

INDIAN POINT 3

OFFSITE DOSE CALCULATION MANUAL

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8306210188 830617
PDR ADOCK 05000286
P PDR

ODCM

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1.0 INSTRUMENTATION AND SYSTEMS

1.1 Effluent Monitoring System Description

Effluent monitor information is provided in Table 1-1, including an indication of which monitors use effluent set points. Figures 1-1 and 1-2 show a schematic of the possible radioactive release points with monitor locations for gaseous and liquid pathways respectively.

1.2 Setpoints

This section provides equations and methodology used for each alarm and trip set point on each effluent release point according to Specifications 3.3.3.8 and 3.3.3.9.

1.2.1 Set Points for Gaseous Effluent Monitors

Set points for gaseous monitors are based on the permissible discharge rate as calculated in section 3.4 of this ODCM. The most restrictive set points (based on annual average dose limit) should be used if practical. If not practical and with the concurrence of the Shift Supervisor and/or Superintendent of Power, as appropriate, the quarterly average or instantaneous set points may be used. (per Reference 10, AP-11). The set points are based on the following permissible discharge rates:

<u>Basis of Limit</u>	<u>Permissible Discharge Rate (Ci/sec)</u>	
	<u>Iodine/Particulate*</u>	<u>Noble Gases</u>
Annual Average**	1.66 E-7	3.04 E-3
Quarterly Average**	3.33 E-7	6.08 E-03
Instantaneous (Tech Spec 3.11.2.1)	3.49 E-6	9.84 E-03

*(half-lives greater than 8 days)

** These limits are not part of the Tech Spec requirement 3.11.2.1, but are included for information, as these limits are used for operational control of releases.

The noble gas limits are based on an isotopic mix as described in section 3.4.1

The generic equation for determining an alarm set point is as follows:

$$S = \frac{D}{(E)(F)(4.72 \times 10^{-4})}$$

Where: S = Alarm set point (cpm)
 D = permissible discharge rate (Ci/sec)
 E = Monitor Calibration Factor ($\frac{\mu\text{Ci/cc}}{\text{cpm}}$)
 F = vent duct flow rate (ft^3/min)
 4.72×10^{-4} = conversion factor to convert from $\frac{\mu\text{Ci}}{\text{cc}} \frac{\text{ft}^3}{\text{min}}$ to Ci/sec

GASEOUS EFFLUENT SETPOINTS (CONTINUED)

During normal operation without a primary to secondary leak, the only release point is the Unit 3 main plant vent. However, in the event of a leak, the blowdown flash tank vent and the condenser air ejector would also be release points. In that case, the total discharge rate for all release points must remain less than the permissible discharge rate. Alarm set points would be reduced accordingly, depending on the fraction of the permissible discharge rate allowed to be released from each release point.

1.2.2 Set Points for Liquid Effluent Monitors

Liquid Effluent Monitors R18 and R19 have set points based on limiting the concentrations in the discharge canal to the levels listed in 10 CFR 20 Appendix B, Table 2, Column 2. The set points are calculated based on the following equation:

$$S = \frac{(MPCw) (F)}{E \times f}$$

S = set points on monitor (cpm)

MPCw = Maximum Permissible Concentration (uCi/cc) for isotopic mixture being released per 10 CFR 20, Appendix B, Table 2, Column 2
This will be calculated for each release.

F = Dilution Flow in Discharge Canal (gpm)

f = Release Discharge Rate (gpm)

