E-03	4.96E-04			1.49E-03
CS-134M	2.00E-03				3.59E-04	5.97E-06		4.67E-04
CS-136	6.00E-06							
CS-137	1.00E-06	9.60E-02	2.11E-02	7.54E-03	8.63E-03	2.80E-03	1.94E-03	8.93E-03
CS-138	4.00E-04	1.11E-03	5.48E-03	3.24E-03				
F-18	7.00E-04		1.00E-02	1.67E-02	7.56E-04	1.66E-03	2.26E-03	4.06E-04
FE-59	1.00E-05			2.76E-04				
LA-140	9.00E-06							
MN-54	3.00E-05	7.46E-03	1.18E-03	4.68E-03	1.54E-04	2.68E-04	3.10E-05	1.96E-04
M0-99	2.00E-05				3.70E-05			
NB-95	3.00E-05	6.28E-03	6.65E-04	3.21E-03	1.61E-04	2.33E-06	8.68E-05	
NB-97	3.00E-04	1.35E-03	5.22E-04	6.16E-05	1.06E-05	3.90E-06	8.80E-06	5.30E-06
RB-88	4.00E-04	8.46E-05	1.11E-02	3.33E-03				
RB-89	9.00E-04		7.98E-04	2.34E-04				
RU-103	3.00E-05	3.59E-03	1.68E-06	8.41E-04	5.86E-05			
RU-106	3.00E-06	8.07E-04	2.88E-03	7.33E-03	1.04E-04			
SB-124	7.00E-06	3.86E-02	2.96E-04	1.42E-04	2.34E-04			
SB-125	3.00E-05	1.12E-02	1.20E-03	1.95E-03	1.00E-03	2.12E-02	1.28E-05	1.08E-02
SN-113	3.00E-05	1.07E-03	4.20E-03	5.13E-04	3.21E-04			3.07E-06
SR-89	8.00E-06	2.27E-04	3.46E-05	3.89E-03	2.68E-03	8.69E-06		
SR-90	5.00E-07	1.29E-03	2.28E-04	2.80E-04	3.50E-04	2.55E-04		
TC-99M	1.00E-03	1.75E-05	3.75E-06		3.30E-05			
TC-101	2.00E-03			1.10E-05				
TE-131	8.00E-05				7.98E-05			
TE-132	9.00E-06	5.83E-07	6.94E-05	2.74E-05	7.19E-06			1.74E-04
W-187	3.00E-05				3.41E-05			
Y-91M	2.00E-03							
ZN-65	5.00E-06			5.15E-05				
ZR-95	2.00E-05	7.95E-05	2.61E-04	2.45E-03		1.58E-05		
ZR-97	9.00E-06	1.49E-06	3.09E-06		1.74E-05			
TOTAL CI		8.06E+02	8.12E+02	7.10E+02	3.57E+02	5.59E+02	8.72E+02	7.87E+02
TOTAL W/O H-3		1.37E+00	5.39E-01	5.12E-01	5.99E-02	5.65E-02	9.57E-03	5.42E-02

TABLE A-2
FRACTIONAL MEC IN LIQUID EFFLUENT

NUCLIDE	MEC uCi/cc	1985	1986	1987	1988	1989	1990	1991
H-3	1.00E-03	1.27E-03	1.25E-03	1.04E-03	5.17E-04	8.36E-04	1.26E-03	1.22E-03
I-131	1.00E-06	1.61E-04	5.75E-05	1.52E-05	2.03E-06	2.65E-06	2.21E-07	2.84E-06
I-132	1.00E-04	9.70E-07	1.12E-06	8.53E-07	1.49E-08	1.22E-08	6.43E-10	1.46E-07
I-133	7.00E-06	2.86E-05	3.27E-05	2.18E-05	2.51E-06	1.73E-06	6.21E-07	2.24E-06
I-134	4.00E-04	1.25E-07	1.69E-07	1.46E-07	8.30E-10			2.65E-09
I-135	3.00E-05	5.47E-06	6.87E-06	6.01E-06	2.16E-08			4.24E-08
AG-110M	6.00E-06	6.70E-09	7.28E-08	7.55E-07	2.38E-07	1.17E-07	4.12E-08	1.05E-07
BA-133	2.00E-05							
BA-139	2.00E-04			6.33E-11	1.79E-09			
BA-140	8.00E-06	1.36E-09	0.00E+00	8.16E-09	1.11E-08			
CD-109	6.00E-06		1.62E-08		3.16E-08			
CE-139	7.00E-05							
CE-141	3.00E-05	6.89E-08		3.67E-08				
CE-144	3.00E-06		7.03E-07	1.02E-06	2.30E-07	7.92E-08	4.56E-09	4.98E-09
CO-56	6.00E-06							
CO-57	6.00E-05	6.62E-08	3.41E-09	7.84E-09	1.22E-09	1.72E-11	9.83E-11	
CO-58	2.00E-05	3.19E-05	6.94E-07	2.46E-06	4.93E-07	2.33E-07	2.35E-08	2.27E-07
CO-60	3.00E-06	1.51E-04	1.46E-05	3.10E-05	9.86E-06	7.67E-06	6.79E-07	2.86E-06
CR-51	5.00E-04	8.55E-08	9.72E-10	4.63E-08	1.54E-10	1.33E-09	2.52E-10	
CS-134	9.00E-07	8.34E-05	1.18E-05	1.92E-06	7.99E-07			2.57E-06
CS-134M	2.00E-03				2.60E-10	4.46E-12		3.62E-10
CS-136	6.00E-06							
CS-137	1.00E-06	1.51E-04	3.25E-05	1.11E-05	1.25E-05	4.19E-06	2.80E-06	1.38E-05
CS-138	4.00E-04	4.38E-09	2.11E-08	1.19E-08				
F-18	7.00E-04		2.20E-08	3.50E-08	1.57E-09	3.54E-09	4.67E-09	8.99E-10
FE-59	1.00E-05			4.05E-08				
LA-140	9.00E-06							
MN-54	3.00E-05	3.92E-07	6.05E-08	2.29E-07	7.44E-09	1.34E-08	1.49E-09	1.01E-08
M0-99	2.00E-05				2.68E-09			
NB-95	3.00E-05	3.30E-07	3.41E-08	1.57E-07	7.78E-09	1.16E-10	4.18E-09	
NB-97	3.00E-04	7.10E-09	2.68E-09	3.01E-10	5.12E-11	1.94E-11	4.24E-11	2.74E-11
RB-88	4.00E-04	3.34E-10	4.27E-08	1.22E-08				
RB-89	9.00E-04		1.36E-09	3.81E-10				
RU-103	3.00E-05	1.89E-07	8.62E-11	4.11E-08	2.83E-09			
RU-106	3.00E-06	4.24E-07	1.48E-06	3.58E-06	5.02E-08			
SB-124	7.00E-06	8.70E-06	6.51E-08	2.97E-08	4.84E-08			
SB-125	3.00E-05	5.89E-07	6.15E-08	9.53E-08	4.83E-08	1.06E-06	6.17E-10	5.58E-07
SN-113	3.00E-05	5.63E-08	2.15E-09	2.51E-08	1.55E-08			1.59E-10
SR-89	8.00E-06	4.48E-08	6.65E-09	7.13E-07	4.86E-07	1.62E-09		
SR-90	5.00E-07	4.07E-06	7.02E-07	8.21E-07	1.01E-06	7.62E-07		
TC-99M	1.00E-03	2.76E-11	5.77E-12		4.78E-11			
TC-101	2.00E-03			8.06E-12				
TE-131	8.00E-05				1.45E-09			
TE-132	9.00E-06	1.02E-10	1.19E-08	4.46E-09	1.16E-09			3.00E-08
W-187	3.00E-05				1.65E-09			
Y-91M	2.00E-03							
ZN-65	5.00E-06			1.51E-08				
ZR-95	2.00E-05	6.27E-09	2.01E-08	1.80E-07			1.14E-09	
ZR-97	9.00E-06	2.61E-10	5.28E-10		2.80E-09			

TABLE A-2 (continued)

FRACTIONAL MEC IN LIQUID EFFLUENT

	1985	1986	1987	1988	1989	1990	1991
ANNUAL VOL(CCs)	6.34E+14	6.50E+14	6.82E+14	6.90E+14	6.69E+14	6.92E+14	6.45E+14
TOT FRACTION	1.90E-03	1.41E-03	1.14E-03	5.48E-04	8.54E-04	1.26E-03	1.25E-03
FRACT W/O H-3	6.29E-04	1.61E-04	9.83E-05	3.04E-05	1.85E-05	4.41E-06	2.55E-05
TOTAL CI	8.06E+02	8.12E+02	7.10E+02	3.57E+02	5.59E+02	8.72E+02	7.87E+02
TOTAL W/O H-3	1.37E+00	5.39E-01	5.12E-01	5.99E-02	5.65E-02	9.57E-03	5.42E-02
TOT CONC(uCi/CC)	1.27E-06	1.25E-06	1.04E-06	5.17E-07	8.36E-07	1.26E-06	1.22E-06
TCON W/O H-3	2.16E-09	8.30E-10	7.51E-10	8.69E-11	8.44E-11	1.38E-11	8.40E-11
EMEC	6.70E-04	[illegible].86E-04	9.14E-04	9.45E-04	9.78E-04	9.97E-04	9.80E-04
EMEC W/O H-3	3.43E-06	5.14E-06	7.64E-06	2.85E-06	4.56E-06	3.14E-06	3.30E-06

APPENDIX B

DERIVATION OF ATMOSPHERIC RELEASE MODE

EFFECTIVE MAXIMUM EFFLUENT CONCENTRATION

B1.0 DERIVATION OF ATMOSPHERIC RELEASE EFFECTIVE MAXIMUM EFFLUENT CONCENTRATION

B1.1 Source Term

The effective maximum effluent concentration (EMEC) for atmospheric effluents is calculated from the annual releases for the years 1985 - 1991 (Table B-1). Unlike liquid releases, tritium was not omitted from the EMEC calculation. Instead, the EMEC was calculated with H-3 and then modified by the fraction of non-tritium radionuclides in the effluent.

B1.2 Effective Maximum Effluent Concentration

The maximum concentration of a radionuclide mixture that is allowable at the site boundary is called the effective maximum effluent concentration (EMEC). The EMEC for an effluent mixture is defined by the equation

$$EMEC = \sum C_i / \sum (C_i / MEC_i)$$

where

C_i = concentration of radionuclide "i"

MEC_i = maximum effluent concentration for radionuclide "i" from 10 CFR 20, Appendix B, Table 2, Column 1

$\Sigma (C_i / MEC_i)$ = summation of fractions (SOF), as discussed in Section 3.6, applied to atmospheric releases

The EMEC is calculated from the reference radionuclide mixture which is the radionuclides released during the years 1985 - 1991. The average annual site boundary concentration for each year was calculated using the highest annual average χ/Q of 1.56E-06 sec/m^3. Then the total EMEC was calculated for each year (Table B-2). The average total EMEC is 8.04E-08 ± 1.31E-08 μCi/cc with a range of 5.84E-08 to 9.50E-08 μCi/cc. Next, the annual EMEC was modified for the presence of H-3, which is not detected by the atmospheric RMS, by multiplying each EMEC by the ratio of the non H-3 concentration to the total concentration. The annual H-3 corrected EMECs were averaged to obtain a value of 1.92E-08 ± 1.23E-08 μCi/cc with a range of 5.02E-09 to 3.70E-08 μCi/cc.

TABLE B-1
CURIES IN ATMOSPHERIC EFFLUENT

NUCLIDE	MEC uCi/ml	1985	1986	1987	1988	1989	1990	1991
H-3	1.00E-07	6.71E+01	1.20E+02	1.18E+02	1.26E+02	1.42E+02	1.28E+02	1.13E+02
AR-41	1.00E-08	1.27E+00	6.81E-01	2.17E+00	1.96E+00	1.57E+00	1.11E+00	1.07E+00
KR-85M	1.00E-07	1.84E+01	6.77E-01	1.18E+00	7.31E-01	2.24E-01	1.85E-01	1.03E-01
KR-85	7.00E-07	1.67E+01	1.32E+00	7.11E-01	9.84E-01	3.58E-01	1.78E-01	2.74E-01
KR-87	2.00E-08	4.78E+00	1.01E+00	2.37E+00	1.48E+00	4.94E-01	4.05E-01	2.31E-01
KR-88	9.00E-09	5.73E+00	1.30E+00	2.72E+00	1.69E+00	5.64E-01	4.49E-01	2.56E-01
XE-131M	2.00E-06	8.54E-02						
XE-133M	6.00E-07	3.30E-01	1.38E-01	2.12E-01	3.35E-01	4.94E-03	2.06E-02	3.97E-02
XE-133	5.00E-07	3.45E+01	1.53E+01	2.06E+01	6.04E+01	7.54E+00	1.96E+00	1.60E+01
XE-135M	4.00E-08	5.76E+00	1.27E+00	3.68E+00	2.54E+00	7.37E-01	6.49E-01	3.44E-01
XE-135	7.00E-08	1.19E+01	3.21E+00	5.64E+00	3.53E+00	1.08E+00	1.09E+00	6.03E-01
XE-138	2.00E-08	1.65E+01	2.91E+00	8.87E+00	7.19E+00	2.45E+00	1.99E+00	1.06E+00
AG-110M	1.00E-10				2.31E-07			
BA-133	9.00E-10							
BA-139	4.00E-08							1.17E-07
BA-140	2.00E-09			3.41E-07				
CD-109	2.00E-10	8.92E-06	1.26E-06	2.28E-04				
CE-139	9.00E-10							
CE-141	8.00E-10	8.48E-09						
CE-144	2.00E-11		2.04E-06			3.92E-07		3.94E-09
CO-57	9.00E-10	2.10E-07		2.52E-11	1.13E-08		1.23E-06	4.80E-07
CO-58	1.00E-09	1.57E-04	1.33E-05	1.01E-04	3.59E-05	1.69E-04	2.74E-05	3.85E-06
CO-60	5.00E-11	7.94E-05	1.11E-04	1.18E-05	3.64E-04	1.63E-04	3.56E-06	1.06E-04
CR-51	3.00E-08					5.28E-04		7.58E-09
CS-134	2.00E-10	1.18E-03	9.49E-04	5.86E-05	7.27E-05			1.10E-03
CS-136	9.00E-10							
CS-137	2.00E-10	4.02E-03	2.94E-04	3.08E-04	6.74E-04	2.10E-03	1.91E-04	1.90E-03
CS-138	8.00E-08	9.64E-07	1.92E-06	1.85E-03	1.26E-07	3.44E-06		1.92E-02
F-18	1.00E-07		1.08E-05	2.52E-04	3.87E-05	3.31E-04	1.10E-05	6.60E-04
FE-59	7.00E-10							4.87E-09
MN-54	1.00E-09	1.99E-06	1.70E-06		4.86E-05			
M0-99	2.00E-09			7.27E-09	2.71E-08			
NA-24	7.00E-09	1.39E-04		4.32E-04	4.29E-04			
NB-95	2.00E-09	2.52E-06	7.70E-07	5.97E-07	6.25E-08		9.56E-10	
NB-97	1.00E-07				1.60E-08			1.65E-09
RB-88	9.00E-08	4.63E-05	3.46E-05	1.03E-02	4.00E-06	1.81E-05		1.62E-01
RB-89	2.00E-07					4.30E-09		
RU-103	9.00E-10	1.91E-08	1.89E-05					
SB-125	7.00E-10	1.25E-07		3.68E-06	9.39E-08			
SN-113	8.00E-10	2.16E-08			4.80E-10			
SR-89	2.00E-10	4.87E-08	1.54E-06	7.70E-07	3.71E-06			
SR-90	6.00E-12			1.68E-10	4.30E-06			
SR-91	5.00E-09							
TC-99M	3.00E-07			6.43E-08	2.20E-07	9.24E-07		
TC-101	5.00E-07							
TE-132	9.00E-10				3.07E-06	7.33E-08		2.34E-06
Y-88	3.00E-10			1.28E-10				
ZN-65	4.00E-10				9.27E-06			
ZR-95	4.00E-10	1.31E-06			3.56E-09		7.43E-10	
ZR-97	2.00E-09	2.97E-10						

TABLE B-1 (continued)

CURIES IN ATMOSPHERIC EFFLUENT

NUCLIDE	MEC uCi/ml	1985	1986	1987	1988	1989	1990	1991
I-131	2.00E-10	3.44E-03	1.11E-03	3.08E-03	5.43E-04	3.18E-04	7.85E-05	3.46E-04
I-132	2.00E-08	3.75E-03	1.79E-03	2.42E-03	4.78E-04	4.20E-05	1.09E-05	2.95E-05
I-133	1.00E-09	1.37E-03	6.80E-04	3.04E-03	1.53E-03	1.19E-03	1.13E-04	1.13E-04
I-134	6.00E-08	1.33E-05		9.32E-04				
I-135	6.00E-09	5.79E-04	1.09E-04	2.19E-03	9.18E-05	1.26E-05	3.15E-08	1.58E-05

TABLE B-2
FRACTIONAL MEC FOR ATMOSPHERIC EFFLUENT

NUCLIDE	1985	1986	1987	1988	1989	1990	1991
H-3	3.20E-05	5.71E-05	5.62E-05	6.00E-05	6.76E-05	6.10E-05	5.38E-05
AR-41	6.05E-06	3.24E-06	1.03E-05	9.33E-06	7.48E-06	5.29E-06	5.10E-06
KR-85M	8.76E-06	3.22E-07	5.62E-07	3.48E-07	1.07E-07	8.81E-08	4.90E-08
KR-85	1.14E-06	8.98E-08	4.84E-08	6.69E-08	2.44E-08	1.21E-08	1.86E-08
KR-87	1.14E-05	2.40E-06	5.64E-06	3.52E-06	1.18E-06	9.64E-07	5.50E-07
KR-88	3.03E-05	6.88E-06	1.44E-05	8.94E-06	2.98E-06	2.38E-06	1.35E-06
XE-131M	2.03E-09						
XE-133M	2.62E-08	1.10E-08	1.68E-08	2.66E-08	3.92E-10	1.63E-09	3.15E-09
XE-133	3.29E-06	1.46E-06	1.96E-06	5.75E-06	7.18E-07	1.87E-07	1.52E-06
XE-135M	6.86E-06	1.51E-06	4.38E-06	3.02E-06	8.77E-07	7.73E-07	4.10E-07
XE-135	8.10E-06	2.18E-06	3.84E-06	2.40E-06	7.35E-07	7.41E-07	4.10E-07
XE-138	3.93E-05	6.93E-06	2.11E-05 1.71E-05	5.83E-06	4.74E-06	2.52E-06	
AG-110M				1.10E-10			
BA-139							1.39E-13
BA-140			8.12E-12				
CD-109	2.12E-09	3.00E-10	5.43E-08				
CE-141	5.05E-13						
CE-144		4.86E-09			9.33E-10		9.38E-12
CO-57	1.11E-11		1.33E-15	5.98E-13		6.51E-11	2.54E-11
CO-58	7.48E-09	6.33E-10	4.81E-09	1.71E-09	8.05E-09	1.30E-09	1.83E-10
CO-60	7.56E-08	1.06E-07	1.12E-08	3.47E-07	1.55E-07	3.39E-09	1.01E-07
CR-51					8.38E-10		1.20E-14
CS-134	2.81E-07	2.26E-07	1.40E-08	1.73E-08			2.62E-07
CS-136							
CS-137	9.57E-07	7.00E-08	7.33E-08	1.60E-07	5.00E-07	4.55E-08	4.52E-07
CS-138	5.74E-13	1.14E-12	1.10E-09	7.50E-14	2.05E-12		1.14E-08
F-18		5.14E-12	1.20E-10	1.84E-11	1.58E-10	5.24E-12	3.14E-10
FE-59							3.31E-13
MN-54	9.48E-11	8.10E-11		2.31E-09			
M0-99			1.73E-13	6.45E-13			
NA-24	9.46E-10		2.94E-09	2.92E-09			
NB-95	6.00E-11	1.83E-11	1.42E-11	1.49E-12		2.28E-14	
NB-97				7.62E-15			7.86E-16
RB-88	2.45E-11	1.83E-11	5.45E-09	2.12E-12	9.58E-12		8.57E-08
RB-89					1.02E-15		
RU-103	1.01E-12	1.00E-09					
SB-125	8.50E-12		2.50E-10	6.39E-12			
SN-113	1.29E-12			2.86E-14			
SR-89	1.16E-11	3.67E-10	1.83E-10	8.83E-10			
SR-90			1.33E-12	3.41E-08			
SR-91							
TC-99M			1.02E-14	3.49E-14	1.47E-13		
TC-101							
TE-132				1.62E-10	3.88E-12		1.24E-10
Y-88			2.03E-14				
ZN-65				1.10E-09			
ZR-95	1.56E-10			4.24E-13		8.85E-14	
ZR-97	7.07E-15						

TABLE B-2 (continued)

FRACTIONAL MEC FOR ATMOSPHERIC EFFLUENT

NUCLIDE	1985	1986	1987	1988	1989	1990	1991
I-131	8.19E-07	2.64E-07	7.33E-07	1.29E-07	7.57E-08	1.87E-08	8.24E-08
I-132	8.93E-09	4.26E-09	5.76E-09	1.14E-09	1.00E-10	2.60E-11	7.02E-11
I-133	6.52E-08	3.24E-08	1.45E-07	7.29E-08	5.67E-08	5.38E-09	5.38E-09
I-134	1.06E-11		7.40E-10				
I-135	4.60E-09	8.65E-10	1.74E-08	7.29E-10	1.00E-10	2.50E-13	1.25E-10
TOTALFRAC	1.49E-04	8.29E-05	1.20E-04	1.11E-04	8.83E-05	7.62E-05	6.67E-05
TOTAL-H3	1.17E-04	2.57E-05	6.34E-05	5.13E-05	2.07E-05	1.52E-05	1.29E-05
EFF MEC	5.84E-08	8.49E-08	6.62E-08	8.85E-08	8.46E-08	8.50E-08	9.50E-08
W/O H-3	3.70E-08	1.60E-08	1.92E-08	3.46E-08	8.10E-09	5.02E-09	1.44E-08

APPENDIX C

CALCULATION OF TOTAL DOSE FACTORS

USING

REGULATORY GUIDE 1.109, REV. 1

C1.0 CALCULATION OF TOTAL DOSE FACTORS USING REGULATORY GUIDE 1.109 METHODOLOGY

C1.1 Liquid Release Dose Factors

The equations and values used to calculate the total dose to the maximum exposed individual for each of the liquid release mode pathways evaluated according to Regulatory Guide 1.109, Rev. 1, 1977 methodology is shown below. The total dose factor in mrem/Ci released is the sum of all pathway doses in mrem/Ci for the following pathways: milk, meat, fish, potable water, and shoreline deposits. The results for an organ is summed for each pathway and the total presented by age group and target organ in a matrix format for each radionuclide in Section 5, Table 5.1.1. The derivation of dilution factors used in the calculations is presented in Appendix D. The highest dose in each matrix is used as the dose tracking factor to be used for the monthly tracking of release doses. These values are found in Section 5, Table 5.2.

C1.1.1 Aquatic Foods

The dose from the eating of fresh fish caught at the edge of the initial mixing zone was calculated using the equation:

$$Dose_{apj} = 1100\frac{M_p U_{ap}}{F} \sum_i Q_i B_{ip} D_{aipj} e^{-\lambda_i t_p}$$

where:

$Dose_{apj}$ = the dose to the organ j of an individual of age group a from all of the nuclides i in pathway p, in mrem/year;

1100 = a factor to convert from Ci-sec/yr-ft^3 to pCi/liter;

M_p = the mixing ratio (reciprocal of the dilution factor) at the point of harvest of aquatic food, dimensionless;

U_{ap} = a usage factor that specifies the intake rate for an individual of age group a associated with pathway p, in kg/year;

F = the flow rate of the liquid effluent, in ft^3/sec;

Q_i = the release rate of nuclide i, in Ci/year;

B_{ip} = the equilibrium bioaccumulation factor for nuclide i in pathway p, expressed as the ratio of the concentration in biota (in pCi/kg) to the radionuclide concentration in water (in pCi/l), in liters/kg;

D_{aipj} = the dose factor, specific to a given age group a, nuclide i, pathway p, and organ j, which is used to calculate the radiation dose from an intake of a nuclide, in mrem/pCi;

λ_i = the radioactive decay constant of nuclide i, in day^{-1};

t_p = the average transit time required for nuclides to reach the point of exposure. For internal dose, t_p is the total time elapsed between release of the nuclides and the ingestion of the water, in days.

To calculate the dose per curie released, the equation above was rearranged and the calculation performed for each nuclide. The rearranged equation is shown below:

$$\frac{Dose_{aipj}}{Q_i} = 1100\frac{M_pU_{ap}}{F}B_{ip}D_{aipj}e^{-\lambda_i t_p}$$

The values used in the equation above are:

M_p = 0.1136 (Point of harvest of the fresh fish is taken at a point 1000 m downstream. The plume centerline dilution factor at this location is 8.8 using RG 1.111 methodology. The dilution factor calculations are attached. The factor of 2 allowed for current reversals was not used.);

U_{ap} = Infant - 0, Child - 6.9, Teen - 16, and Adult - 21 kg/year;

F = 1507 ft^3/sec. (677000 gpm);

B_{ip} = Values used are taken from Table A-1 of RG 1.109;

D_{aipj} = Values used are taken from Tables E-11 through E-14 of RG 1.109;

t_p = 0.5 days.

C1.1.2 Irrigated Foods (Meat From Watered Cattle)

The dose from the ingestion of meat from cattle which have been given contaminated water was calculated using the equation:

$$Dose_{apj} = 1100\frac{M_pU_{ap}Q_{Aw}}{F}\sum_i Q_iF_{iA}D_{aipj}e^{-\lambda_i t_s}$$

where:

$Dose_{apj}$ = the dose to the organ j of an individual of age group a from all of the nuclides i in pathway p, in mrem/year;

1100 = factor to convert from Ci-sec/yr-ft^3 to pCi/liter;

M_p = the mixing ratio (reciprocal of the dilution factor) at the point of exposure, dimensionless;

U_{ap} = a usage factor that specifies the intake rate for an individual of age group a associated with pathway p, in kg/year;

Q_{Aw} = consumption rate of contaminated water by an animal, in liters/day;

F = the flow rate of the liquid effluent, in ft^3/sec;

Q_i = the release rate of nuclide i, in Ci/year;

F_{iA} = the stable element transfer coefficient that relates the daily intake rate by an animal to the concentration in an edible portion of animal product, in pCi/liter of meat per pCi/day;

D_{aipj} = the dose factor, specific to a given age group a, nuclide i, pathway p, and organ j, which is used to calculate the radiation dose from an intake of a nuclide, in mrem/pCi;

λ_i = the radioactive decay constant of nuclide i, in day^{-1};

t_s = the average time from slaughter to consumption, in days.

To calculate the dose per curie released, the equation above was rearranged and the calculation performed for each nuclide. The rearranged equation is shown below:

$$\frac{Dose_{aipj}}{Q_i} = 1100\frac{M_p U_{ap} Q_{Aw}}{F} F_{iA} D_{aipj} e^{-\lambda_i t_s}$$

The values used in the equation above are:

M_p = 0.1111 (Point at which water is taken from the lake is taken as plume centerline 1 mile downstream. The plume centerline dilution factor at this location is 9 using RG 1.111 methodology.);

U_{ap} = Infant - 0, Child - 41, Teen - 65, and Adult - 110 kg/year;

Q_{Aw} = 60 liters/day;

F = 1507 ft^3/sec. (677000 gpm);

F_{iA} = Values used are taken from Table E-1 of RG 1.109;

D_{aipj} = Values used are taken from Tables E-11 through E-14 of RG 1.109;

t_s = 20 days.

C1.1.3 Irrigated Foods (Milk From Watered Cattle)

The dose from the ingestion of milk from cows which have been given contaminated water was calculated using the equation:

$$Dose_{apj} = 1100\frac{M_p U_{ap} Q_{Aw}}{F} \sum_i Q_i F_{iA} D_{aipj} e^{-\lambda_i t_f}$$

where:

$Dose_{apj}$ = the dose to the organ j of an individual of age group a from all of the nuclides i in pathway p, in mrem/year;

1100 = factor to convert from Ci-sec/yr-ft^3 to pCi/liter;

M_p = the mixing ratio (reciprocal of the dilution factor) at the point of exposure, dimensionless;

U_{ap} = a usage factor that specifies the intake rate for an individual of age group a associated with pathway p, in liters/year;

Q_{Aw} = consumption rate of contaminated water by an animal, in liters/day;

F = the flow rate of the liquid effluent, in ft^3/sec;

Q_i = the release rate of nuclide i, in Ci/year;

F_{iA} = the stable element transfer coefficient that relates the daily intake rate by an animal to the concentration in an edible portion of animal product, in pCi/liter of milk per pCi/day;

D_{aipj} = the dose factor, specific to a given age group a, nuclide i, pathway p, and organ j, which is used to calculate the radiation dose from an intake of a nuclide, in mrem/pCi;

λ_i = the radioactive decay constant of nuclide i, in day^{-1};

t_f = the average transport time of the activity from the feed into the milk and to the receptor, in days.

To calculate the dose per curie released, the equation above was rearranged and the calculation performed for each nuclide. The rearranged equation is shown below:

$$\frac{Dose_{aipj}}{Q_i} = 1100\frac{M_p U_{ap} Q_{Aw}}{F} F_{iA} D_{aipj} e^{-\lambda_i t_f}$$

The values used in the equation above are:

M_p = 0.1111 (Point at which water is taken from the lake is taken as plume centerline 1 mile downstream. The plume centerline dilution factor at this location is 9 using RG 1.111 methodology. the dilution factor calculations are attached. The factor of 2 allowed for current reversals was not used. This is a conservative assumption.);

U_{ap} = Infant - 330, Child - 330, Teen - 400, and Adult - 310 liters/year;

Q_{Aw} = 60 liters/day;

F = 1507 ft^3/sec. (677000 gpm);

F_{iA} = Values used are taken from Table E-1 of RG 1.109;

D_{aipj} = Values used are taken from Tables E-11 through E-14 of RG 1.109;

t_f = 2 days.

C1.1.4 Potable Water

The dose from ingestion of water was calculated using the equation:

$$Dose_{apj} = 1100 \frac{M_p U_{ap}}{F} \sum_i Q_i D_{aipj} e^{-\lambda_i t_p}$$

where:

$Dose_{apj}$ = the dose to the organ j of an individual of age group a from all of the nuclides i in pathway p, in mrem/year;

1100 = a factor to convert from Ci-sec/yr-ft^3 to pCi/liter;

M_p = the mixing ratio (reciprocal of the dilution factor) at the point of withdrawal of drinking water, dimensionless;

U_{ap} = a usage factor that specifies the intake rate for an individual of age group a associated with pathway p, in l/year;

F = the flow rate of the liquid effluent, in ft^3/sec;

Q_i = the release rate of nuclide i, in Ci/year;

D_{aipj} = the dose factor, specific to a given age group a, nuclide i, pathway p, and organ j, which is used to calculate the radiation dose from an intake of a nuclide, in mrem/pCi;

λ_i = the radioactive decay constant of nuclide i, in day^{-1};

t_p = the average transit time required for nuclides to reach the point of exposure. For internal dose, t_p is the total time elapsed between release of the nuclides and the ingestion of the water, in days.

To calculate the dose per curie released, the equation above was rearranged and the calculation performed for each nuclide. The rearranged equation is shown below:

$$\frac{Dose_{aipj}}{Q_i} = 1100\frac{M_p U_{ap}}{F} D_{aipj} e^{-\lambda_i t_p}$$

The values used in the equation above are:

M_p = 0.0384 (Withdrawal point is taken as the Two Rivers municipal water intake located a distance of 12 miles downstream. The plume centerline dilution factor at this location is 26 using RG 1.111 methodology and the factor of 2 allowed for current reversals. The dilution factor calculations are attached.);

U_{ap} = Infant - 330, Child - 510, Teen - 510, and Adult - 730 liters/year;

F = 1507 ft^3/sec. (677000 gpm);

D_{aipj} = Values used are taken from Tables E-11 through E-14 of RG 1.109

t_p = 2 days (This was calculated using a current speed of 12.2 cm/s plus 12 hours to reflect the transport of the water through the water purification plant and distribution system.)

C1.1.5 Shoreline Deposits

The dose from exposure to radioactive materials deposited on the shoreline of the lake was calculated using the equation:

$$Dose_{apj} = 110000 \frac{M_p U_{ap} W}{F} \sum_i Q_i T_i D_{aipj} e^{-\lambda_i t_p}(1 - e^{-\lambda_i t_b})$$

where:

$Dose_{apj}$ = the dose to the organ j of an individual of age group a from all of the nuclides i in pathway p, in mrem/year;

110000 = a factor to convert from Ci-sec/yr-ft^3 to pCi/liter and to account for the proportionality constant used in the sediment radioactivity model;

M_p = the mixing ratio (reciprocal of the dilution factor) at the point of exposure, dimensionless;

U_{ap} = a usage factor that specifies the exposure time for an individual of age group a associated with pathway p, in hours/year;

W = shoreline width factor, dimensionless;

F = the flow rate of the liquid effluent, in ft^3/sec;

Q_i = the release rate of nuclide i, in Ci/year;

T_i = the radioactive half life of nuclide i, in days;

D_{aipj} = the dose factor, specific to a given age group a, nuclide i, pathway p, and organ j, which is used to calculate the radiation dose from an intake of a nuclide, in mrem/pCi;

λ_i = the radioactive decay constant of nuclide i, in day^{-1};

t_p = the average transit time required for nuclides to reach the point of exposure. For internal dose, t_p is the total time elapsed between release of the nuclides and the ingestion of the water, in days;

t_b = the period of time for which the sediment or soil is exposed to the contaminated water, in days.

To calculate the dose per curie released, the equation above was rearranged and the calculation performed for each nuclide. The rearranged equation is shown below:

$$\frac{Dose_{aipj}}{Q_i} = 110000\frac{M_p U_{ap} W}{F} B_{ip} T_i D_{aipj} e^{-\lambda_i t_p}\left(1 - e^{-\lambda_i t_b}\right)$$

The values used in the equation above are:

M_p = 0.01821 (Point of exposure is taken as the Point Beach State Park beach which is located 8000 meters downstream. The plume shoreline dilution factor at this location is 54.9 using RG 1.111 methodology. The dilution factor calculations are attached. The factor of 2 allowed for current reversals was not used.);

U_{ap} = Infant - 0, Child - 14, Teen - 67, and Adult - 12 hours/year;

W = 0.3;

B_{ip} = Values used are taken from Table A-1 of RG 1.109;

F = 1507 ft^3/sec. (677000 gpm);

D_{aipj} = Values used are taken from Table E-6 of RG 1.109;

t_p = 0.5 day;

t_b = 5458 days.

C1.2 Atmospheric Release Dose Factors: Non-Gaseous

The equations and values used to calculate the total dose to the maximum exposed individual factors for non-gaseous radionuclides released to the atmosphere using Regulatory Guide 1.109, Rev. 1, 1977 is shown below. The total dose factor in mrem/Ci released is the sum of all airborne effluent doses in mrem/Ci for the following pathways: milk, meat, leafy vegetables, potable water, and shoreline deposits. A summary of totals is presented by age group and target organ in matrix format for each radionuclide in Section 5, Table 5-1. The highest dose in each matrix is used as the dose tracking factor to be used for the monthly tracking of release doses. These values are found in Section 5, Table 5-2.

C1.2.1 Inhalation of Nuclides In Air

The dose from the inhalation of nuclides in the air was calculated using the equation:

$$Dose_{ja} = 3.17E+04 R_a \left(\frac{\chi}{Q}\right) \sum_i Q_i DFI_{ija}$$

where:

$Dose_{ja}$ = the annual dose to organ j of an individual of age group a due to inhalation, in mrem/year;

3.17E+04 = the number of pCi/Ci divided by the number of sec/year;

R_a = the annual air intake for individuals in the age group a, in m^3/year;

χ/Q = the annual average atmosphere dispersion factor, in sec/m^3 (The location at which the dose was calculated was the site boundary in the south sector - a distance of 1270 meters.);

Q_i = the release rate of nuclide i, in Ci/year;

DFI_{ija} = the inhalation dose factor for radionuclide i, organ j, and age group a, mrem/pCi.

To calculate the dose per curie released, the equation above was rearranged and the calculation performed for each nuclide. The rearranged equation is shown below:

$$\frac{Dose_{ija}}{Q_i} = 3.17E+04\ R_a \left(\frac{\chi}{Q}\right) DFI_{ija}$$

The values used in the equation above are:

R_a = Infant - 1400, Child - 3700, Teen - 8000, and Adult - 8000 m^3/year;

χ/Q = 9.36E-07 seconds/m^3 (This value taken from Table I.4-2 of the FSAR, release mode 1B, annual average, site boundary.);

DFI_{ija} = Values used are taken from Tables E-7 through E-10 of RG 1.109.

C1.2.2 Annual Organ Dose From External Irradiation From Nuclides Deposited On the Ground

The organ dose from external irradiation from nuclides deposited on the ground was calculated using the equation:

$$Dose_j = 1E+12\ (8760)\ \delta_i\ S_F \sum_i \frac{Q_i\left(1 - e^{-\lambda_i t_b}\right)}{\lambda_i} DFG_{ij}$$

where:

$Dose_j$ = the annual dose to the organ j, in mrem/year;

1E+12 = the number of pCi per Ci;

8760 = the number of hours in a year;

δ_i = the annual average relative deposition of nuclide i, considering depletion of the plume during transport, in m^{-2}, (The location at which the dose is calculated is the site boundary in the south sector - a distance of 1300 meters.);

S_F = the attenuation factor that accounts for the dose reduction due to shielding provided by residential structures, dimensionless;

Q_i = the release rate of nuclide i, in Ci/year;

λ_i = the radioactive decay constant of nuclide i, in day^{-1};

t_b = the time period over which the accumulation is evaluated, in days;

DFG_{ij} = the open field ground plane dose conversion factor for organ j from nuclide i, in mrem-m^2/pCi-hour.

To calculate the dose per curie released, the equation above was rearranged and the calculation performed for each nuclide. The rearranged equation is shown below:

$$\frac{Dose_{ij}}{Q_i} = 1E{+}12\ (8760)\ \delta_i\ S_F \frac{\left(1 - e^{-\lambda_i t_b}\right)}{\lambda_i} DFG_{ij}$$

The values used in the equation above are:

δ_i = 31E-09 m^{-2} (This value taken from Table I.4-2 of the FSAR, release mode 1B, annual average, site boundary.);

S_F = 1 (No structural shielding is assumed.);

t_b = 5479 days (15 years);

DFG_{ij} = Values used are taken from Table E-6 of RG 1.109.