E = Calibration Factor of monitor $\frac{(uCi/cc)}{cpm}$

EFFLUENT MONITORING SYSTEM DATA

TABLE 1-1

CHANNEL ¹	MONITOR DESCRIPTION	SAMPLING LOCATIONS	DETECTOR TYPE	RANGE	CONTROL FUNCTIONS	Alarm SET POINT USED*	REFERENCE CALIBRATION SOURCES
R-11 P	Containment Particulate Monitor	Samples Drawn from 32 and 35 PCV Air Discharge	Scintillation	0-10 ⁶ cpm	Containment Ventilation Isolation	No	Swipes of Representative Particulate Activity (counted on GeLi)
R-12 G	Containment Gas Monitor	Sample drawn from Containment Fan Coolers #'s 32 & 35	GM-Tube	0-10 ⁶ cpm	Containment Ventilation Isolation	Yes	Gas Marinelli Sample Counted on GeLi
R-13 P	Plant Vent Particulate Monitor	73' level of Fan House monitor plant vent	Scintillation	0-10 ⁶ cpm	None	No	Swipes of representative part. activity counted on GeLi
R-14 G	Plant Vent Radiogas Monitor	In Plant Vent @ approx. 105' level.	GM-Tube	0-10 ⁶ cpm 0- uCi/cc (typical)	Secures waste gas tank release	Yes	Gas Sample Counted on Ge(Li)
R-15 G	Condenser Air Ejector Monitor	In-line detector on the air ejector exhaust header	GM	0-10 ⁶ cpm	On alarm diverts air ejector flow to VC, flash evaporator is shut down, steam to condenser priming ejector flow stopped	NO	Gas Marinelli of Condenser Air Ejector Counted on GeLi
R-20 G	Waste Gas Disposal System Monitor	15' PAB - Waste Gas Tank	Ionization Chamber	0-10 ⁵ mR/hr	None	No	Gas Sample Counted on Ge(Li)
RE-101 G	Admin. Building Vent Radiogas Monitor	4th Floor Admin. Bldg. Monitor Exhaust plenum for controlled Areas	Scintillation	0-10 ⁶ cpm	None	Yes	Gas as per R-12 part as per R-13 Iodine - Charcoal spiked with I131 or BA133 counted on Ge(Li)
RE-102 G	RAMS Bldg. Vent Particulate Monitor	55' RAMS Bldg Monitor Exhaust Plenum	Scintillation	0-10 ⁶ cpm	None	Yes	Same as RE-101
R-18 L	Waste Disposal Liquid Effluent Monitor	55' PAB Waste Condensate Rm. monitors liquid waste discharge	Scintillation	0-10 ⁶ cpm	Stops release on alarm	Yes	Release steam or representative liquid sample
R-19 L	S/G Samples Blowdown Monitor	PAB blowdown room monitors Steam Generator blowdown	Scintillation	0-10 ⁶ cpm	Closes blowdown isolation Valve	Yes	Release steam or representative liquid sample

* Alarm Set Point used for effluent considerations

CHANNEL ¹	MONITOR DESCRIPTION	SAMPLING LOCATIONS	DETECTOR TYPE	RANGE	CONTROL FUNCTIONS	Alarm SET POINT USED *	REFERENCE CALIBRATION SOURCES
RE-202 L	Sewage Treatment Plant	Sewage Treatment Bldg Monitor Plant Effluent	Scintillation	0-10 ⁶ cpm	None	Yes	Not normally calibrated Release stream used when activity is sufficient
RE-623 L	Laundry Monitor	Monitors Admin. Laundry Tanks Release lines	Scintillation	0-10 ⁶ cpm	Isolates Laundry tanks Release to River	Yes	Not normally calibrated Release stream used when activity is sufficient
	Note; 1. "G" denotes "L" denotes	gaseous monitor liquid monitor					

NOTE ON RANGE OF MONITORS:

Maximum release rate that can be detected onscale by the detector (Ci/sec) is based on the maximum readout range of the detector, the calibration factor and the volume flow rate of the discharge.

$$\text{Ci/sec (max)} = (\text{max cpm}) \times (\text{uCi/cc/cpm}) \times (\text{cfm}) \times (4.72 \text{ E-04})$$