C1.2.3 Annual Organ Dose From Atmospherically Released Nuclides In Milk

The organ dose from atmospherically released nuclides in milk was calculated using the equation:

$$Dose_{ja} = 2.7E{+}09\ U_a Q_F \delta_i \sum_i Q_i F_{im} DFI_{ija} e^{-\lambda_i t_f} \left\{ f_p f_s + e^{-90\lambda_i}(1 - f_p f_s) \right\} \times \left\{ \frac{r(1 - e^{-\lambda_{Ei} t_e})}{Y_V \lambda_{Ei}} + \frac{B_{iv}(1 - e^{-\lambda_i t_b})}{P \lambda_i} \right\}$$

where:

$Dose_{ja}$ = the annual dose to the organ j of an individual in age group a from a dietary intake of atmospherically released nuclides, in mrem/year;

2.7E+09* = the number of pCi per Ci divided by the number of days per year;

U_a = the ingestion rate of milk for individuals in age group a, in liters/year;

Q_F = the amount of feed consumed by a cow per, in kg/day;

δ_i = the annual average relative deposition of nuclide i, considering depletion of the plume during transport, in m^{-2}, (The location at which the dose is calculated is the nearest animal location in the south-southeast sector - a distance of 1300 meters.);

Q_i = the release rate of nuclide i, in Ci/year;

λ_i = the radioactive decay constant of nuclide i, in day^{-1};

t_b = the time period over which the accumulation is evaluated, in days;

DFI_{ija} = the dose conversion factor for the ingestion of nuclide i, organ j, and age group a, in mrem/pCi;

F_{im} = the average fraction of the animal's daily intake of nuclide i which appears in each liter of milk, in days/liter;

t_f = the average transport time of the activity from the feed into the milk and to the receptor, in days;

f_p = the fraction of the year that the animals graze on pasture, dimensionless;

f_s = the fraction of the daily feed that is pasture grass when the animal grazes on pasture, dimensionless;

r	=	the fraction of the deposited activity retained on crops, dimensionless;
λ_{Ei}	=	the effective removal rate constant for nuclide i from crops, in days^{-1}, where $\lambda_{Ei} = \lambda_i + \lambda_w$, and λ_w is the removal rate constant for physical loss by weathering;
λ_w	=	0.0504 day^{-1};
t_e	=	the time period that crops are exposed to contamination during the growing season, in days;
Y_V	=	the agricultural productivity, in kg (wet weight)/m^2;
B_{iv}	=	the concentration factor for the uptake of nuclide i in pathway p, expressed as the ratio of the concentration in biota (in pCi/kg) to the nuclide concentration in water (in pCi/liter), in liters/kg;
P	=	the effective surface density for soil, in kg (dry soil)/m^2.

* For iodines, this factor is changed to 1.4E+09.

To calculate the dose per curie released, the equation above was rearranged and the calculation performed for each nuclide. The rearranged equation is shown below:

$$\frac{Dose_{ija}}{Q_i} = 2.7E{+}9\ U_a Q_F \delta_i \sum_i F_{im} DFI_{ija} e^{-\lambda_i t_f} \left\{f_p f_s + e^{-90\lambda_i}(1 - f_p f_s)\right\} \times \left\{\frac{r\left(1 - e^{-\lambda_{Ei} t_e}\right)}{Y_V \lambda_{Ei}} + \frac{B_{iv}\left(1 - e^{-\lambda_i t_b}\right)}{P\lambda_i}\right\}$$

The values used in the equation above are:

U_a = Infant - 330, Child - 330, Teen - 400, and Adult - 310 liters/year;

Q_F = 50 kg/day;

δ_i = 18.8E-09 m^{-2} (This value taken from Table I.4-2 of the FSAR, release mode 1B, grazing season, site boundary.);

F_{im} = Values used are taken from Table E-1 of RG 1.109;

DFI_{ija} = Values used are taken from Tables E-11 through E-14 of RG 1.109;

t_f = 2 days;

f_p = 0.5;

f_s = 0.5;

r = 0.25, 1.0 for iodines, and 0.20 for noble gases, tritium, and carbon-14;

t_e = 30 days;

Y_V = 0.7 kg/m^2;

B_{iv} = Values used are taken from Table E-1 of RG 1.109;

P = 240 kg/m^2;

t_b = 5458 days (15 years).

C1.2.4 Annual Organ Dose From Atmospherically Released Nuclides In Meat

The organ dose from atmospherically released nuclides in meat was calculated using the equation:

$$\text{Dose}_{ja} = 2.7E{+}9\ U_a Q_F \delta_i \sum_i Q_i F_{if} DFI_{ija} e^{-\lambda_i t_s} \left\{ f_p f_s + e^{-90\lambda_i}(1 - f_p f_s) \right\} \times \left\{ \frac{r\left(1 - e^{-\lambda_{Ei} t_e}\right)}{Y_V \lambda_{Ei}} + \frac{B_{iv}\left(1 - e^{-\lambda_i t_b}\right)}{P\lambda_i} \right\}$$

where:

Dose_{ja} = the annual dose to the organ j of an individual in age group a from a dietary intake of atmospherically released nuclides, in mrem/year;

2.7E+9* = the number of pCi per Ci divided by the number of days per year;

U_a = the ingestion rate of meat for individuals in age group a, in liters/year;

Q_F = the amount of feed consumed by a cow per, in kg/day;

δ_i = the annual average relative deposition of nuclide i, considering depletion of the plume during transport, in m^{-2}, (The location at which the dose is calculated is the nearest animal location in the south-southeast sector - a distance of 1300 meters.);

Q_i = the release rate of nuclide i, in Ci/year;

λ_i = the radioactive decay constant of nuclide i, in day^{-1};

t_b = the time period over which the accumulation is evaluated, in days;

DFI_{ija} = the dose conversion factor for the ingestion of nuclide i, organ j, and age group a, in mrem/pCi;

F_{if} = the average fraction of the animal's daily intake of nuclide i which appears in each kilogram of flesh, in days/kg;

t_s = the average time from slaughter to consumption, in days;

f_p = the fraction of the year that the animals graze on pasture, dimensionless;

f_s = the fraction of the daily feed that is pasture grass when the animal grazes on pasture, dimensionless;

r = the fraction of the deposited activity retained on crops, dimensionless;

λ_{Ei} = the effective removal rate constant for nuclide i from crops, in days^{-1}, where $\lambda_{Ei} = \lambda_i + \lambda_w$, and λ_w is the removal rate constant for physical loss by weathering;

t_e = the time period that crops are exposed to contamination during the growing season, in days;

Y_V = the agricultural productivity, in kg (wet weight)/m^2;

B_{iv} = the concentration factor for the uptake of nuclide i in pathway p, expressed as the ratio of the concentration in biota (in pCi/kg) to the nuclide concentration in water (in pCi/liter), in liters/kg;

P = the effective surface density for soil, in kg (dry soil)/m^2.

* For iodines, this factor is changed to 1.4E+09.

To calculate the dose per curie released, the equation above was rearranged and the calculation performed for each nuclide. The rearranged equation is shown below:

$$\frac{Dose_{ija}}{Q_i} = 2.7E{+}9\ U_a Q_F \delta_i \sum_i F_{if} DFI_{ija} e^{-\lambda_i t_s} \left\{ f_p f_s + e^{-90\lambda_i}(1 - f_p f_s) \right\} \times \left\{ \frac{r(1 - e^{-\lambda_{Ei} t_e})}{Y_V \lambda_{Ei}} + \frac{B_{iv}(1 - e^{-\lambda_i t_b})}{P \lambda_i} \right\}$$

The values used in the equation above are:

U_a = Infant - 0, Child - 41, Teen - 65, and Adult - 110 kg/year;

Q_F = 50 kg/day;

δ_i = 18.8E-09 m^{-2} (This value taken from Table I.4-2 of the FSAR, release mode 1B, grazing season, site boundary.);

F_{if} = Values used are taken from Table E-1 of RG 1.109;

DFI_{ija} = Values used are taken from Tables E-11 through E-14 of RG 1.109;

t_s = 20 days;

f_p = 0.5;

f_s = 1.0;

r = 0.25, 1.0 for iodines, and 0.20 for noble gases, tritium, and carbon-14;

t_e = 30 days;

B_{iv} = Values used are taken from Table E-1 of RG 1.109;

Y_V = 0.7 kg/m^2;

P = 240 kg/m^2;

λ_w = 0.0504 day^{-1};

t_b = 5458 days (15 years).

C1.2.5 Annual Organ Dose From Atmospherically Released Nuclides In Produce

The organ dose from atmospherically released nuclides in produce was calculated using the equation:

$$\text{Dose}_{ja} = 2.7\text{E+9}\ U_a f_g \delta_i \sum_i Q_i DFI_{ija} e^{-\lambda_i t_h} \left\{ \frac{r\left(1 - e^{-\lambda_{Ei} t_e}\right)}{Y_V \lambda_{Ei}} + \frac{B_{iv}\left(1 - e^{-\lambda_i t_b}\right)}{P \lambda_i} \right\}$$

where:

Dose_{ja} = the annual dose to the organ j of an individual in age group a from a dietary intake of atmospherically released nuclides, in mrem/year;

2.7E+9* = the number of pCi per Ci divided by the number of days per year;

U_a = the ingestion rate of produce for individuals in age group a, in kg/year;

f_g = fraction of produce ingested grown in garden of interest, dimensionless;

δ_i = the annual average relative deposition of nuclide i, considering depletion of the plume during transport, in m^{-2}, (The location at which the dose is calculated is the nearest garden location in the south-southwest sector - a distance of 1460 meters.);

Q_i = the release rate of nuclide i, in Ci/year;

λ_i = the radioactive decay constant of nuclide i, in day^{-1};

t_b = the time period over which the accumulation is evaluated, in days;

DFI_{ija} = the dose conversion factor for the ingestion of nuclide i, organ j, and age group a, in mrem/pCi;

t_h = the holdup time that represents the time interval between harvest and consumption of the food, in days;

r = the fraction of the deposited activity retained on crops, dimensionless;

λ_{Ei} = the effective removal rate constant for nuclide i from crops, in $days^{-1}$, where $\lambda_{Ei} = \lambda_i + \lambda_w$, and λ_w is the removal rate constant for physical loss by weathering;

t_e = the time period that crops are exposed to contamination during the growing season, in days;

Y_V = the agricultural productivity, in kg (wet weight)/m^2;

B_{iv} = the concentration factor for the uptake of nuclide i in pathway p, expressed as the ratio of the concentration in biota (in pCi/kg) to the nuclide concentration in water (in pCi/liter), in liters/kg;

P = the effective surface density for soil, in kg (dry soil)/m^2.

* For iodines, this factor is changed to 1.4E+09.

To calculate the dose per curie released, the equation above was rearranged and the calculation performed for each nuclide. The rearranged equation is shown below:

$$\frac{Dose_{ija}}{Q_i} = 2.7E+9\ U_a f_g \delta_i \sum_i DFI_{ija} e^{-\lambda_i t_h} \left\{ \frac{r\left(1 - e^{-\lambda_{Ei} t_e}\right)}{Y_V \lambda_{Ei}} + \frac{B_{iv}\left(1 - e^{-\lambda_i t_b}\right)}{P\lambda_i} \right\}$$

The values used in the equation above are:

U_a = Infant - 0, Child - 520, Teen - 630, and Adult - 520 kg/year;

f_g = 0.76;

δ_i = 18.8E-09 m^{-2} (This value taken from Table I.4-2 of the FSAR, release mode 1B, growing season, site boundary.);

DFI_{ija} = Values used are taken from Tables E-11 through E-14 of RG 1.109;

t_h = 60 days;

r = 0.25, 1.0 for iodines, and 0.20 for noble gases, tritium, and carbon-14;

λ_w = 0.0504 day^{-1};

t_e = 60 days;

Y_V = 0.7 kg/m^2;

B_{iv} = Values used are taken from Table E-1 of RG 1.109;

P = 240 kg/m^2;

t_b = 5458 days (15 years).

C1.2.6 Annual Organ Dose From Atmospherically Released Nuclides In Leafy Vegetables

The organ dose from atmospherically released nuclides in leafy vegetables was calculated using the equation:

$$Dose_{ja} = 2.7E+9\ U_a f_l \delta_i \sum_i Q_i DFI_{ija} e^{-\lambda_i t_h} \left\{ \frac{r(1 - e^{-\lambda_{Ei} t_e})}{Y_V \lambda_{Ei}} + \frac{B_{iv}(1 - e^{-\lambda_i t_b})}{P \lambda_i} \right\}$$

where:

$Dose_{ja}$ = the annual dose to the organ j of an individual in age group a from a dietary intake of atmospherically released nuclides, in mrem/year;

2.7E+9* = the number of pCi per Ci divided by the number of days per year;

U_a = the ingestion rate of produce for individuals in age group a, in kg/year;

f_l = fraction of leafy vegetables ingested grown in garden of interest, dimensionless;

δ_i = the annual average relative deposition of nuclide i, considering depletion of the plume during transport, in m^{-2}, (The location at which the dose is calculated is the nearest garden location in the south-southwest sector - a distance of 1460 meters.);

Q_i = the release rate of nuclide i, in Ci/year;

λ_i = the radioactive decay constant of nuclide i, in day^{-1};

t_b = the time period over which the accumulation is evaluated, in days;

DFI_{ija} = the dose conversion factor for the ingestion of nuclide i, organ j, and age group a, in mrem/pCi;

t_h = the holdup time that represents the time interval between harvest and consumption of the food, in days;

r = the fraction of the deposited activity retained on crops, dimensionless;

λ_{Ei} = the effective removal rate constant for nuclide i from crops, in $days^{-1}$, where $\lambda_{Ei} = \lambda_i + \lambda_w$, and λ_w is the removal rate constant for physical loss by weathering;

t_e = the time period that crops are exposed to contamination during the growing season, in days;

Y_V = the agricultural productivity, in kg (wet weight)/m²;

B_{iv} = the concentration factor for the uptake of nuclide i in pathway p, expressed as the ratio of the concentration in biota (in pCi/kg) to the nuclide concentration in water (in pCi/liter), in liters/kg;

P = the effective surface density for soil, in kg (dry soil)/m².

* For iodines, this factor is changed to 1.4E+09.

To calculate the dose per curie released, the equation above was rearranged and the calculation performed for each nuclide. The rearranged equation is shown below:

$$\frac{Dose_{ija}}{Q_i} = 2.7E+9\ U_a f_l \delta_i \sum_i DFI_{ija} e^{-\lambda_i t_h} \left\{ \frac{r\left(1 - e^{-\lambda_{Ei} t_e}\right)}{Y_V \lambda_{Ei}} + \frac{B_{iv}\left(1 - e^{-\lambda_i t_b}\right)}{P \lambda_i} \right\}$$

The values used in the equation above are:

U_a = Infant - 0, Child - 26, Teen - 42, and Adult - 64 kg/year;

f_l = 1;

δ_i = 18.8E-09 m^{-2} (This value taken from Table I.4-2 of the FSAR, release mode 1B, growing season, site boundary.);

DFI_{ija} = Values used are taken from Tables E-11 through E-14 of RG 1.109;

t_h = 1 day;

r = 0.25, 1.0 for iodines, and 0.20 for noble gases, tritium, and carbon-14;

λ_w = 0.0504 day^{-1};

t_e = 60 days;

Y_V = 0.7 kg/m²;

B_{iv} = Values used are taken from Table E-1 of RG 1.109;

P = 240 kg/m²;

t_b = 5458 days (15 years).

C1.3 Atmospheric Release Dose Factors: Noble Gases

The equations and values used to calculate the total dose factors for noble gases released to the atmosphere using Regulatory Guide 1.109, Rev. 1, 1977 is shown below. The dose factor in mrem/Ci and mrad/Ci released for each radionuclide is presented in Section 5, Table 5-1.

C1.3.1 Annual Gamma and Beta Air Dose From All Noble Gas Releases

The dose from the submersion of individuals in air containing noble gases was calculated using the equation:

$$\text{Dose}^{\gamma} \text{ or } \text{Dose}^{\beta} = 3.17E+04\left(\frac{\chi}{Q}\right)\sum_{i} Q_i\left(DF_i^{\gamma} \text{ or } DF_i^{\beta}\right)$$

where:

Dose^{γ} or Dose^{β} = the annual gamma and beta air dose, in mrad/year;

3.17E+04 = the number of pCi/Ci divided by the number of sec/year;

χ/Q = the annual average atmosphere dispersion factor, in sec/m^3 (The location at which the dose was calculated was the site boundary in the south sector - a distance of 1270 meters.);

Q_i = the release rate of nuclide i, in Ci/year;

DF_i^{γ} or DF_i^{β} = the gamma and beta air dose factors for a uniform semi-infinite cloud of radionuclide i, in mrad-m^3/pCi-year.

To calculate the dose per curie released, the equation above was rearranged and the calculation performed for each nuclide. The rearranged equation is shown below:

$$\frac{\text{Dose}_i^{\gamma} \text{ or } \text{Dose}_i^{\beta}}{Q_i} = 3.17E+04\left(\frac{\chi}{Q}\right)\left(DF_i^{\gamma} \text{ or } DF_i^{\beta}\right)$$

The values used in the equation above are:

χ/Q = 9.36E-07 seconds/m^3 (This value taken from Table I.4-2 of the FSAR, release mode 1B, intermittent, annual average, site boundary.);

DF_i^{γ} or DF_i^{β} = Values used are taken from Table B-1 of RG 1.109.

C1.3.2 Annual Skin Dose From All Noble Gas Releases

The skin dose from the submersion of individuals in air containing noble gases was calculated using the equation:

$$Dose = 3.17E+04 \left(\frac{\chi}{Q}\right)\left(1.11 S_F \sum_i Q_i DF_i^{\gamma} + \sum_i Q_i DFS_i\right)$$

where:

Dose = the annual skin dose due to immersion in a semi-infinite cloud, in mrem/year;

3.17E+04 = the number of pCi/Ci divided by the number of sec/year;

1.11 = the average ratio of tissue to air energy absorption coefficients;

S_F = the attenuation factor that accounts for the dose reduction due to shielding provided by residential structures, dimensionless;

χ/Q = the annual average atmosphere dispersion factor, in sec/m^3 (The location at which the dose was calculated was the site boundary in the south sector - a distance of 1270 meters.);

Q_i = the release rate of nuclide i, in Ci/year;

DF_i^{γ} = the annual gamma air dose factor for a uniform semi-infinite cloud of nuclide i, in mrad-m^3/pCi-year;

DFS_i = the beta skin dose factor for a semi-infinite cloud of nuclide i, which includes the attenuation by 7 mg/cm^2 of skin, in mrem-m^3/pCi-year.

To calculate the dose per curie released, the equation above was rearranged and the calculation performed for each nuclide. The rearranged equation is shown below:

$$\frac{Dose_i}{Q_i} = 3.17E+04 \left(\frac{\chi}{Q}\right)\left(1.11\ S_F DF_i^{\gamma} + DFS_i\right)$$

The values used in the equation above are:

S_F = 1 (No structural shielding is assumed.);

χ/Q = 9.36E-07 seconds/m^3 (This value taken from Table I.4-2 of the FSAR, release mode 1B, annual average, site boundary.);

DF_i^{γ} = Values used are taken from Table B-1 of RG 1.109;

DFS_i = Values used are taken from Table B-1 of RG 1.109.

C1.3.3 Annual Total Body Dose From All Noble Gas Releases

The total body dose from the submersion of individuals in air containing noble gases was calculated using the equation:

$$Dose = 3.17E+04\ S_F\left(\frac{\chi}{Q}\right)\sum_i Q_i DFB_i$$

where:

Dose = the annual total body dose due to immersion in a semi-infinite cloud, in mrem/year;

3.17E+04 = the number of pCi/Ci divided by the number of sec/year;

S_F = the attenuation factor that accounts for the dose reduction due to shielding provided by residential structures, dimensionless;

χ/Q = the annual average atmosphere dispersion factor, in sec/m^3 (The location at which the dose was calculated was the site boundary in the south sector - a distance of 1270 meters.);

Q_i = the release rate of nuclide i, in Ci/year;

DFB_i = the total body dose factor for a uniform semi-infinite cloud of nuclide i, which includes the attenuation of 5 g/cm^2 of tissue, in mrem-m^3/pCi-year.

To calculate the dose per curie released, the equation above was rearranged and the calculation performed for each nuclide. The rearranged equation is shown below:

$$\frac{Dose_i}{Q_i} = 3.17E{+}04\ S_F\left(\frac{\chi}{Q}\right)DFB_i$$

The values used in the equation above are:

S_F = 1 (No structural shielding is assumed.);

χ/Q = 9.36E-07 seconds/m^3 (This value taken from Table I.4-2 of the FSAR, release mode 1B, annual average, site boundary.);

DFB_i = Values used are taken from Table B-1 of RG 1.109.

APPENDIX D

DERIVATION OF DILUTION FACTORS

USING

REGULATORY GUIDE 1.113

D1.0 LIQUID EFFLUENT DILUTION FACTOR CALCULATIONS

D1.1 Methodology

The dilution factors used for calculating the doses from liquid effluent released to Lake Michigan were calculated using the methodology of Regulatory Guide 1.113, "Estimating Aquatic Dispersion of Effluents from Accidental and Routine Reactor Releases for the Purpose of Implementing Appendix I." The parameters used in the calculation and the results of the calculation are given in Table D-1. The results are presented graphically in Figure D-1.

The centerline and shoreline values were calculated using Reg Guide 1.113 formulae 17 and 18 which apply to discharges to the Great Lakes. (The formulae are not presented here. See Section 5 of the PBNP FSAR for the formulae and origin of values used.) These results are applied as calculated for fish caught near PBNP. But for other pathways, an extra factor of two (2) is applied to account for current reversals which occur in Lake Michigan as described in the Appendix I, Section 5, of the PBNP FSAR.

TABLE D-1
SURFACE DILUTION FACTORS
LIQUID EFFLUENTS IN A LARGE LAKE

Downstream Distance (meters)	Plume Centerline	Shoreline
10	8.81	
20	8.81	
30	8.81	
40	8.81	
50	8.81	
60	8.81	
70	8.81	
80	8.81	
90	8.81	
100	8.81	
200	8.81	
300	8.81	
400	8.81	
500	8.81	
600	8.81	
700	8.81	
800	8.81	
900	8.81	
1000	8.81	122000
2000	8.86	1758
3000	9.01	401
4000	9.25	186
5000	9.53	116
6000	9.85	83.8
7000	10.2	65.9
8000	10.5	54.9
9000	10.8	47.4
10000	11.1	42.1
20000	14.0	24
30000	16.1	20.1
40000	17.7	18.7
50000	18.8	18.3
60000	19.6	18.2
70000	20.3	18.3
80000	20.9	18.6
90000	21.4	18.9
100000	21.9	19.2
200000	25.9	23.2
300000	29.2	26.9
400000	32.3	30.3
500000	35.2	33.3
600000	37.8	36.0
700000	40.2	38.6
800000	42.6	41.0
900000	44.8	43.3
1000000	46.9	45.5

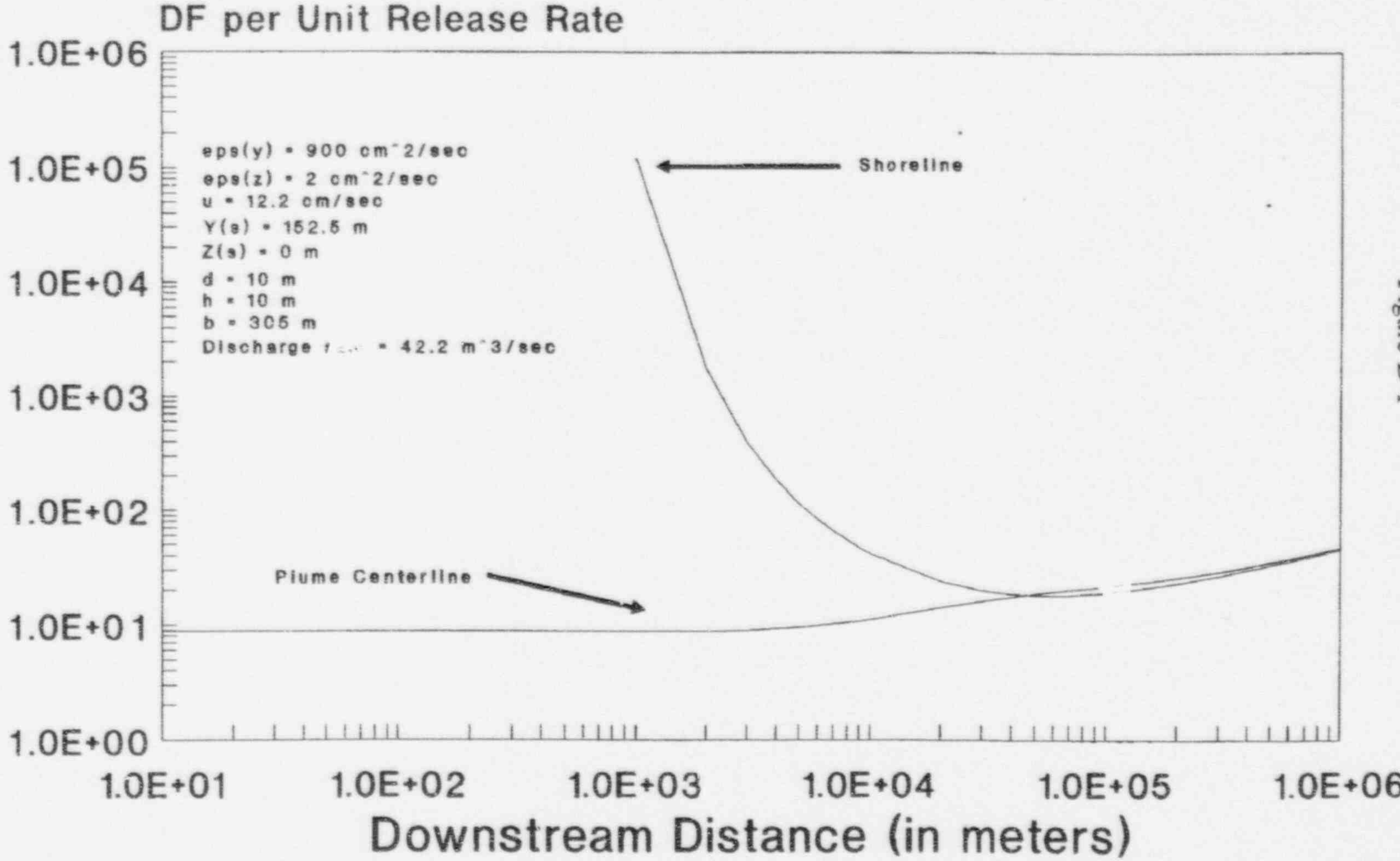
NOTE: *These values were calculated using the equation described in Secti n 5.2 of the PBNP FSAR and the following values:*

ϵ_y	=	$900\ cm^2/sec$	z_o	=	0 meters
ϵ_z	=	$2\ cm^2/sec$	d	=	10 meters
u	=	12.2 cm/sec	h	=	10 meters
$y_{\mathfrak{L}}$	=	152.5 meters	b	=	305 meters

and a discharge rate of 42.2 m^3/sec.

Dilution Factor at Surface

Liquid Effluents in a Large Lake



Area source, width 305 m and height 10 m

Figure D-1

D1.2 Dilution Factor Twelve Miles Downstream: Two Rivers Water Intake

The dilution factor used at the Two Rivers water intake twelve miles downstream from PBNP included the factor of two described in Section D1.1. However, instead of using the straight centerline dilution factor shown in Table 1, the weighted average dilution factor calculated over the width of the plume was used.

This approach was used for the following reasons. First, the path that the current takes to reach the Two Rivers water intake is not straight. In order to reach Two Rivers, the water must flow southeast around Point Beach State Park, which juts into Lake Michigan, and then curves back 90 degrees towards Two Rivers. As a result of this deviation from straight line flow, any part of the plume or possibly none of the plume would impinge upon the intake structure.

Second, there is a difference in the distance offshore of the PBNP discharge and the Two Rivers water intake. The Two Rivers water intake is located 5080 feet offshore. By contrast, PBNP discharges close to the shoreline through two flumes, one directed north and one directed south, and is modeled as a source that extends 1000 feet out into the lake from the shoreline.

Based on these two considerations, it was concluded that the weighted average dilution across the width of the plume as it diverges while flowing south would constitute a better estimate of the dilution factor instead of the calculated for the centerline of an area source as is assumed for the FSAR calculation. The calculation and the values used are shown below.

The average dilution factor at 12 miles downstream was calculated in the following manner:

1. The standard deviation of the radionuclide concentration in the y direction at 12 miles downstream on the surface of the lake was calculated. This calculation used the following formula:

$$\sigma_y = \sqrt{\frac{2 \times \epsilon_y \times x}{u}}$$

where

ϵ_y = lateral turbulent diffusion coefficient in cm^2/sec
x = the downstream distance in cm
u = current in cm/sec

Substituting the values for ϵ_y, x, and u of 900 cm^2/sec, 19308 m, and 12.2 cm/sec, respectively, into the equation yields

$$\sigma_y = \frac{\sqrt{\dfrac{2 \times 900\ \dfrac{cm^2}{sec} \times 19308\ m \times 100\ \dfrac{cm}{m}}{12.2\ \dfrac{cm}{sec}}}}{100\ \dfrac{cm}{m}} = 168.8\ \text{meters}$$

2. At distances of 0.1σ, 0.2σ, etc., off the plume centerline, the dilution factor was calculated using the equation shown in Section 5.2 of the PBNP FSAR. The distances off the plume centerline, the calculated dilution factor, and the fraction of the area under the normal distribution curve is listed below.

Distance Off Plume Centerline

Fraction of Standard Deviation	Equivalent Distance (m)	Fraction of Total Area Under the Curve for Interval	Dilution Factor
0.1σ	16.9	0.080	13.8
0.2σ	33.8	0.080	14.0
0.3σ	50.6	0.078	14.3
0.4σ	67.5	0.075	14.7
0.5σ	84.4	0.072	15.2
0.6σ	101.3	0.068	15.8
0.7σ	118.1	0.065	16.6
0.8σ	135.0	0.060	17.6
0.9σ	151.9	0.056	18.8
1.0σ	168.8	0.051	20.2
1.1σ	185.6	0.046	21.9
1.2σ	202.5	0.042	23.9
1.3σ	219.4	0.037	26.3
1.4σ	236.3	0.032	29.2
1.5σ	253.2	0.028	32.6
1.75σ	295.4	0.053	44.7
2.0σ	337.6	0.035	64.7
2.25σ	379.8	0.021	98.4
2.5σ	421.9	0.012	158.4
3.0σ	506.3	0.010	482
Totals		1.00	

* It is assumed that the standard deviation of the radionuclide concentrations across the plume can be represented by a normal distribution curve. The fraction of the total area under the curve is that fraction of the area under the curve that lies between, for example, the interval 0.1σ and 0.2σ which also includes the area of the curve in the interval -0.1σ and -0.2σ.

The average dilution factor over the width of the plume was calculated by multiplying the dilution factor at each of the locations off of the plume centerline by the fraction of the total area of the curve occupied by that interval and then summing over all the intervals. An average dilution actor of 29 was calculated.

APPENDIX E

Wisconsin Electric submittal to the United States Nuclear Regulatory Commission, dated October 8, 1987 (VPNPD-87-430, NRC-87-104)

The submittal consists of the letter and two Attachments. Attachment II contains Appendices A - G.

Wisconsin Electric POWER COMPANY
231 W MICHIGAN, P O BOX 2046, MILWAUKEE, WI 53201
(414) 277-2345

VPNPD-87-430
NRC-87-104

October 8, 1987

U.S. NUCLEAR REGULATORY COMMISSION
Document Control Desk
Washington, D.C. 20555

Gentlemen:

DOCKET NOS. 50-266 AND 50-301
RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION
FOR 10 CFR 20.302 APPLICATION
POINT BEACH NUCLEAR PLANT

On July 14, 1987, Wisconsin Electric Power Company submitted an application, under the provisions of 10 CFR 20.302, for approval of a proposed procedure to dispose of sewage treatment sludge containing minute quantities of radioactive materials. Subsequent to the application, Mr. Ted Quay of the NRC staff requested additional information regarding the environmental characteristics of the area surrounding the Point Beach Nuclear Plant. The responses to this request were furnished in our submittal dated August 6, 1987.

By letter dated September 9, 1987, the NRC has requested Wisconsin Electric supply additional information in order to complete the review of our application. This Request for Additional Information (RAI) contains ten specific items which require responses or commitments from Wisconsin Electric. In addition, the NRC requests the previously submitted information and the information supplied in response to the RAI be compiled into "one complete, extensive, and self-contained package". To facilitate your review, Attachment I is included to provide direct responses to the ten items contained in the RAI. Attachment II is provided as the complete application, including the information from our letters dated July 14, 1987, and August 6, 1987, and information supplied in response to the NRC RAI.

We request that you complete your review of this complete, self-contained package and issue an approval of our application as soon as possible. In order to facilitate your review and to expedite processing, we would be pleased to discuss these matters or provide additional information by telephone. Please feel free to contact us.

Very truly yours,

C. W. Fay
Vice President
Nuclear Power

bjm

Attachments

Copies to NRC Resident Inspector
NRC Regional Administrator, Region III

Blind copies to Britt/Gorske/Finke, Burstein, Charnoff,
Fay, Krieser, Lipke, Newton, Zach

ATTACHMENT I

RESPONSES TO QUESTIONS CONTAINED IN THE
REQUEST FOR ADDITIONAL INFORMATION (RAI)
ON POINT BEACH 1 AND 2 REQUEST
FOR DISPOSAL OF LOW LEVEL RADIOACTIVITY
CONTAMINATED SEWAGE SLUDGE BY LAND APPLICATION
WISCONSIN ELECTRIC POWER COMPANY
UNDER 10 CFR 20.302(a)

The numbering system used in these responses corresponds directly to numbering used in the NRC RAI, dated September 9, 1987.

1. a. This request is for multiple applications, approximately 2 to 4 per year.
   b. This request is for multiple years, expiration to coincide with conclusion of decommissioning activities associated with retirement of PBNP Units 1 & 2.
   c. Please refer to the response to question number 10.

2. The pathways used to determine doses to both the maximally exposed individual and the inadvertent intruder are documented in Attachment II, Appendices D and E.

   Due to the extremely low concentrations of radionuclides in the sewage sludge and the associate low doses, Wisconsin Electric will control access to the disposal sites by conditions of use defined in lease agreements with the lease. Use of the land is not controlled beyond the conditions of the lease, thereby not restraining a casual visitor from the disposal site. However continuous occupancy would be readily observed, and remedial action would be taken.

3. Information contained in previous submittals has been included in Attachment II with modifications to provide specific commitments to the NRC.

4. Please refer to the response to question number 10.

5. Site maps have been updated and are included in Attachment II, Appendix C.

6. The direct grazing of cattle on the proposed disposal sites is controlled by restrictions contained in the lease agreement.

   There will be no restrictions placed on fishermen on Lake Michigan. Calculations of doses due to all pathways associated with a release to Lake Michigan (Attachment II, Appendix E) do not indicate a need to apply restrictions to fishermen.

7. Please refer to revised site maps included in Attachment II, Appendix C. Site number 5 is located on company owned land beyond the PBNP site boundary. All other sites are within the PBNP site boundary area.

8. a. Please refer to Attachment II, Section 3.2, Disposal Procedure.
   b. Please refer to Attachment II, Section 3.2, Disposal Procedure.
   c. Please refer to Attachment II, Section 3.2, Disposal Procedure.
   d. Please refer to Attachment II, Appendix A.

9. Please refer to Attachment II, including Appendix D and Appendix E for additional pathways analyzed for this submittal. These identified pathways will be analyzed prior to all subsequent disposals to insure doses are maintained within prescribed limits, i.e., 1 mrem/year to the maximally exposed individual and 5 mrem/year to the inadvertent intruder.

10. A limiting concentration level for the sludge contained in the storage tank is discussed, in Attachment II, Appendix F. Since this application is for multiple applications over multiple years, Attachment II, Appendix F also addresses an activity limit.

ATTACHMENT II

COMPLETE ANALYSIS AND EVALUATION
POINT BEACH NUCLEAR PLANT
10 CFR 20.302(a) APPLICATION

1.0 Purpose

By this submittal Wisconsin Electric Power Company requests approval of the U.S. Nuclear Regulatory Commission for a proposed procedure to dispose of sewage treatment sludge containing trace quantities of radionuclides generated at the Point Beach Nuclear Plant. This request is submitted in accordance with the provisions of 10 CFR 20.302(a).

2.0 Waste Description

The waste involved in this disposal process consists of the residual solids remaining in solution upon completion of the aerobic digestion sewage treatment process utilized at PBNP. The PBNP sewage treatment plant is used to process waste water from the plant sanitary and potable water systems. These systems produce non-radioactive waste streams with the possible exception of wash basins located in the radiologically controlled area of the plant. These wash basins are believed to be the primary source of the extremely small quantities of radionuclides in the sludge.

The sewage sludge generated at PBNP is allowed to accumulate in the sewage plant digestor and aeration basin. Two to four times annually, depending on work activities and corresponding work force at PBNP, the volume of the sludge in the digestor and aeration basin needs to be reduced to allow continued efficient operation of the treatment facility. The total volume of sludge removed during each disposal operation is typically on the order of 15,000 gallons. The maximum capacity for the entire PBNP treatment facility and hence the maximum disposal volume is about 30,000 gallons. In the case of a maximum capacity disposal, doses would not necessarily increase in proportion to the volume, since more than one disposal site may be used.

Trace amounts of radionuclides have been identified in PBNP sludge currently being stored awaiting disposal. The radionuclides identified and their concentrations in the sludge are summarized below:

Nuclide	Concentration (μCi/cc)
Co-60	2.33E-07
Cs-137	1.50E-07

The total activity of the radionuclides in the stored sludge, based on the identified concentrations and a total volume of 15,000 gallons of sewage sludge, are as follows:

Nuclide	Activity (μCi)
Co-60	13.2
Cs-137	8.5

These concentrations and activities are consistent with expected values based on prior analyses of sewage sludge. The radionuclide concentration in the sewage sludge has remained relatively constant during sampling conducted since December 30, 1983. A detailed summary of the results of this sampling program are contained in Appendix A for your review.

In addition to monitoring for the radionuclide content of the sludge, the WDNR requires several other physical and chemical properties of the sludge to be determined. These properties are the percent total solids, percent total nitrogen, percent ammonium nitrogen, pH, percent total phosphorus, percent total potassium, cadmium, copper, lead, nickel, mercury, zinc, and boron. An example of a typical sludge sample analysis is included in Appendix B.

3.0 Disposal Method

In the context of this application, Wisconsin Electric commits to the following methodology. No distinction is made or intended between "shall" or "will", as used in the descriptions contained in this section.

3.1 Transport of Sludge

The method used to dispose of the sludge shall utilize a technique approved by the WDNR. The process of transporting the sewage sludge for disposal involves pumping the sludge from the PBNP sewage treatment plant storage tanks into a truck mounted tank. The truck mounted tank shall be required to be maintained tightly closed to prevent spillage while in transit to the disposal site. The sludge shall be transported to one or more of the six sites approved by the WDNR for land application of the sewage sludge from PBNP.

3.2 Disposal Procedure

The radionuclide concentrations in the sludge shall be determined prior to each disposal by obtaining three representative samples from each of the sludge storage tanks. The sludge contained in the sludge tanks is prevented from going septic by a process known as complete mix and continuous aeration. This process completely mixes the sludge allowing for representative samples to be obtained.

The samples shall be counted utilizing a GeLi detector and multichannel analyzer with appropriate geometry. The detection system is routinely calibrated and checked to ensure the lower limits of detection are within values specified in the Radiological Effluent Technical Specifications (RETS).