4.72 E-04 is a conversion factor from $\frac{\text{uCi}}{\text{cc}} \frac{\text{ft}^3}{\text{min}}$ to Ci/sec

P = Particulates

G = Gaseous

L = Liquid

* Alarm Set Point used for effluent considerations

2.0 LIQUID EFFLUENTS

- 2.1 Liquid Effluent Releases - General Information
- 2.1.1 The surveillance and lower limit of detection requirements for liquid radioactive effluents are contained in Section 4.11.1 of the Technical Specifications. For any and all discharges, a minimum of 100,000 gpm of dilution flow should be available for IP3NPP.
- 2.1.2 A completed and properly authorized Liquid Radioactive Waste Permit shall be issued prior to the release of any radioactive waste from an isolated tank to the discharge canal. A permit is required for each tank to be discharged and must be retained for the life of the plant.
- 2.1.3 All activity determinations for liquid radioactive effluents will be performed in such a manner as to be representative of the activity released to the river. One half of the limits delineated in Section 2.3.1 are applicable to IP3NPP since it is a two unit site.
- 2.1.4 The radioactivity in liquid waste and the discharge flow rate of that waste shall be continuously monitored and recorded during release. If the radiation monitor is inoperable for up to 72 hours, two independent samples of each tank shall be taken and two plant personnel shall independently check valving prior to discharge. If the discharge radiation monitor is inoperable for more than 72 hours, that liquid discharge shall be stopped until the monitor is placed back in service.
- 2.1.5 The radioactivity in steam generator blowdown shall be continuously monitored and recorded. Whenever this monitor is inoperable, the blowdown shall be sampled once per watch until the monitor is returned to service.
- 2.1.6 Prior to discharge, the tank contents shall be recirculated for two tank volumes. After this recirculation, and prior to discharge, a sample shall be taken and analyzed for activity with a portion of the sample set aside for composite analysis. The measured activity shall be used for calculating permissible discharge rate and the alarm set point for the liquid waste discharge monitor. The chemistry technician will provide to the watch the concentration of radioactivity and the MPC for the sample taken and this information will be used to determine the permissible discharge rate and alarm set point.
- 2.1.7 Releases that are continuous such as steam generator blowdown during primary-secondary leaks when released to the river shall be documented on Liquid Radioactive Waste Release Permits on a daily basis using data supplied by the Chemistry technician.

2.1.8 Assurance that combined liquid releases from units 2 and 3 do not exceed section 2.3. limits for the site is provided by administrative controls agreed to in the Memorandum of Understanding (#15) between Con Edison and the Power Authority concerning liquid discharges and the requirements of this document.

2.1.9 The dilution flow from Unit No. 3 should be used for calculating discharge canal concentrations. However, by agreement with Con Edison's IP2NPP Watch Supervisor, and the Power Authority's IP3NPP Watch Supervisor one party can reduce or eliminate radioactive liquid waste discharge for a period of time to allow the other party to use the full site dilution flow, or a specified portion thereof, for a discharge when necessary.

2.2 LIQUID EFFLUENT CONCENTRATIONS

- 2.2.1 This section provides a description of the means that will be used to demonstrate compliance with Technical Specification 3.11.1.1.
- 2.2.2 Compliance with the instantaneous limits of 10CFR20 is achieved by observance of discharge limits and monitor set points. Only dilution water from Unit 3 circulators is taken credit for so the maximum concentration will not exceed limits if Unit 2 is discharging simultaneously. A monthly report is issued which summarizes the radioactive releases from the site for the preceding month. This report provides information necessary to comply with quarterly and annual average limitations on discharge. This report will also contain a calculation of dose based on the method provided in section 2.5 of the ODCM. This dose will be compared to one half of the Appendix I, 10CFR50 limits to determine whether time averaged limits are being approached.
- 2.2.3 Each isolated liquid waste tank must be recirculated for two tank volumes prior to sampling in order to obtain a representative sample.
- 2.2.4 The concentration in liquid effluents prior to dilution in the discharge canal is determined by sampling prior to release, for batch releases. For continuous releases, the concentration is determined by the following equation:

$$C = E \times R$$

C = concentration of liquid effluent (uCi/cc) prior to dilution

E = Calibration factor of monitor $\frac{\text{(uCi/cc)}}{\text{cpm}}$

R = count rate of monitor (cpm)

- 2.2.5 The concentration in liquid effluents after dilution in the discharge canal is determined by the following equation:

$$C_D = \frac{E \times R \times f}{F}$$

C_D = Diluted concentration of liquid effluent (uCi/cc)

f = Release Discharge Rate (gpm)

F = Dilution Flow in Discharge Canal, Unit 3 circulators only (gpm)

2.3 LIQUID EFFLUENT DOSE CALCULATION REQUIREMENTS

2.3.1 Calculational Requirements

2.3.2 Section 3.11.1.2, of the Technical Specification requires that the dose or dose commitment above background to an individual in an unrestricted area from radioactive materials in liquid effluents released from all reactors at the site shall be limited:

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

Cumulative dose concentrations shall be calculated at least once per 31 days.