To insure the samples are representative of the overall concentration in the storage tanks, the radionuclide concentration determination for each of the three samples shall be analyzed to insure each sample is within two standard deviations of the average value of the three samples. If this criteria is not met, additional samples will be obtained and analyzed to insure a truly representative radionuclide concentration is utilized for dose calculations and concentration limit determinations. The average of all statistically valid concentration determinations will be utilized in determining the storage tank concentration values.

Prior to disposal the waste stream will be monitored to determine the physical and chemical properties of the sludge, as discussed in the last paragraph of Section 2.0, Waste Description. The results will be compared to State of Wisconsin limits to insure the sludge does not pose a chemical hazard to people or to the environment.

The radionuclides identified in the sludge, along with their respective concentrations, will be compared to concentration limits prior to disposal. The methodology discussed in Appendix F will be used in determining compliance with the proposed concentration limit. The total activity of the proposed disposal will be compared to the proposed activity limit as described in Appendix F.

If the concentration and activity limit criteria are met, the appropriate exposure pathways (as described in Appendix D) will be evaluated prior to each application of sludge. These exposures will be evaluated to insure the dose to the maximally exposed individual will be maintained less than 1 mrem/year and the dose to the inadvertent intruder is maintained less than 5 mrem/year. The exposures will be calculated utilizing the methodology used in Appendix E, including the current activity to be landspread along with the activity from all prior disposal. The remaining radioactivity from prior disposals will be corrected for radiological decay prior to performing dose calculations for the meat, milk, and vegetable ingestion pathways, the inhalation of resuspended radionuclides, and all pathways associated with a release to Lake Michigan. The residual radioactivity will be corrected for radiological decay and, if appropriate, the mixing of the radionuclides in the soil by plowing prior to performing external exposure calculations.

The sewage sludge is applied on the designated area of land utilizing the WDNR approved technique and adhering to the following requirements of WPDES Permit Number WI-0000957-3.

- Discharge to the land disposal system shall be limited so that during surface spreading all of the sludge and any precipitation falling onto or flowing onto the disposal field shall not overflow the perimeter of the system.

- Sludge shall not be land spread on land with a slope greater than 12%. During the period from December 15 through March 31 sludge shall not be land spread on land with a slope greater than 6% unless the wastes are injected immediately into the soil.

- Sludge shall not be surface spread closer than 500 feet from the nearest inhabited dwelling except that this distance may be reduced with the dwelling owner's written consent.

- Sludge shall not be spread closer than 1,000 feet from a public water supply well or 250 feet from a private water supply well.

- Sludge shall not be land spread within 200 feet of any surface water unless a vegetative buffer strip is maintained between the surface watercourse and the land spreading system, in which case a minimum separation distance of at least 100 feet is required between the system and the surface watercourse.

- Depth to groundwater and bedrock shall be greater than 3 feet from the land surface elevation during use of any site.

- Sludge shall not be land spread in a floodway.

- Sludge shall not be land spread within 50 feet of a property line road or ditch unless the sludge is incorporated with the soil, in which case a minimum separation distance of at least 25 feet is required.

- The pH of the sludge-soil mixture shall be maintained at 6.5 or higher.

- Low areas of the approved fields, subject to seasonally high groundwater levels, are excluded from the sludge application.

- Crops for human consumption shall not be grown on the land for up to one year following the application of the sludge.

- The sludge shall be plowed, disked, injected or otherwise incorporated into the surface soil layer at appropriate intervals.

The flexibility implied in the latter provision for soil incorporation is intended to allow for crops which require more than a one year cycle. For the Point Beach disposal sites, alfalfa is a common crop which is harvested for several years after a single planting. Sludge disposal on an alfalfa plot constitutes good fertilization, but the plot cannot be plowed without destroying the crop. The alfalfa in this case aids in binding the layer of sludge on the surface of the plot. At a minimum, however, plowing (or disking or other method of injection and mixing to a nominal depth of 6 inches) shall be done prior to planting any new crop, regardless of the crop.

3.3 Administrative Procedures

Complete records of each disposal will be maintained. These records will include the concentration of radionuclides in the sludge, the total volume of sludge disposed, the total activity, the plot on which the sludge was applied, the results of the chemical composition determinations, and all dose calculations.

The annual disposal rate for each of the approved land spread sites will be limited to 4,000 gallons/acre, provided WDNR chemical composition, NRC dose guidelines, and concentration and activity limits are maintained within the appropriate values.

The farmer leasing the site used for the disposal will be notified of the applicable restrictions placed on the site due to the land spreading of sewage sludge.

4.0 Evaluation of Environmental Impact

4.1 Site Characteristics

4.1.1 Site Topography

The disposal sites are located in the Town of Two Creeks in the northeast corner of Manitowoc County, Wisconsin, on the west shore of Lake Michigan about 30 miles southeast of the center of the city of Green Bay, and 90 miles NNE of Milwaukee. This site is located at longitude 87° 32.5'W and latitude 44° 17.0'N. The six sites are on property owned and controlled by Wisconsin Electric and are within or directly adjacent to the Point Beach site boundary. The sites are described below and are outlined on the map contained in Appendix C as Figure 3.

Site No. PB-01 - The approximately 15 acres located in the NE 1/4 of the NE 1/4 of Section 23, T. 21N - R. 24E.

Site No. PB-02 - The approximately 20 acres located in the SE 1/4 of the SE 1/4 of Section 14, T. 21N - R. 24E.

Site No. PB-03 - The approximately 5 acres located in the NW 1/4 of Section 24, T. 21N - R. 24E.

Site No. PB-04 - The approximately 5 acres located in the NW 1/4 of the SW 1/4 of Section 24, T. 21N - R. 24E.

Site No. PB-05 - The approximately 5 acres located in the NE 1/4 of the NW 1/4 of Section 25, T. 21N - R. 24E.

Site No. PB-06 - The approximately 5 acres located in the NE 1/4 of the SW 1/4 of Section 14, T. 21N - R. 24E.

The overall ground surface at the site of the Point Beach Nuclear Plant is gently rolling to flat with elevations varying from 5 to 60 feet above the level of Lake Michigan. Subdued knob and kettle topography is visible from aerial photographs. The land surface slopes gradually toward the lake from the higher glacial moraine areas west of the site. Higher ground adjacent to the lake, however, diverts the drainage to the north and south.

The major surface drainage features are two small creeks which drain to the north and south. One creek discharges into the lake about 1500 feet above the northern corner of the site and the other near the center of the site. During the spring, ponds of water may occupy the shallow depressions. As mentioned in Section 3.2, Disposal Procedure, these low areas are excluded from the sludge application.

A site topographic map covering details out to a 5 mile radius may be found in the FSAR at Figure 2.2-3 and is included in Appendix C as Figure 2.

The disposal of sewage sludge at these six sites will have no impact on the topography of this area.

4.1.2 Site Geology

Prior to construction of the Point Beach Nuclear Plant, an evaluation of the geological characteristics of the area in and surrounding the site was made. The geologic structure of the region is essentially simple. Gently dipping sedimentary rock strata of Paleozoic age outcrop in a horseshoe pattern around a shield of Precambrian crystalline rock which occupies the western part of the region. The site is located on the western flank of the Michigan Basin, which is a broad downwarp ringed by discontinuous outcrops of more resistant formations. The bedrock formations are principally limestones, dolomites, and sandstones with subordinate shale layers. The rocks form a succession of extensive layers that are relatively uniform in thickness. The bedrock strata dip very gently towards Lake Michigan at rates from 15 to 35 feet per mile.

The uppermost bedrock under the site is Niagara Dolomite. Bedrock does not outcrop on the site but is covered by glacial till and lake deposits. The soils contain expansive clay minerals and have moderately high base exchange capacity.

In the area of the site, the overburden soils are approximately 70 to 100 feet in thickness. Although the character of the glacial deposits may vary greatly within relatively short distances, a generalized section through the overburden soils adjacent to Lake Michigan at the site consists of the following sequence:

1. An upper layer of brown clay silt topsoil underlain with several feet of brown silty clay with layers of silty sand;

2. A layer of 20 feet of reddish-brown silty clay with some sand and gravel and occasional lenses of silt;

3. A layer of 25 feet of reddish-brown silty clay with layers of silty sand and lenses of silt;

4. A layer of 50 feet of reddish-brown silty clay with some sand and gravel, the lower portion of which contains gravels, cobbles, and boulders resting on a glacial eroded surface of Niagara dolomite bedrock.

Site drainage is poor due to the high clay content of the soil combined with the pock-marked surface. Additional information on site geology may be found in Section 2.8 of the FSAR.

The use of these sites for disposal of sewage sludge will not impact the geology of the area.

4.2 Area Characteristics

4.2.1 Meteorology

The climate of the site region is influenced by the general storms which move eastward along the northern tier of the United States and by those which move northeastward from the southwestern part of the country to the Great Lakes. This continental type of climate is modified by Lake Michigan. During spring, summer, and fall months the lake temperature differs markedly from the air temperature. Wind shifts from westerly to easterly directions produce marked cooling of day-time temperatures in spring and summer. In autumn the relatively warm water to the lake prevents night-time temperatures from falling as low as they do a few miles inland from the shoreline. Summer time temperatures exceed 90°F for six days on the average. Freezing temperatures occur 147 days and below zero on 14 days of the winter on the average. Rainfall averages about 28 inches per year with 55 percent falling in the months of May through September. Snowfall averages about 45 inches per year. Sludge spreading shall be managed such that the surface spreading together with any precipitation falling on the field shall not overflow the perimeter of the field. Additional information on site meteorology may be found in Section 2.6 of the FSAR.

There will be no impact on the meteorology of the area due to the disposal of the sewage sludge.

4.2.2 Hydrology

The dominant hydrological feature of this site is Lake Michigan, one of the largest of the Great Lakes. The normal water level in Lake Michigan is approximately 580 feet above mean sea level. In the general vicinity of the site, the 30 foot depth contour is between 1 and 1-1/2 miles offshore and the 60 foot contour is 3 to 3-1/2 miles off shore. The disposal sites are twenty or more feet above the normal lake level. There is no record that the sites have been flooded by the lake during modern times. There are no rivers or large streams which could create a flood hazard at or near the sites.

The subsurface water table at the Point Beach site has a definite slope eastward toward the lake. The gradient indicated by test drilling on the site is approximately 30 feet per mile. It is therefore extremely unlikely that any release of radioactivity on the site could spread inland. Furthermore, the rate of subsurface flow is small due to the relative impervious nature of the soil and will not promote the spread of releases. Further information on site hydrology is detailed in the PBNP FSAR Section 2.5.

There will be no adverse impact on hydrology of the area due to disposal of sewage sludge by land spreading.

4.3 Water Usage

4.3.1 Surface Water

Lake Michigan is used as the source of potable water supplies in the vicinity of the site for the cities of Two Rivers (12 miles south), Manitowoc (16 miles sourth), Sheboygan (40 miles south), and Green Bay (intake at Rostok 1 mile north of Kewaunee, 13 miles north). No other potable water uses are recorded within 50 miles of the site along the lake shore. All public water supplies drawn from Lake Michigan are treated in purification plants. The nearest surface water used for drinking other than Lake Michigan are the Fox River 30 miles NW and

Lake Winnebago 40 miles W of the site.

Lake Michigan is also utilized by various recreational activities, including fishing, swimming and boating.

There will be no impact on surface water usage due to the disposal of sewage sludge.

4.3.2 Ground Water

Ground water provides the remaining population with potable supplies. Public ground water supplies within a 20 mile radius of the site are listed in Table 2.5-3 of the FSAR. Additional wells for private use are in existence throughout the region. The location of private wells within a two mile radius of PBNP are indicated on Figure 3, Appendix C.

The potable water for use at the Point Beach Nuclear Plant is drawn from a 257 feet deep well located at the southwest corner of the plant yard. Water from this well is routinely sampled as part of the environmental monitoring program.

There will be no adverse impact on ground water usage due to the disposal of sewage sludge.

4.4 Land Usage

Manitowoc County, in which the site is located, and the adjacent counties of Kewaunee, Brown, Calumet, and Sheboygan are predominantly rural. Agricultural pursuits account for approximately 90% of the total county acreage. With the exception of the Kewaunee Nuclear Plant located 4.5 miles north, the region within a radius of five miles of the site is presently devoted exclusively to agriculture. Dairy products and livestock account for 85% of the counties' farm production, with field crops and vegetables accounting for most of the remainder. The principal crops are grain corn, silage corn, oats, barley, hay, potatoes, green peas, lima beans, snap beans, beets, cabbage, sweet corn, cucumbers, and cranberries. Within the township of Two Creeks surrounding the site (15 sq. miles), there are about 800 producing cows on about 40 dairy farms. Some beef cattle are raised 2.5 miles north of the site. Cows are on pasture from the first of June to late September or early October. During the winter, cows are fed on locally produced hay and silage. Of the milk produced in this area, about 25 percent is consumed as fluid milk and 50 percent is converted to cheese, with the remainder being used in butter making and other by-products.

It has been the policy of Wisconsin Electric to permit the controlled use of crop land and pasture land on company owned property. No direct grazing of dairy or beef cattle or other animals is permitted on these company owned properties. Crops intended for human consumption shall not be grown on the disposal sites for at least one year following the application of the sludge.

The proposed land application of sewage sludge will not have any direct effect on the adjacent facilities. Additional land use information may be found in Section 2.4 of the FSAR.

4.5 Radiological Impact

The rate of sewage sludge application on each of the six proposed sites will be monitored to insure doses are maintained within applicable limits. These limits are based on NRC Nuclear Reactor Regulation (NRR) staff proposed guidance (described in AIF/NESP-037, August, 1986). These limits require doses to the maximally exposed member of the general public to be maintained less than 1 mrem/year due to the disposal material. In addition, NRR guidance requires doses of less than 5 mrem/year to an inadvertent intruder.

To assess the doses received by the maximally exposed individual and the inadvertent intruder, six credible pathways have been identified for the maximally exposed individual and four credible pathways for the inadvertent intruder. The identified credible pathways are described in Appendix D.

Calculations detailed in Appendix E demonstrate the disposal of the currently stored PBNP sewage sludge would remain below these limits. The total annual exposure to the maximally exposed individual based on the identified exposure pathways is equal to 0.072 mrem. The dose to a hypothetical intruder assuming an overly conservative occupancy factor of 100% is calculated to be 0.115 mrem/year. By definition, the inadvertent intruder would not be exposed to the processed food pathways (meat and milk).

The calculational methodology used in determining doses for the proposed disposal of sludge stored at PBNP shall be utilized prior to each additional land application to insure doses are maintained less than those proposed by NRR. This calculation will include radionuclides disposed of in previous sludge applications. The activity from these prior disposals will be corrected for radiological decay prior to performing dose calculations for the meat, milk, and vegetable ingestion pathways, the inhalation of resuspended radionuclides, and all pathways associated with a potential release to Lake Michigan. The residual radioactivity will be corrected for radiological decay and, if applicable, the mixing of radionuclides in the soil prior to performing external exposure calculations. In addition, the dose to a farmer potentially leasing more than one application site will be addressed by summing the doses received from the external exposure from a ground plane source and resuspension inhalation pathways for each leased site. In addition, the maximum site specific dose due to the other pathways identified in Appendix D, will be utilized in the total exposure estimation.

5.0 Radiation Protection

The disposal operation will follow the applicable PBNP procedures to maintain doses as low as reasonably achievable. Technical review and guidance will be provided by the PBNP Superintendent - Health Physics.

APPENDIX A

SUMMARY OF RADIOLOGICAL ANALYSES
OF SEWAGE SLUDGE SINCE DECEMBER 30, 1983

Sample Date	Tank	Tank Volume (Gallons)	Radionuclide	Concentration (µCi/cc)
12-30-83	Digester	8400	Co-58	5.58E-07
			Co-60	1.87E-06
			Cr-51	4.88E-07
			Cs-134	1.59E-07
			Cs-137	3.57E-07
4-06-84	Digester	7560	Co-60	7.89E-07
	Aeration	6667	Co-60	1.87E-07
12-05-84	Digester	7560	Co-58	1.75E-07
	Aeration	6667	Co-60	8.29E-07
6-03-85	Digester	7560	Co-60	8.29E-07
			Cs-137	2.46E-07
	Aeration	6700	Co-60	3.27E-07
			Cs-137	1.33E-07
4-10-86	Digester	7560	Co-60	6.79E-07
			Cs-137	1.72E-07
			Mn-54	4.91E-08
			Co-60	1.65E-07
11-04-86	Digester	7560	Co-58	8.04E-08
	Aeration & Clarifier	25100	Co-58	1.37E-07
			Co-60	2.18E-07
			Cs-137	1.64E-07

APPENDIX B

CHEMICAL COMPOSITION ANALYSIS OF SEWAGE SLUDGE

STATE OF WISCONSIN
DEPARTMENT OF NATURAL RESOURCES

SLUDGE CHARACTERISTIC
Wisconsin Statute 147.02(1) and
Wisconsin Administrative Code NR 110.27(6)
FORM 3400-49 REV. 10-80

ewage Treatment Plant Sludge

. lease complete this form and send to the Department of Natural Resources appropriate District/Area Office. Keep one copy for your records.
For additional forms, please contact your appropriate District/Area Office.

PERMITTEE	WPDES PERMIT NUMBER
Wisconsin Electric Power Company	WI 00 0 0 9 5 7
STREET OR ROUTE 231 W. Michigan Street	COUNTY Milwaukee
CITY, STATE, ZIP CODE Milwaukee, WI 53203	TELEPHONE NUMBER (INCLUDE AREA CODE) 414-277-2153

1. Please report laboratory testing results for the following parameters:

*Parameter	Abbreviation	Result	*Parameter	Abbreviation	Result
Total Solids, %	–	1.63	Chromium, ppm	Cr	[illegible]
Total Nitrogen, %	TOT N	1.0	Copper, ppm	Cu	2200
Ammonium Nitrogen, %	NH_4^+–N	0.34	Lead, ppm	Pb	190
Total Phosphorous, %	P	< 0.01	Mercury, ppm	Hg	5.6
Total Potassium, %	K	0.25	Nickel, ppm	Ni	12
Arsenic, ppm	As	1.0	Zinc, ppm	Zn	2800
Cadmium, ppm	Cd	12.	pH	–	7.0

*Suggested analysis procedures for the above parameters can be found in NR 219, analytical tests and procedures, Wisconsin Administrative Code. All parameters other than percent solids and pH shall be reported on a dry weight basis.

2. What is the name of the laboratory that did the analysis and when was it performed?

Laboratory Name: Wisconsin Electric Power Co. Laboratory Services Division   Date sent to lab: April 12, 1983

Where at the treatment plant was the sample taken? From sludge holding tank prior to hauling

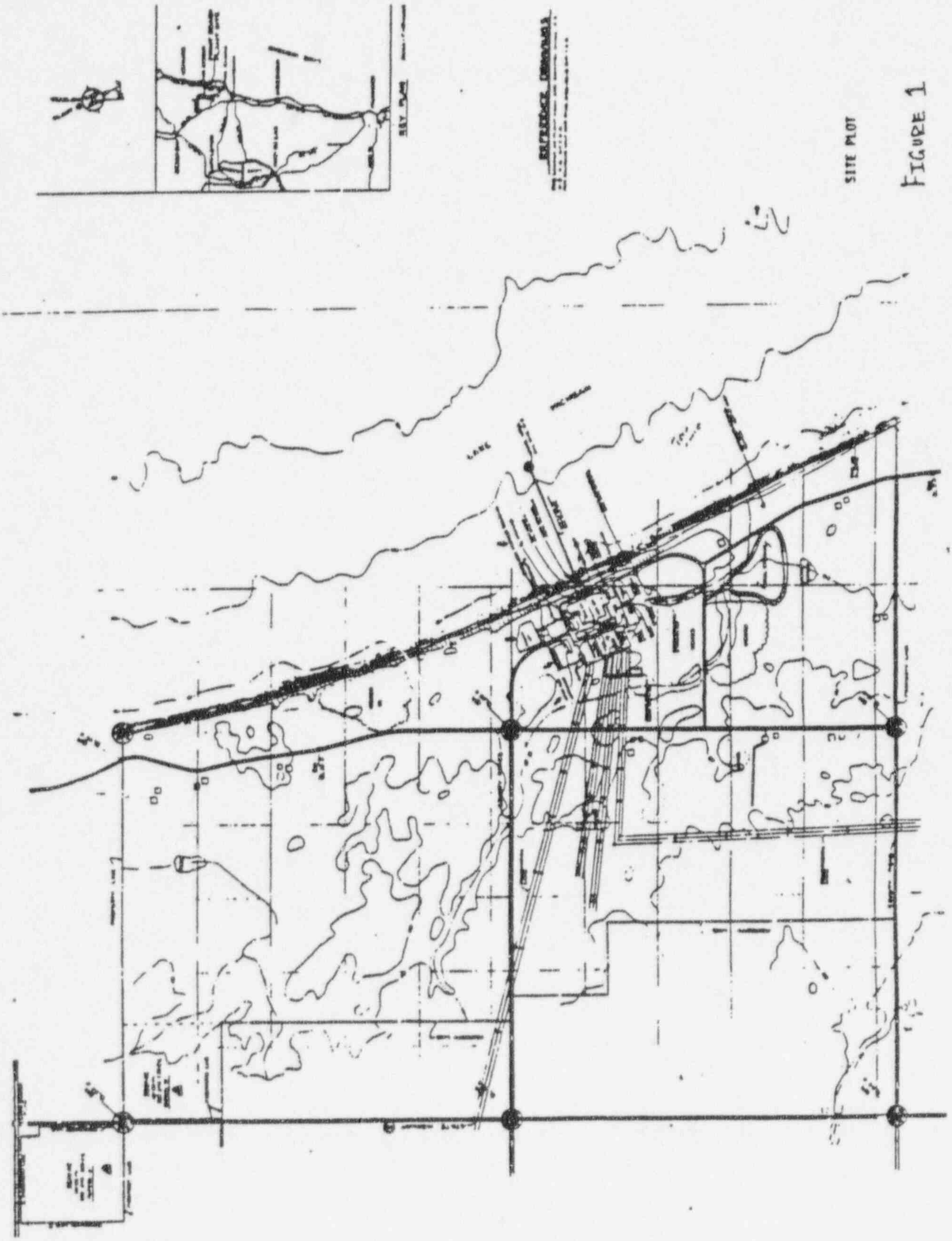
. When was the sample taken? April 12, 1983

SIGNATURE	TITLE	DATE
[signature]	Water Quality Engineer	

E-10

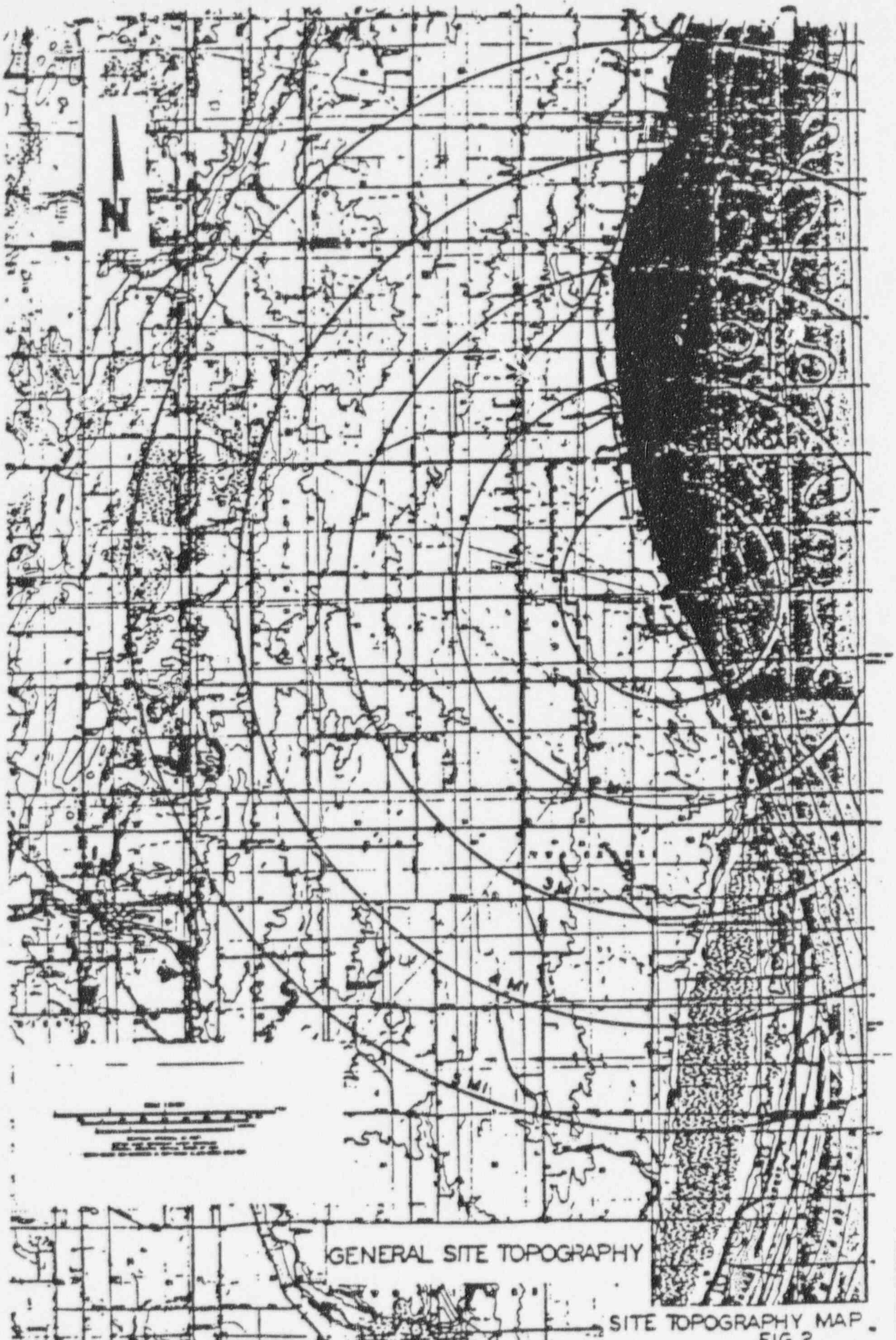
APPENDIX C

SITE MAPS

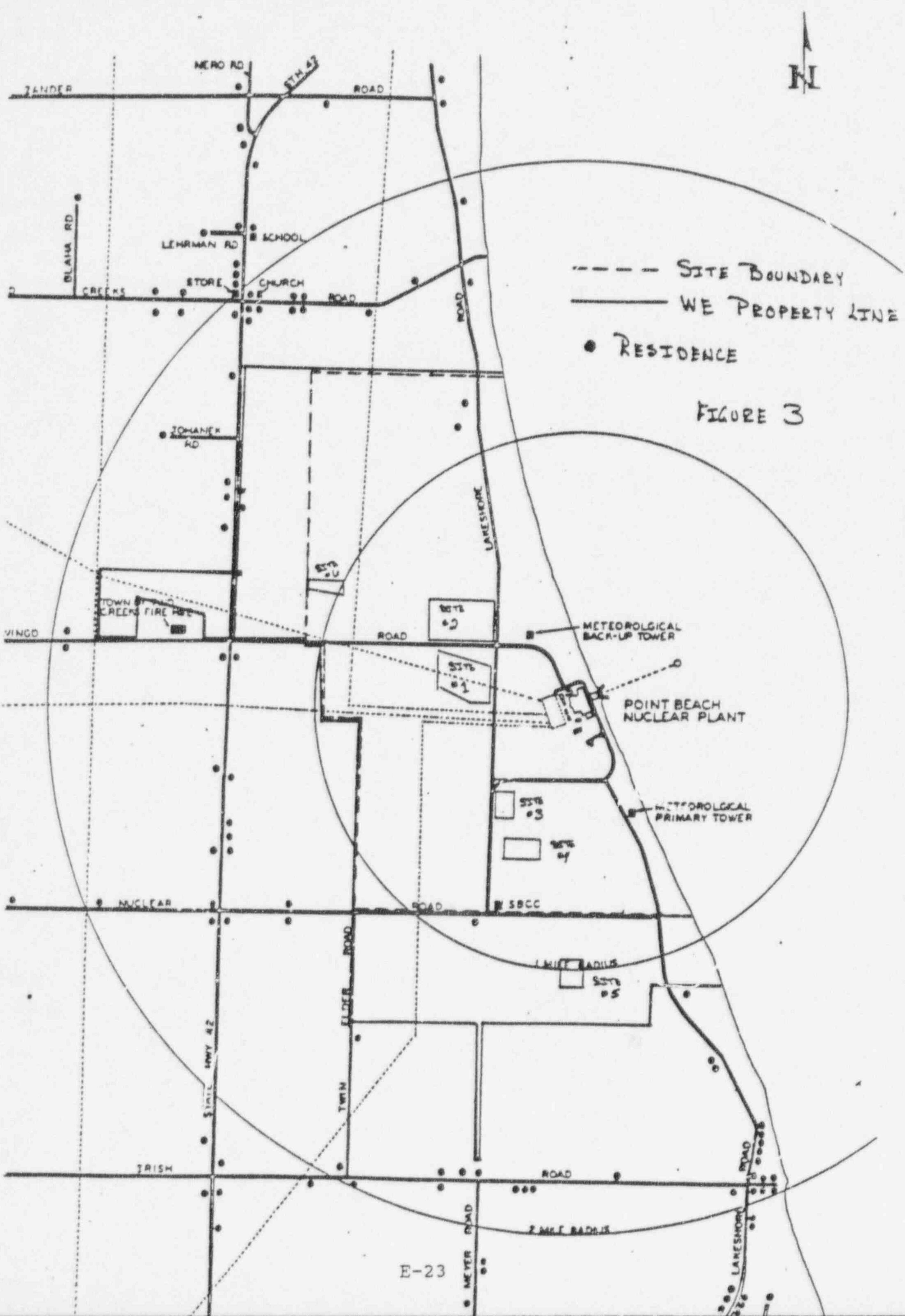


SITE PLOT

FIGURE 1



SITE TOPOGRAPHY MAP
FIG 2


N
ZANDER
ROAD
MERO RD
STH 42
BLAHA RD
SCHOOL
LEHRMAN RD
STORE
CHURCH
CREEKS
ROAD
ROAD
SITE BOUNDARY
WE PROPERTY LINE
RESIDENCE
FIGURE 3
ZOHANEK RD
LAKESHORE
TOWN OF TWO CREEKS FIRE HSE
VINGO
ROAD
SITE #2
SITE #1
METEOROLGICAL BACK-UP TOWER
POINT BEACH NUCLEAR PLANT
SITE #3
SITE #4
METEOROLGICAL PRIMARY TOWER
NUCLEAR
ROAD
SBCC
1 MILE RADIUS
SITE #5
STATE HWY 42
TWIN ELDER ROAD
IRISH
ROAD
MEYER ROAD
2 MILE RADIUS
ROAD
LAKESHORE

APPENDIX D

EXPOSURE PATHWAYS

I. EXPOSURE PATHWAYS - MAXIMALLY EXPOSED INDIVIDUAL

1. External whole body exposure due to a ground plane source of radionuclides.

2. Milk ingestion pathway from cows fed alfalfa grown on plot.

3. Meat ingestion pathway from cows fed alfalfa grown on plot.

4. Vegetable ingestion pathway from vegetables grown on plot.

5. Inhalation of radioactivity resuspended in air above application site.

6. Pathways associated with a release to Lake Michigan. Ingestion of potable water at Two Rivers, Wisconsin municipal water supply, ingestion of fish from edge of initial mixing zone of radionuclide release, ingestion of fresh and stored vegetables irrigated with water source as Lake Michigan, ingestion of milk and meat from cows utilizing Lake Michigan as drinking water source, swimming and boating activities at edge of initial mixing zone, and shoreline deposits.

II. EXPOSURE PATHWAYS - INADVERTENT INTRUDER

1. External whole body exposure due to a ground plane source of radionuclides.

2. Vegetable ingestion pathway from vegetables grown on plot.

3. Inhalation of radioactivity resuspended in air above application site.

4. Pathways associated with a release to Lake Michigan. Ingestion of potable water at Two Rivers, Wisconsin municipal water supply, ingestion of fish from edge of initial mixing zone of radionuclide release, ingestion of fresh and stored vegetables irrigated with water source as Lake Michigan, ingestion of milk and meat from cows utilizing Lake Michigan as drinking water source, swimming and boating activities at edge of initial mixing zone, and shoreline deposits.

The milk and meat pathways are not included in calculating the dose to the inadvertent intruder. The doses due to these pathways are calculated based on feeding the cows alfalfa grown on the sludge applied land. Since direct grazing on these lands is prohibited, the alfalfa must be cropped prior to being used as feed. This effectively removes the availability of these pathways to the inadvertent intruder, who by definition occupies the sludge applied land continuously.

III. GROUND WATER PATHWAY

The ingestion of groundwater is not a credible exposure pathway. The two factors contributing to this determination are as follows:

1. The site map in Appendix C, Figure 3 details the spatial relationship between the proposed disposal sites and the local ground water wells. The flow gradient of ground water was determined for the PBNP FSAR to be towards Lake Michigan. Reviewing the sites and local wells shows no private well located in the path of radionuclide migration towards Lake Michigan.

   The PBNP site well is loczted on the plant site, potentially in a path of radionuclide migration. The PBNP well is routinely sampled as a requirement of the PBNP environmental monitoring program.

2. The cation exchange capacity (CEC) of the soils at each site has been determined.

Site	Cation Exchange Capacity (MEQ/100g)
1	16
2	11
3	11
4	10
5	8
6	9

The cation exchange capacity of soil is dependent on the valance of the radionuclides and is determined by the relation:

$$MEQ = \frac{\text{ATOMIC WEIGHT}}{\text{VALANCE}} * 1.0E-03$$

Radionuclide	Valance	CEC (MEQ/100g)
Co-60	+2	3.00E-02
Co-58	+2	2.90E-02
Cs-137	+1	1.37E-01
Mn-54	+2	2.70E-02
Cr-51	+3	1.70E-02
Cs-134	+1	1.34E-01

Using the values for Cs-137 and site 5 which has the lowest CEC, the total exchange capacity of the soil is

$$\frac{\text{1.10 grams of Cs-137}}{\text{100 grams of soil}}$$

Calculating the specific activity of Cs-137,

$$\text{Specific Activity} = \frac{3.578E+05}{T_{1/2}(\text{yrs.}) \cdot \text{ATOMIC MASS}} = \frac{3.578E+05}{30 \cdot 137}$$

$$= 87.1 \text{ Ci/gram}$$

The cation exchange capacity of the soil expressed in the number of Curies of radionuclide per 100 grams of soil is

$$\frac{95.8 \text{ Ci Cs-137}}{100 \text{ grams of soil}}$$

Since the proposed disposal of sewage sludge contains quantities of radionuclides on the order of 10-100 μCi the soil at each site has the capacity to effectively eliminate the migration of the radionuclide to ground water.

APPENDIX E

EXPOSURE ANALYSIS

GENERAL ASSUMPTIONS

1. Sewage sludge is uniformly applied over plot acreage.

2. Sewage sludge is applied to one of the 5 acre plots, site PB-03, PB-04, PB-05, or PB-06. (Assuming the smallest site size is conservative for the calculation methodology herein.)

3. Based on the sewage sludge currently stored at PBNP, the following data is used in the calculations.

Radionuclide	Sludge Volume (Gallons)	Sludge Volume (cm^3)	Activity (μCi)	Concentration ($\mu Ci/cm^3$)	Ground Plane Concentration ($\mu Ci/cm^2$)
Co-60	15,000	5.68E+07	13.2	2.33E-07	6.53E-08
Cs-137	15,000	5.68E+07	8.5	1.50E-07	4.21E-08

I. CALCULATION OF EXTERNAL EXPOSURES

A. Specific Assumptions

1. Conservatively assume radioactivity remains on surface of land plot. Calculation ignores any plowing or mixing of radioactivity within soil. Calculations for the proposed disposal will therefore ignore self absorption or shielding from soil.

   The external exposure at the application site due to prior disposals will be calculated utilizing the methodology in Appendix G and added to that calculated for the proposed disposal.

2. The plots are owned by Wisconsin Electric and have been approved by the Wisconsin Department of Natural Resources (DNR) as disposal sites. The land is leased and potentially farmed. Occupancy of the land can be realistically expected only during plowing, planting and harvesting. Occupancy has been estimated to be 64 hours per year.

B. Summary of Calculational Methodology

1. Calculate ground plane radionuclide concentrations in pCi/cm^2.

2. The dose from a plane of uniformly deposited radionuclides is calculated using Regulatory Guide 1.109, Revision 1, Appendix C, Formula C-2.

3. Dose rates were calculated assuming continuous occupancy then adjusted for realistic occupancy factors.

C. External Exposure Rate Calculations

The dose from a plane of uniformly deposited radionuclides is calculated using Regulatory Guide 1.109, Revision 1, Appendix C, formula C-2

$$D_j^G(r,\theta) = 8760\ S_F \sum_i C_i^G(r,\theta)\ DFG_{ij}$$

where

$D_j^G(r,\theta)$ = yearly dose

8760 = hours per year

S_F = 1.0, since no dose reduction due to residential shielding is applicable.

$C_i^G(r,\theta)$ = ground plane radionuclide concentration (pCi/m²)

DFG(i,j) = external dose factor for standing on contaminated ground as given in Table E-6 of Regulatory Guide 1.109, Revision 1.

Radionuclide	γ Dose Factor (mrem/hr per pCi/m²)	Ground Plane Concentration (μCi/cm²)	Ground Plane Concentration (pCi/m²)	γ Dose Rate (mrem/yr)
Co-60	1.70E-08	6.53E-08	6.53E+02	9.72E-02
Cs-137	4.20E-09	4.21E-08	4.21E+02	1.55E-02

TOTAL: 1.13E-01 mrem/year

These calculated dose rates assume continuous occupancy. In reality, these sites will be occupied only during plowing, planting, and harvesting. Assuming an occupancy of 2 hours per day, 1 day per week, and 32 weeks (8 month growing season) per year, the occupancy factor becomes

2 hr/day * 1 day/week * 32 weeks/yr * 1/8760 hours/yr = 7.3E-03.

EXTERNAL EXPOSURE DOSE RATE (mrem/year)

Radionuclide	Continuous Occupancy	Realistic Occupancy
Co-60	9.72E-02	7.10E-04
Cs-137	1.55E-02	1.13E-04
TOTAL:	1.13E-01	8.23E-04

II. CALCULATION OF MEAT AND MILK INGESTION PATHWAY EXPOSURES

A. Specific Assumptions

1. All feed consumed by cow is grown on sludge applied acreage.
2. All meat and milk consumed by human is from cattle exclusively fed feed from sludge applied land.
3. Stable element transfer coefficients (B_{iv}) are utilized from Regulatory Guide 1.109 to estimate the fraction of radioactivity which is transferred from the soil to the feed.

Radionuclide	B_{iv}
Co-60	9.4E-03
Cs-137	1.0E-02

4. Alfalfa has typically been grown on the plots. Soil tests have indicated a minimum alfalfa yield of 4.1 tons per acre can be expected.

B. Summary of Calculational Methodology

1. The concentration of radionuclides in feed grown on the disposal plots is estimated. Transfer coefficients (B_{iv}) from Table E-1 of Regulatory Guide 1.109 were used to estimate the fraction of radionuclide which may be expected to transfer to the feed from the soil.
2. Concentrations of radionuclides in milk and meat were estimated using Formula A-11 from Regulatory Guide 1.109.
3. Ingestion dose rates were estimated using Formula A-12 from Regulatory Guide 1.109.