2.3.3 Section 3.11.1.3, of the Technical Specifications requires that appropriate portions of the radwaste treatment system be used to reduce the radioactive material in liquid waste prior to their discharge when the projected dose due to liquid effluent from all reactors on the site when averaged over 31 days, would exceed 0.06 mrem to the total body or 0.2 mrem to any organ. Also doses due to liquid release shall be projected at least once per 31 days.

Based on past operating history and data, expected future releases can be estimated. By applying the appropriate equations from Section 2.5, projected doses from effluent releases can be approximated.

2.3.4 Section 3.11.1.1, of Technical Specifications require that the concentration of radioactive material released from the site shall be limited to the concentrations specified in 10 CFR Part 20, Appendix B, Table II, Column 2 for radionuclides other than dissolved or entrained noble gases. For dissolved or entrained noble gases the concentration shall be limited to 2×10^{-4} uCi/ml total activity.

2.4 Theoretical Dose Methodology - Maximum Exposed Individual

2.4.1 NUREG 0133 (ref. 1, section 4.3, pg. 14) states that cumulative dose contributions should consider the dose contribution from the maximum exposed individual's consumption of fish, invertebrates and potable water as appropriate. The river at IP3NPP is considered to be fresh water when in reality it is a tidal estuary and never completely fresh. Observed average chlorosity at IP3NPP has ranged as high as 2.5 g/l or about 13% sea water and 87% fresh water. Hence, use of the Hudson River for water supply purposes is precluded south of Chelsea (mile point 65) which is the nearest point of potable water supply. Radionuclide concentration in the nearest water supply have been calculated (ref. 2) to be a factor of at least 500 lower than the river water in the Indian Point area. Exposures from ingestion of the drinking water is therefore negligible.

Based on these factors, potable water consumption is not considered to be a pathway at IP3NPP. Thus, at IP3NPP, the cumulative dose considers only the dose contributions from the maximum exposed individuals consumption of fish and invertebrates. Also, IP3NPP takes the position that the adult is the maximum exposed individual, as recommended by NUREG 0133 (ref. 1, section 4.3, pg. 14). Subsequently, tables of dose factors for the adult case were developed in section 2.4.3.

2.4.2 The relationships and methods that form the calculational base for dose accounting for the liquid effluent pathway are described in this section. These relationships can be used to meet the calculational requirements of section 2.3.1. The cumulative dose factors ($A_{i\gamma}$) are calculated in Section 2.4.3 the following equation is generally applicable and can be used for any number of isotopes released over any time period.

$$D_{\gamma} = \sum_i [A_{i\gamma} \sum_{l=1}^m \Delta t_l C_{i,l} F_l]$$

where:

D_{γ} = The cumulative dose commitment to the total body or any organ, γ , from the liquid effluents for the total time period $\sum_{l=1}^m \Delta t_l$, in mrem.

Δt_l = the length of the l th time period over which $C_{i,l}$ and F_l are averaged for all liquid releases, in hours.

$C_{i,l}$ = the average concentration of radionuclide, i , in undiluted liquid effluent during time period Δt_l from any liquid release, in uCi/ml.

$A_{i\gamma}$ = the site related ingestion dose commitment factor to the total body or any organ γ for each IP3-NPP identified principal gamma and beta emitter listed in table 2-1, in mrem-ml per hr - uCi.

$F\lambda$ = the near field average dilution factor for $Ci\lambda$ during any liquid effluent release. Defined as the ratio of the maximum undiluted liquid waste flow during release to the average flow from the site discharge structure to unrestricted receiving waters.

The term $Ci\lambda$ is the composite undiluted concentration of radioactive material in liquid waste at the release point as determined by the radioactive liquid waste sampling and analysis program as contained in the Technical Specifications. All dilution factors beyond the sample point are included in the $F\lambda$ and $Ai\gamma$ terms.

The term $F\lambda$ is a near field average dilution factor and is determined as follows:

$$F\lambda = \frac{\text{Liquid Radioactive Waste Flow}}{(\text{Discharge Structure Exit Flow} \times (\text{Applicable Factor}))}$$

The liquid radioactive waste flow is the flow from all continuous and batch radioactive effluent releases specified in Technical Specifications from all liquid radioactive waste management systems. The discharge structure exit flow is the average flow during disposal from the discharge structure release point into the receiving body of water. As recommended in NUREG 0133 (ref. 1, section 4.3, pg. 16) the "Applicable Factor" is set equal to 1 because the plant has a once through cooling system.