C. Milk and Meat Ingestion Pathway Dose Rate Calculation

1. Concentration in feed.

Activity in Feed = B_{iv} * Activity in Soil

Concentration in Feed = Activity in Feed/($\frac{\text{kg of Feed}}{\text{Acre}}$ * 5 Acres)

Radionuclide	Activity in Soil (μCi)	Activity in Feed (μCi)	Radionuclide Concentration in Feed (pCi/kg)
Co-60	13.2	1.24E-01	6.67E+00
Cs-137	8.5	8.50E-02	4.57E+00

2. Concentration in Milk and Meat

Calculate concentrations of radionuclides in milk and meat using

Formula A-11 in Regulatory Guide 1.109, Revision 1 which is

$$C_{iA} = F_{iA} * C_{iF} * Q_F$$

where C_{iA} = radionuclide concentration of i in component A
F_{iA} = stable element transfer coefficient whose values are in Table E-1 of the Regulatory Guide
C_{iF} = radionuclide concentration in feed
Q_F = consumption rate of feed = 50 kg/d (wet weight) from Regulatory Guide 1.109

Use the following Regulatory Guide 1.109 values for F_{iA}

Element	$F_{iA}=_m$ (d/l) for milk	$F_{iA}=_f$ (d/kg) for meat
Co	1.0E-03	1.3E-02
Cs	1.2E-02	4.0E-03

Radionuclide	Concentration in Milk (pCi/l)	Concentration in Meat (pCi/kg)
Co-60	3.34E-01	4.34E+00
Cs-137	2.74E+00	9.14E-01

3. Calculated Dose rates

The formula for total dose from eating animal products fed vegetation (alfalfa) grown on PBNP sludge applied land is given by Regulatory Guide 1.109, Revision 1, Formula A-12, page 1.109-16. But, as noted following equation A-13, it is necessary to compute separately the milk and meat portions of the dose.

$$DOSE = \Sigma(U_{ap} * D_{iapg} * exp(-\lambda_i t_s))$$

where U_{ap} = consumption rate of animal product
C_{iA} = conc of radionuclide i in animal product A
D_{iapg} = dose factor
t_s = average time between milking or slaughtering and consumption

	U_{ap} by Age Group			
	Infant	Child	Teenager	Adult
Milk (l/yr)	330	330	400	310
Meat (kg/yr)	-	41	65	110

C_{iA} = concentration calculated above

D_{iapg} = DF whole body dose factors, Regulatory Guide 1.109, Revision 1.

Whole Body Dose Factors (mrem/pCi Ingested)

Nuclide	Infant Ingestion	Child Ingestion	Teenager Ingestion	Adult Ingestion
Co-60	2.55E-05	1.56E-05	6.33E-06	4.72E-06
Cs-137	4.33E-05	4.62E-05	5.19E-05	7.14E-05

T_s = 0 for milk (assume consumption on farm)
= 20 days for meat (Regulatory Guide 1.109, Revision 1, Table E-15)

MILK INGESTION DOSE RATE (mrem/year)

Radionuclide	Infant	Child	Teenager	Adult
Co-60	2.81E-03	1.72E-03	8.46E-04	4.89E-04
Cs-137	3.92E-02	4.18E-02	5.69E-02	6.06E-02
TOTALS:	4.20E-02	4.35E-02	5.77E-02	6.11E-02

MEAT INGESTION DOSE RATE (mrem/year)

Radionuclide	Infant	Child	Teenager	Adult
Co-60	-	2.76E-03	1.77E-03	2.24E-03
Cs-137	-	1.73E-03	3.08E-03	7.18E-03
TOTALS:	-	4.49E-03	4.85E-03	9.42E-03

MEAT AND MILK INGESTION PATHWAY DOSE RATES (mrem/year)

Infant - 4.20E-02
Child - 4.80E-02
Teenager - 6.26E-02
Adult - 7.05E-02

III. CALCULATION OF VEGETABLE INGESTION PATHWAY EXPOSURES

A. Specific Assumptions

1. The WPDES permit issued to PBNP for the disposal of sewage sludge prohibits the growing of crops for human consumption for one year following the application of the sewage sludge. Therefore, prior to planting vegetables on the application site, the soil would be plowed. Plowing is assumed to uniformly mix the top 6 inches of soil.

2. The soil density is assumed to be 1.3 grams/cm^3.

3. All vegetables consumed by the individual of interest are grown on the sludge applied acreage.

4. Stable element transfer coefficients (B_{iv}) from Regulatory Guide 1.109 are used to estimate the fraction of radioactivity transfered from the soil to the vegetables.

Radionuclide	B_{iv}
Co-60	9.4E-03
Cs-137	1.0E-02

5. The consumption factors of food medium (U_{ap}) and the mass basis distributions from Regulatory Guide 1.109, Table E-5 are used to determine annual consumption of vegetables.

U_{ap} by Age Group*

Infant	Child	Teen	Adult
-	280 kg/yr	340 kg/yr	280 kg/yr

*Based on 54% vegetable consumption by mass of fruit, vegetable, and grain.

6. The Ingestion Dose Factors by age group are from Regulatory Guide 1.109, Tables E-11, E-12, E-13, and E-14.

Whole Body Ingestion Dose Factors (mrem/pCi ingested)

Radionuclide	Infant	Child	Teen	Adult
Co-60	2.55E-05	1.56E-05	6.33E-06	4.72E-06
Cs-137	4.33E-05	4.62E-05	5.19E-05	7.14E-05

7. Radiological decay of the radionuclides applied to the plot is not taken into account in these calculations.

B. Summary of Calculational Methodology

1. The radionuclide concentration in the soil is calculated in units of pCi/kg based on uniform application over 5 acre plot, plowing to a depth of 6 inches, and a soil density of 1.3 g/cm^3.

2. The B_{iv} values are applied to the soil concentration values to obtain the radionuclide concentration in the vegetables.

3. The consumption factors (U_{ap}) for each age group are then used to determine the annual radionuclide intake by age group due to eating these vegetables.

4. Finally, the age dependent ingestion dose factors are used to obtain annual doses by age group.

C. Vegetable Pathway Ingestion Dose Rate Calculations

1. Concentration in soil

Radionuclide	Activity Applied (μCi)	Soil Volume (cm^3)	Soil Mass (kg)	Concentration In Soil (pCi/kg)
Co-60	13.2	3.08E+09	4.00E+06	3.30E+00
Cs-137	8.5	3.08E+09	4.00E+06	2.13E+00

2. Concentration in vegetables

Radionuclide	Concentration In Soil (pCi/kg)	B_{iv}	Concentration In Vegetables (pCi/kg)
Co-60	3.30E+00	9.4E-03	3.10E-02
Cs-137	2.13E+00	1.0E-02	2.13E-02

3. Calculated Dose Rates

The dose rate for direct ingestion of vegetables grown on the sludge applied land is given by the equation.

$$\text{DOSE RATE} = \Sigma\ U_{ap} * D_{iapj} * \text{EXP}\ (-\lambda_i t) * C_i$$

where

U_{ap} = consumption -ate of food medium
D_{iapj} = dose factor for radionuclide, i
λ_i = radiological decay constant
t = time between harvest and consumption
C_i = concentration of radionuclide, i, in food medium.

t, the time between harvest and ingestion, is assumed to be zero for this calculation.

VEGETABLE INGESTION DOSE RATE (mrem/year)

Radionuclide	Infant	Child	Teen	Adult
Co-60	-	1.35E-04	6.67E-05	4.10E-05
Cs-137	-	2.75E-04	3.76E-04	4.26E-04
TOTAL	-	4.11E-04	4.43E-04	4.67E-04

IV. CALCULATION OF INHALATION OF RESUSPENDED RADIONUCLIDES PATHWAY EXPOSURE

A. Specific Assumptions

1. The model used to determine the radionuclide concentration in air above the sludge applied land is taken from WASH-1400, USNRC, Reactor Safety Study - An Assessment of Accident Risks in Commercial Nuclear Power Plants, Appendix VI.

2. The radionuclide concentration in air remains constant for year of interest, i.e., radiological decay and decrease in resuspension factor are not taken into account for this calculation.

3. The maximally exposed member of the general public is assumed to be the farmer using the plot of land with an occupancy of 64 hours per year.

4. The inadvertent intruder is assumed to occupy the plot of land for the entire year.

5. The Inhalation Dose Factors by age group are from Regulatory Guide 1.109, Tables E-7, E-8, E-9, and E-10.

WHOLE BODY INHALATION DOSE FACTORS (mrem/pCi inhaled)

Radionuclide	Infant	Child	Teen	Adult
Co-60	8.41E-06	6.12E-06	2.48E-06	1.85E-06
Cs-137	3.25E-05	3.47E-05	3.89E-05	5.35E-05

LUNG INHALATION DOSE FACTORS (mrem/pCi inhaled)

Radionuclide	Infant	Child	Teen	Adult
Co-60	3.22E-03	1.91E-03	1.09E-03	7.46E-04
Cs-137	5.09E-05	2.81E-05	1.51E-05	9.40E-06

6. The age dependent inhalation rates are obtained from Regulatory Guide 1.109, Table E-5.

Inhalation Rates (m^3/yr)

Infant	Child	Teen	Adult
1400	3700	8000	8000

B. Summary of Calculational Methodology

1. The ground plane radionuclide concentrations in pCi/m².

2. Calculate the resuspension factor utilizing equation given in WASH-1400.

3. Obtain the radionuclide concentration in air (pCi/m³) above plot utilizing methodology in WASH-1400.

4. Using parameters contained in Regulatory Guide 1.109, calculate annual dose for continuous occupancy and for realistic occupancy.

C. Inhalation of Resuspended Radionuclides in Air Pathway Dose Rate Calculations - Resuspension of Radionuclide in Air

1. Ground plane radionuclide concentration

Radionuclide	Ground Plane Concentration (μCi/cm²)	Ground Plane Concentration (pCi/m²)
Co-60	6.53E-08	6.53E+02
Cs-137	4.21E-08	4.21E+02

2. Calculation of resuspension factor, K (m^{-1})

From WASH-1400,
K(t) = 1.0E-09 + 1.0E-05 * EXP [-0.6769 * t]

where t = time since radionuclides were deposited on ground surface.

t is assumed to be 0 for these calculations, thereby maximizing the resuspension factor.

Therefore,

$$K = 1.0\text{E-}05\ m^{-1}$$

3. Calculate radionuclide concentration (pCi/m³) in air.

From WASH-1400,

$$K(m^{-1}) = \frac{\text{air concentration (pCi/m}^2\text{)}}{\text{surface deposit (pCi/m}^2\text{)}}$$

or

$$\text{Air Concentration (pCi/m}^3\text{)} = \text{surface deposit (pCi/m}^2\text{)} * K(m^{-1})$$

AIR CONCENTRATIONS

Radionuclide	Air Concentrations (pCi/m³)
Co-60	6.53E-03
Cs-137	4.21E-03

4. Dose Rate Calculations

Dose Rate (mrem/yr) = Inhalation Rate (m^3/yr) * Air Conc. (pCi/m^3) * Dose Conversion Factor (mrem/pCi)

WHOLE BODY INHALATION DOSE RATE (mrem/year)

Radionuclide	Infant	Child	Teen	Adult
Co-60	7.69E-05	1.48E-04	1.30E-04	9.66E-05
Cs-137	1.92E-04	5.41E-04	1.31E-03	1.80E-03
TOTAL	2.69E-04	6.89E-04	1.44E-03	1.90E-03

LUNG INHALATION DOSE RATE (mrem/year)

Radionuclide	Infant	Child	Teen	Adult
Co-60	2.94E-02	4.61E-02	5.69E-02	3.90E-02
Cs-137	3.00E-04	4.38E-04	5.09E-04	3.17E-04
TOTAL	2.97E-02	4.65E-02	5.74E-02	3.93E-02

INHALATION OF RESUSPENDED RADIONUCLIDES IN AIR DOSE RATES

WHOLE BODY DOSE RATE (mrem/year)

Occupancy	Infant	Child	Teen	Adult
Continuous	2.69E-04	6.89E-04	1.44E-03	1.90E-03
Realistic	1.96E-06	5.03E-06	1.05E-05	1.39E-05

LUNG DOSE RATE (mrem/year)

Occupancy	Infant	Child	Teen	Adult
Continuous	2.97E-02	4.65E-02	5.74E-02	3.93E-02
Realistic	2.17E-04	3.39E-04	4.19E-04	2.87E-04

V. CALCULATION OF WHOLE BODY EXPOSURES DUE TO RELEASE TO LAKE MICHIGAN

A. Specific Assumptions

1. The methodology contained in the PBNP Offsite Dose Calculation Manual (ODCM) is used to perform this calculation.

2. The entire activity contained in the sludge is released into Lake Michigan.

3. The exposure pathways addressed by the ODCM methodology are ingestion of potable water from Two Rivers, WI water supply, ingestion of fish at edge of initial mixing zone, ingestion of fresh and stored vegetables, irrigated with Lake Michigan as source of water, ingestion of milk and meat from cows utilizing Lake Michigan as drinking water source, swimming and boating activities at edge of initial mixing zone, and shoreline deposits.

B. Summary of Calculational Methodology

1. The activity released in the sludge is converted into Co-60 dose equivalent Curies.

2. The annual design release limit from the ODCM is 94.7 Co-60 equivalent curies.

3. The annual design release limit is based on a limiting dose of 6 mrem adult whole body. The annual dose due to sewage sludge is calculated by a ratio of calculated release compared to release limit.

C. Whole Body Exposure Calculations

1. Co-60 equivalent Curies

Radionuclide	Activity (µCi)	DF_i/DF_{Co-60}	Co-60 eq. Activity (µCi)
Co-60	13.2	1.00E+00	13.2
Cs-137	8.5	1.51E+01	128.4
		TOTAL	141.6µCi Co-60 equivalent

2. Ratio of dose limit to annual design release limit

$$\frac{6 \text{ mrem}}{94.7 \text{ Co-60 equivalent curies}}$$

3. Whole Body Dose Calculation

$$\frac{\text{Dose}}{141.6\mu\text{Ci}} = \frac{6 \text{ mrem}}{94.7\times10^{6}\mu\text{Ci}}$$

Dose = 8.97E-06 mrem

WHOLE BODY DOSE RATE (mrem/year)

DOSE SUMMARY

Maximally Exposed Individual

The identified credible exposure pathways for the maximally exposed individual are:

1.) External exposure from ground plane source (realistic occupancy)
2.) Milk ingestion pathway
3.) Meat ingestion pathway
4.) Vegetable ingestion pathway
5.) Resuspension inhalation pathway (realistic occupancy)
6.) Pathways identified due to release to Lake Michigan.

	AGE GROUP			
Pathway	Infant	Child	Teen	Adult
External	8.23E-04	8.23E-04	8.23E-04	8.23E-04
Milk	4.20E-02	4.35E-02	5.77E-02	6.11E-02
Meat	-	4.49E-03	4.85E-03	9.42E-03
Vegetable	-	4.11E-04	4.43E-04	4.67E-04
Inhalation	1.96E-06	5.03E-06	1.05E-05	1.39E-05
Water	8.97E-06	8.97E-06	8.97E-06	8.97E-06
TOTAL: (mrem/year)	0.043	0.049	0.064	0.072

Inadvertent Intruder

The identified credible exposure pathways for the inadvertent intruder are:

1.) External exposure from ground plane source (continuous occupancy)
2.) Vegetable ingestion pathway
3.) Resuspension inhalation pathway (continuous occupancy)
4.) Pathways identified due to release to Lake Michigan.

	AGE GROUP			
Pathway	Infant	Child	Teen	Adult
External	1.13E-01	1.13E-01	1.13E-01	1.13E-01
Vegetable	-	4.11E-04	4.43E-04	4.67E-04
Inhalation	2.96E-04	6.89E-04	1.44E-03	1.90E-03
Water	8.97E-06	8.97E-06	8.97E-06	8.97E-06
TOTAL: (mrem/year)	0.113	0.114	0.115	0.115

Reviewing these tables, the calculated limiting doses for both the maximally exposed individual and the inadvertent intruder occur for the adult age group. These doses are:

Maximally Exposed Individual:	0.072 mrem/year
Inadvertent Intruder:	0.115 mrem/year

APPENDIX F

BASIS FOR SETTING CONCENTRATION LIMITS AND ACTIVITY LIMIT FOR DISPOSAL OF SLUDGE

Analyses of previously disposed sewage sludge have identified six different radionuclides in the sludge. All six radionuclides did not occur in each disposal. Therefore, it is difficult to determine a single concentration limit for regulating the disposal of the sludge from the storage tanks.

To provide a basis to regulate the disposal of the sewage sludge based on identified radionuclide concentrations, the following relation is proposed.

$$\sum_{i=1}^{N} \frac{C_i}{0.1 * MPC_i} \leq 1$$

where

- N = number of different radionuclides identified in the sewage sludge.
- C_i = concentration of the ith radionuclide in the sewage sludge.
- MPC_i = the MPC value of the ith radionuclide in the sewage sludge, as listed in 10 CFR Part 20 Appendix B, Table II, Column 2.

If this criteria is met, the sewage sludge may be disposed of by land spreading provided the dose calculations (as identified in Appendix E) indicate dose rates within the prescribed limits.

The attachment to this Appendix details calculations performed to determine doses from four radionuclides identified in the sludge. The calculations are based on an identified concentration equal to 10% of the 10 CFR Part 20, Appendix B, Table II, Column 2 valves. The calculations use the methodology in Appendix E along with the exposure pathways identified in Appendix D to determine the dose rates. These calculations indicate the use of this methodology will maintain radiation doses within the appropriate limits.