In order to accurately determine $F\lambda$, it is calculated based on actual operating parameters that exist at the time of releases. This affords a quantitative assessment of radiation dose resulting from liquid effluent releases at IP3NPP. The determination and use of dilution factors is discussed in Section 2.2.

2.4.3 Dose Factor for Liquid Effluent Calculations.

2.4.3.1 The equation for dose from liquid effluents requires the use of a dose factor $Ai\gamma$ for each nuclide, i , which embodies the dose factors, pathway transfer factor, pathway usage factors, and dilution factors for the points of pathway origin. IP3NPP has followed the guidance of NUREG 0133 and has calculated $Ai\gamma$ for the total body and critical organ of the maximum exposed individual e.g. the adult. All the factors needed in the equation were obtained from Regulatory Guide 1.109 (ref. 3) with the exception of the fish bioaccumulator factor (BFI) for Cesium. A factor of 150 was used instead of the 2,000 presented in Table A-1 of the Regulatory Guide. The justification for this substitution is presented in Section 2.5.3. The summary dose factor is as follows:

$$Ai\gamma = K_o (U_F BFi + U_I \cdot BI_i) DF_i$$

where:

Ai = Composite dose parameter for the total body or critical organ for nuclide, i , for all appropriate pathways, mrem/hr per uCi/ml.

k_o = units conversion factor, $1.14E05 = 10^6 \text{ pCi/uCi/ml} \times 10^3 \text{ ml/kg} \div 8760 \text{ hr/yr}$

U_F = 21 Kg/yr, adult fish consumption from table E-5 of Regulatory Guide 1.109.

BF_i = Bioaccumulation factor for nuclide, i , in fish pCi/kg per pCi/l from table A-1 of Regulatory Guide 1.109.

U_I = 5 Kg/yr, adult invertebrate consumption from table E-5 of Regulatory Guide 1.109.

BI_i = Bioaccumulation Factor for nuclide, i , in invertebrates, pCi/kg per pCi/l from table A-1 of Regulatory Guide 1.109.

DF_i = dose conversion factor for nuclide, i , for adults in pre-selected organs, γ , in mrem/pCi, from table E-11 of Regulatory Guide 1.109.

For the IP3NPP site, $Ai\gamma$ can be expressed as:

$$Ai\gamma = 1.14E05 (21 BF_i + 5 BI_i) DF_i$$

IP3NPP has compiled $Ai\gamma$ factors for total body and critical organs for the maximum exposed individual. These are included as table 2-1.

2.5 Operational Dose Methodology

2.5.1 This method is a simple version of that presented in section 2.4. and is more amenable to manual calculation. However, if the resultant dose, calculated using this method exceeds 10% of the limits presented in section 2.3.2, the calculational method presented in Section 2.4 and 2.4.3 must be utilized.

2.5.2 This method is identical to that presented in section 2.1 except that only releases of Cs-134 and Cs-137 are considered and that ingestion of invertebrates is not considered. This is justified based on a previous study (ref. 4) of past releases which identified that doses via the fish ingestion pathway were found to account for more than 90% of the total dose received by the hypothetical maximum exposed individual. In addition, the isotopes Cs-134 and Cs-137 contributed more than 90% of the dose received from fish ingestion. Utilizing these assumptions the equation reduces to the following.

$$D_T = \sum_{l=1}^m A_{Tl} F_l (A_{T_1} C_{l_1} + A_{T_2} C_{l_2})$$

where:

All terms have been previously defined and the subscripts 1 and 2 refer to Cs-134 and Cs-137 respectively.

2.5.3 As stated in section 2.4.3 the bioaccumulation factor (BF_I) for cesium is assumed to be 150 instead of the 2000 listed in Regulatory Guide 1.109 (ref. 3). This is based on the fact that the Hudson River at IP3NPP is not completely fresh, BF_I for salt water is 40 (ref. 2), and that the behavior of cesium in the Hudson is a complex phenomenon.