The maximum allowable activity disposed of per year per acre is calculated utilizing 10% of the MPC value, 10 CFR Part 20, Appendix B, Table II, Column 2, for Co-58. Volume limit per acre has been proposed at 4,000 gallons/acre/year. Then,

$$1.0E\text{-}05\ \mu Ci/cc * 4{,}000\ \text{gallons/acre/year} \times 3.785.43\ \text{cc/gallon}$$
$$= 151.4\ \mu Ci/acre/year$$

Cs-134

Concentration in Sludge: 9.0E-07 mCi/ml

Sludge Volume (Gallons)	(cm³)	Concentration (μCi/cm³)	Activity (μCi)	Ground Plane Concentration (μCi/cm²)
15000	5.68E+07	9.00E-07	5.11E+01	2.53E-07

External Exposure

γ Dose Factor (mrem/hr. per pCi/m²)	Ground Plane Concentration (pCi/m²)	γ Dose Rate (mrem/year)
1.20E-08	2.53E+03	2.66E-01

Continuous Occupancy: 2.66E-01 mrem/year
Realistic Occupancy: 1.94E-03 mrem/year

Meat & Milk Pathway

Activity in Soil (μCi)	Activity in Feed (μCi)	Concentration in Feed (pCi/Kg)	Concentration in Milk (pCi/ℓ)	Concentration in Meat (pCi/kg)
5.22E+01	5.11E-01	2.75E+01	1.65E+01	5.50E+00

Milk Dose Rates (mrem/year)

Infant	Child	Teenager	Adult
3.87E-01	4.41E-01	6.03E-01	6.19E-01

Meat Dose Rate (mrem/year)

Infant	Child	Teenager	Adult
-	1.83E-02	3.27E-02	7.32E-02

Vegetable Pathway

Activity (μCi)	Soil Volume (Cm³)	Soil Mass (Kg)	Concentration in Soil (pCi/Kg)	Concentration in Vegetables (pCi/Kg)
5.11E+01	3.08E+09	4.00E+06	1.28E+01	1.28E-01

Vegetable Pathway Dose Rates (mrem/year)

Infant	Child	Teenager	Adult
-	2.90E-03	3.98E-03	4.34E-03

Inhalation Pathway

Ground Plane Concentration (pCi/m²)	K_1 (m^{-1})	Air Concentration (pCi/m³)
2.53E+03	1.0E-05	2.53E-02

Inhalation Pathway Dose Rates (mrem/year)

	Infant	Child	Teenager	Adult
Continuous Occupancy	1.88E-03	5.68E-03	1.39E-02	1.84E-02
Realistic Occupancy	1.38E-05	4.15E-05	1.01E-04	1.35E-04

Release to Lake Michigan

Activity (μCi)	DF_i/DF_{Co-60}	Co-60 eq. activity (μCi)
5.11E+01	2.56E+01	1.31E+03

$$\frac{6 \text{ mrem}}{94.7 \text{ Ci}} * 1.31E{+}03 * \frac{1 \text{ Ci}}{1.0E{+}06\ \mu\text{Ci}} = 8.29E{-}05 \text{ mrem}$$

Maximally Exposed Individual

	Infant	Child	Teenager	Adult
External	1.94E-03	1.94E-03	1.94E-03	1.94E-03
Milk	3.87E-01	4.41E-01	6.03E-01	6.19E-01
Meat	-	1.83E-02	3.27E-02	7.32E-02
Vegetable	-	2.90E-03	3.98E-03	4.34E-03
Inhalation	1.38E-05	4.15E-05	1.01E-04	1.35E-04
Water	8.29E-05	8.29E-05	8.29E-05	8.29E-05
Totals:	3.89E-01	4.64E-01	6.42E-01	6.99E-01

Inadvertent Intruder

	Infant	Child	Teenager	Adult
External	2.66E-01	2.66E-01	2.66E-01	2.66E-01
Vegetable	-	2.90E-03	3.98E-03	4.34E-03
Inhalation	1.88E-03	5.68E-03	1.39E-02	1.84E-02
Water	8.29E-05	8.29E-05	8.29E-05	8.29E-05
Totals:	2.68E-01	2.75E-01	2.84E-01	2.89E-01

Cs-137

Concentration in Sludge: 2.0E-06 μCi/ml

Sludge Volume (Gallons)	Sludge Volume (cm^3)	Concentration ($\mu Ci/cm^3$)	Activity (μCi)	Ground Plane Concentration ($\mu Ci/cm^2$)
15000	5.68E+07	2.00E-06	1.14E+02	5.62E-07

External Exposure

γ Dose Factor (mrem/hr. per pCi/m^2)	Ground Plane Concentration (pCi/m^2)	γ Dose Rate (mrem/year)
4.20E-09	5.62E+03	2.07E-01

Continuous Occupancy: 2.07E-01 mrem/year
Realistic Occupancy: 1.51E-03 mrem/year

Meat & Milk Pathway

Activity in Soil (μCi)	Activity in Feed (μCi)	Concentration in Feed (pCi/Kg)	Concentration in Milk (pCi/ℓ)	Concentration in Meat (pCi/kg)
1.14E+02	1.14E+00	6.13E+01	3.68E+01	1.23E+01

Milk Dose Rates (mrem/year)

Infant	Child	Teenager	Adult
5.26E-00	5.61E-01	7.64E-01	8.15E-01

Meat Dose Rate (mrem/year)

Infant	Child	Teenager	Adult
-	2.33E-02	4.15E-02	9.56E-02

Vegetable Pathway

Activity (μCi)	Soil Volume (Cm^3)	Soil Mass (Kg)	Concentration in Soil (pCi/Kg)	Concentration in Vegetables (pCi/Kg)
1.14E+02	3.08E+09	4.00E+06	2.85E+01	2.85E-01

Vegetable Pathway Dose Rates (mrem/year)

Infant	Child	Teenager	Adult
-	3.69E-03	5.03E-03	5.70E-03

Inhalation Pathway

Ground Plane Concentration (pCi/m²)	K_{-1} (m^{-1})	Air Concentration (pCi/m³)
5.62E+03	1.0E-05	5.62E-02

Inhalation Pathway Dose Rates (mrem/year)

	Infant	Child	Teenager	Adult
Continuous Occupancy	2.56E-03	7.22E-03	1.75E-02	2.41E-02
Realistic Occupancy	1.87E-05	5.27E-05	1.28E-04	1.76E-04

Release to Lake Michigan

Activity (µCi)	DF_i/DF_{Co-60}	Co-60 eq. activity (µCi)
1.14E+02	1.51E+01	1.72E+03

$$\frac{6 \text{ mrem}}{94.7 \text{ Ci}} * 1.72E{+}03 * \frac{1 \text{ Ci}}{1.0E{+}06 \ \mu\text{Ci}} = 1.09E{-}04 \text{ mrem}$$

Maximally Exposed Individual

	Infant	Child	Teenager	Adult
External	1.51E-03	1.51E-03	1.51E-03	1.51E-03
Milk	5.26E-01	5.61E-01	7.64E-01	8.15E-01
Meat	-	2.33E-02	4.15E-02	5.70E-03
Vegetable	-	3.69E-03	5.03E-03	5.70E-03
Inhalation	1.87E-05	5.27E-05	1.28E-04	1.76E-04
Water	1.09E-04	1.09E-04	1.09E-04	1.09E-04
Totals:	5.28E-01	5.90E-01	8.12E-01	9.19E-01

Inadvertent Intruder

	Infant	Child	Teenager	Adult
External	2.07E-01	2.07E-01	2.07E-01	2.07E-01
Vegetable	-	3.69E-03	5.03E-03	5.70E-03
Inhalation	2.56E-03	7.22E-03	1.75E-02	2.41E-02
Water	1.09E-04	1.09E-04	1.09E-04	1.09E-04
Totals:	2.10E-01	2.18E-01	2.30E-01	2.37E-01

Co-58

Concentration in Sludge: 1.00E-05 μCi/ml

Sludge Volume (Gallons)	Sludge Volume (cm^3)	Concentration ($\mu Ci/cm^3$)	Activity (μCi)	Ground Plane Concentration ($\mu Ci/cm^2$)
15000	5.68E+07	1.00E-05	5.68E+02	2.81E-06

External Exposure

γ Dose Factor (mrem/hr. per pCi/m^2)	Ground Plane Concentration (pCi/m^2)	γ Dose Rate (mrem/year)
7.00E-09	2.81E+04	1.72E+00

Continuous Occupancy: 1.72E+00 mrem/year
Realistic Occupancy: 1.26E-02 mrem/year

Meat & Milk Pathway

Activity in Soil (μCi)	Activity in Feed (μCi)	Concentration in Feed (pCi/Kg)	Concentration in Milk (pCi/ℓ)	Concentration in Meat (pCi/kg)
5.68E+02	5.34E+00	2.87E+02	1.44E+01	1.87E+02

Milk Dose Rates (mrem/year)

Infant	Child	Teenager	Adult
4.27E-02	2.62E-02	1.29E-02	7.45E-03

Meat Dose Rate (mrem/year)

Infant	Child	Teenager	Adult
-	4.22E-02	2.72E-02	3.44E-02

Vegetable Pathway

Activity (μCi)	Soil Volume (Cm^3)	Soil Mass (Kg)	Concentration in Soil (pCi/Kg)	Concentration in Vegetables (pCi/Kg)
5.68E+02	3.08E+09	4.00E+06	1.42E-04	1.33E+00

Vegetable Pathway Dose Rates (mrem/year)

Infant	Child	Teenager	Adult
-	2.05E-03	1.01E-03	6.22E-04

Inhalation Pathway

Ground Plane Concentration (pCi/m²)	K_1 (m^{-1})	Air Concentration (pCi/m³)
2.81E+04	1.0E-05	2.81E-01

Inhalation Pathway Dose Rates (mrem/year)

	Infant	Child	Teenager	Adult
Continuous Occupancy	5.11E-04	8.89E-04	7.80E-04	5.82E-04
Realistic Occupancy	3.74E-06	6.49E-06	5.70E-06	4.25E-06

Release to Lake Michigan

Activity (µCi)	DF_i/DF_{Co-60}	Co-60 eq. activity (µCi)
5.68E+02	3.54E-01	2.01E+02

$$\frac{6 \text{ mrem}}{94.7 \text{ Ci}} * 2.01E{+}02 \ \mu\text{Ci} * \frac{1 \text{ Ci}}{1.0E{+}06 \ \mu\text{Ci}} = 1.27E{-}05 \text{ mrem}$$

Maximally Exposed Individual

	Infant	Child	Teenager	Adult
External	1.26E-02	1.26E-02	1.26E-02	1.26E-02
Milk	4.27E-02	2.62E-02	1.29E-02	7.45E-03
Meat	-	4.22E-02	2.72E-02	3.44E-02
Vegetable	-	2.05E-03	1.01E-03	6.22E-04
Inhalation	3.74E-06	6.49E-06	5.70E-06	4.25E-06
Water	1.27E-05	1.27E-05	1.27E-05	1.27E-05
Totals:	5.53E-02	8.31E-02	5.37E-02	5.51E-02

Inadvertent Intruder

	Infant	Child	Teenager	Adult
External	1.72E+00	1.72E+00	1.72E+00	1.72E+00
Vegetable	-	2.05E-03	1.01E-03	6.22E-04
Inhalation	5.11E-04	8.89E-04	7.80E-04	5.82E-04
Water	1.27E-05	1.27E-05	1.27E-05	1.27E-05
Totals:	1.72E+00	1.72E+00	1.72E+00	1.72E+00

Co-60

Concentration in Sludge: 5.0E-06 μCi/ml

Sludge Volume (Gallons)	Sludge Volume (cm^3)	Concentration (μCi/cm^3)	Activity (μCi)	Ground Plane Concentration (μCi/cm^2)
15000	5.68E+07	5.00E-06	2.84E+02	1.41E-06

External Exposure

γ Dose Factor (mrem/hr. per pCi/m^2)	Ground Plane Concentration (pCi/m^2)	γ Dose Rate (mrem/year)
1.70E-08	1.41E+04	2.09E+00

Continuous Occupancy: 2.09E+00 mrem/year
Realistic Occupancy: 1.53E-02 mrem/year

Meat & Milk Pathway

Activity in Soil (μCi)	Activity in Feed (μCi)	Concentration in Feed (pCi/Kg)	Concentration in Milk (pCi/ℓ)	Concentration in Meat (pCi/kg)
2.84E+02	2.67E+00	1.44E+02	7.18E+00	9.33E+01

Milk Dose Rates (mrem/year)

Infant	Child	Teenager	Adult
6.04E-02	3.70E-02	1.82E-02	1.05E-02

Meat Dose Rate (mrem/year)

Infant	Child	Teenager	Adult
-	5.97E-02	3.84E-02	4.84E-02

Vegetable Pathway

Activity (μCi)	Soil Volume (Cm^3)	Soil Mass (Kg)	Concentration in Soil (pCi/Kg)	Concentration in Vegetables (pCi/Kg)
2.84E+02	3.08E+09	4.00E+06	7.10E+01	6.67E-01

Vegetable Pathway Dose Rates (mrem/year)

Infant	Child	Teenager	Adult
-	2.91E-03	1.44E-03	8.82E-04

Inhalation Pathway

Ground Plane Concentration (pCi/m²)	K_1 (m^{-1})	Air Concentration (pCi/m³)
1.41E+04	1.0E-05	1.41E-01

Inhalation Pathway Dose Rates (mrem/year)

	Infant	Child	Teenager	Adult
Continuous Occupancy	1.66E-03	3.19E-03	2.80E-03	2.09E-03
Realistic Occupancy	1.21E-05	2.33E-05	2.05E-05	1.53E-05

Release to Lake Michigan

Activity (μCi)	DF_i/DF_{Co-60}	Co-60 eq. activity (μCi)

$$\frac{6\text{ mrem}}{94.7\text{ Ci}} * 2.84E{+}02\mu Ci * \frac{1\text{ Ci}}{1.0E{+}06\ \mu Ci} = 1.80E{-}05\text{ mrem}$$

Maximally Exposed Individual

	Infant	Child	Teenager	Adult
External	1.53E-02	1.53E-02	1.53E-02	1.53E-02
Milk	6.04E-02	3.70E-02	1.82E-02	1.05E-02
Meat	-	5.97E-02	3.84E-02	4.84E-02
Vegetable	-	2.91E-03	1.44E-03	8.82E-04
Inhalation	1.21E-05	2.33E-05	2.05E-05	1.53E-05
Water	1.80E-05	1.80E-05	1.80E-05	1.80E-05
Totals:	7.57E-02	1.15E-01	7.34E-02	7.51E-02

Inadvertent Intruder

	Infant	Child	Teenager	Adult
External	2.09E+00	2.09E+00	2.09E+00	2.09E+00
Vegetable	-	2.91E-03	1.44E-03	8.82E-04
Inhalation	1.66E-03	3.19E-03	2.80E-03	2.09E-03
Water	1.80E-05	1.80E-05	1.80E-03	1.80E-03
Totals:	2.09E+00	2.10E+00	2.10E+00	2.09E+00

APPENDIX G

CALCULATIONAL METHODOLOGY FOR DETERMINING EXTERNAL DOSE RATES FROM RADIONUCLIDES AFTER INCORPORATION INTO SOIL

Wisconsin Electric utilizes QAD, a nationally recognized computer code, to perform shielding and dose rate analyses. The QAD computer code utilizes a point kernel methodology to calculate the dose rate at a specified point due to a given source of radiation.

QAD will be used to calculate the dose rate due to standing on a plot of land utilized for sludge disposal after the radionuclides have been incorporated into the plot by plowing. The following parameters will be used in the calculation:

- The total activity from all previous disposals will be corrected for radiological decay and used as the radionuclide source term.
- Appropriate values will be used to represent the surface area of the plot.
- The radionuclides will be assumed to be incorporated uniformly into the top six inches of soil.
- The dose rate will be calculated at a height of 1 meter above the ground plane at a depth of 5 centimeters in tissue. (Regulatory Guide 1.109 values).
- The density of the soil will be assumed to be 1.3 grams/cubic centimeter.

This calculated dose rate will be used to assess the radiological consequences of past disposals in conjunction with the consequences of proposed future disposals. The total radiological dose consequence of the past and the proposed disposal will be compared to the applicable limits to insure the dose is maintained at or below the limits.

APPENDIX F

Modifications to the Wisconsin Electric submittal to the United States Nuclear Regulatory Commission dated October 8, 1987 (VPNPD-87-430, NRC-87-104), Disposal by Land Application of Sewage Sludge Containing Minute Quantities of Radioactive Material.

MODIFICATION #1

CHANGE TO ORIGINAL SUBMITTAL

Section 3.2, Disposal Procedure (page 3)

Section 3.3, Administrative Procedure (page 4)

The requirements for sludge characterization (the determination of the chemical and physical properties of the sludge) contained in the sections referenced above are modified to allow characterization of the sludge on an annual basis.

BASIS/EXPLANATION

The October 8, 1987 submittal to the USNRC for permission to dispose of sewage treatment sludge containing minute quantities of radioactive material requires that, "prior to disposal the waste stream will be monitored to determine the physical and chemical properties of the sludge. ..." Subsequent to the submittal and the approval by the NRC, a new Wisconsin Pollutant Discharge Elimination System (WPDES) permit was issued to the Point Beach Nuclear Plant by the Wisconsin Department of Natural Resources on November 30, 1988. Both the new WPDES permit and the Point Beach Nuclear Plant Sludge Management Plan specify an annual required frequency for the evaluation of the sludge characteristics.

The original requirement to perform the characterization of the chemical and physical properties of the sewage sludge prior to each disposal has proven time consuming and costly for Wisconsin Electric Lab Services. Preparation of special analytical standards are required to complete the characterization study. The preparation of these standards, sample preparation, and the actual analyses are all manpower intensive and difficult to perform on a timely basis. This has led to requiring overtime for Lab Services personnel and support from outside companies. In order to better utilize the resources of Lab Services while maintaining the requirements of the WPDES permit, the frequency of sludge characterization in the October 8, 1987 submittal to the NRC should be changed to an annual requirement.

This change in the required frequency for determination of the sludge characteristics does not change the requirement to analyze the sewage sludge for radionuclide content or perform dose evaluations prior to each disposal.

APPENDIX G

Modifications to the Wisconsin Electric submittal to the United States Nuclear Regulatory Commission dated October 8, 1987 (VPNPD-87-430, NRC-87-104), Disposal by Land Application of Sewage Sludge Containing Minute Quantities of Radioactive Material.

MODIFICATION #2

CHANGE TO ORIGINAL SUBMITTAL

Section 3.3, Administrative Procedures (Page E-10)

The limitation on the annual volume of sludge disposal per acre contained in the section referenced above is modified to allow unlimited disposal provided the other requirements of this submittal are met.

BASIS/EXPLANATION

The October 8, 1987, submittal to the USNRC for permission to dispose of sewage treatment sludge containing minute quantities of radioactive material requires that "the annual disposal rate for each of the approved land spread sites will be limited to 4,000 gallons/acre, provided WDNR chemical composition, NRC dose guidelines, and concentration and activity limits are maintained within the appropriate values."

The original requirement to limit sewage sludge disposal to 4,000 gallons per acre is based on the assumption that the sewage sludge is contaminated with Co-58 at a concentration that is ten percent of the 10 CFR Part 20 Appendix B Table 2 Column 2 value. Past sewage sludge disposal experience has shown that the sludge may or may not be contaminated and, if it is, at concentrations far below ten percent of the performed prior to each sewage sludge disposal. With the removal of some of the land spread sites due to their use as a storage site for dry storage of spent fuel, this requirement is limiting our ability to dispose of the sewage sludge on the remaining approved land spread sites.

This removal of the annual volume of sewage sludge that may be disposed of per acre on approved land spread sites does not change the requirement to analyze the sewage sludge for radionuclide content or perform dose evaluations prior to each disposal.

This change was evaluated under SER 95-057, "Removal of licensee Commitment Involved With Sewage Sludge Disposal," 4/20/95.

MODIFICATION #2

- Depth to groundwater and bedrock shall be greater than 3 feet from the land surface elevation during use of any site.
- Sludge shall not be land spread in a floodway.
- Sludge shall not be land spread within 50 feet of a property line road or ditch unless the sludge is incorporated with the soil, in which case a minimum separation distance of at least 25 feet is required.
- The pH of the sludge-soil mixture shall be maintained at 6.5 or higher.
- Low areas of the approved fields, subject to seasonally high groundwater levels, are excluded from the sludge application.
- Crops for human consumption shall not be grown on the land for up to one year following the application of the sludge.
- The sludge shall be plowed, disked, injected or otherwise incorporated into the surface soil layer at appropriate intervals.

The flexibility implied in the latter provision for soil incorporation is intended to allow for crops which require more than a one year cycle. For the Point Beach disposal sites, alfalfa is a common crop which is harvested for several years after a single planting. Sludge disposal on an alfalfa plot constitutes good fertilization, but the plot cannot be plowed without destroying the crop. The alfalfa in this case aids in binding the layer of sludge on the surface of the plot. At a minimum, however, plowing (or disking or other method of injection and mixing to a nominal depth of 6 inches) shall be done prior to planting any new crop, regardless of the crop.

3.3 Administrative Procedures

Complete records of each disposal will be maintained. These records will include the concentration of radionuclides in the sludge, the total volume of sludge disposed, the total activity, the plot on which the sludge was applied, the results of the chemical composition determinations, and all dose calculations.

The annual disposal rate for each of the approved land spread sites will be unlimited ~~limited to 4,000 gallons/acre~~, provided WDNR chemical composition, NRC dose guidelines, and concentration and activity limits are maintained within the appropriate values.

The farmer leasing the site used for the disposal will be notified of the applicable restrictions placed on the site due to the land spreading of sewage sludge.

4.0 Evaluation of Environmental Impact

4.1 Site Characteristics

4.1.1 Site Topography

The disposal sites are located in the Town of Two Creeks in the northeast corner of Manitowoc County, Wisconsin, on the

E-10