The NYU study (ref. 2) shows that cesium concentrations in fish are regulated at a relatively constant value independent of the concentration of cesium in water, and the bioaccumulator factors are thus inversely proportional to the water concentration of cesium. This explains the lower bioaccumulation factor for cesium reported by numerous investigators for salt water fish as opposed to fresh water fish because of the higher stable cesium content of sea water. The NYU report states that water at Indian Point has a dissolved cesium concentration which is much higher than would be expected from simple mixing between sea water and fresh water and postulates that these higher concentrations result from leaching of cesium from bottom sediment by saline water.

Use of the bioaccumulation factors of Regulatory Guide 1.109 for a fresh water site will thus substantially overestimate fish ingestion doses because no account is taken of the phenomena just discussed. However, radiocesium concentrations in fish may still be estimated through the use of a bioaccumulation factor,

provided that this factor is determined from the body of water at interest. This factor has been estimated (ref. 2, table IX-5) to be about 150 for the flesh of indigenous fish caught in the Indian Point area. In contrast, the cesium fresh water bioaccumulation factor presented by Regulatory Guide 1.109 for fish is 2000. Fish ingestion doses would therefore be overestimated by a factor of 13 if the Regulatory Guide value were used.

A second conservatism in the NRC model concerns the location at which the concentrations in the river of the discharged cesium are evaluated. Use of this model implies that these fish have grown directly in such a location prior to being caught, which is unrealistic and adds about a factor of five (ref. 2) in conservatism. This conservatism remains in the calculation, thus the use of the NYU (ref. 2) bioaccumulation factor is justifiable since this remains as a conservative calculation.

2.5.4 Based on the discussions in previous paragraphs, the equation for the cumulative dose factor ($A_i \gamma$) reduces to the following assuming the whole body is the critical organ:

$$A_i \gamma = K_o \quad U_F B F_I \quad D F_I$$

where:

All factors have been previously defined. The resultant values for Cs-134 and Cs-137 are as follows:

$$\begin{aligned} \text{Cs-134} &= A \gamma_1 = (1.14E05) (21) (150) (1.21E-04) = 4.35 E04 \\ \text{Cs-137} &= A \gamma_2 = (1.14E05) (21) (150) (7.14E-05) = 2.56 E04 \end{aligned}$$

2.5.5 The final dose equation is as follows:

$$D = \sum_{l=1}^m \Delta t_l \quad F_l \quad (4.35 E04 C l_1 + 2.56E04 C l_2)$$

where:

All terms have been previously defined and the subscripts 1 and 2 refer to Cs-134 and Cs-137 respectively.

2.3.a Calculation of Maximum Permissible Concentrations in Liquid Effluents

2.3.a.1 This section describes the methodology used to meet the requirements of section 2.3.4. The total discharge canal concentration of discharge from all three units, both continuous and intermittent, must be maintained at less than the effective maximum permissible concentration for the respective radionuclide mixture exclusive of dissolved noble gases. The dissolved noble gas limit is contained in Section 2.3.4.

2.3.a.2 The following methodology is utilized to meet the requirements of section 2.3.4.

1. Record tank identification, time of isolation, volume to be discharged; start tank recirculation, recording rate, start time, and end time (later calculated in 2 below).
2. Assure that at least two tank volumes have been recirculated as follows:

$$T = \frac{2V}{G}$$

where:

T = minimum recirculation time (minutes)

V = volume in tank (gallon)

G = recirculation rate (gpm) end time equal to T plus start time.

3. After recirculation have the tank sampled and obtained the radioactive concentration and MPC for the sample. Record this and the total dilution flow from this unit.
4. Determine if other liquid radioactive discharges are being made from this unit and obtain the radioactive concentration and discharge rate. If another release is occurring, the available dilution flow must be adjusted. The adjusted dilution flow is calculated as follows:

$$\frac{Dr (A)}{MPC_{WA}} = E$$

where:

Dr = current release discharge rate (gpm)

E = required dilution flow for current release (gpm)

A = Activity of current release (uCi/cc)

MPC_{WA} = Maximum permissible concentration for current release (uCi/cc).

Adjusted Dilution Flow = Available dilution flow - E.

5. Calculate the permissible radioactive discharge rate for the isolated tank as follows:

$$D = \frac{(MPC_w) (B)}{C}$$

where:

- D = maximum permissible discharge rate (gpm)
B = Adjusted dilution flow available from unit (gpm)
C = radioactive concentration in tank for discharge (uCi/ml).

TABLE 2-1

Ai γ - Liquid Effluent

Case - Adult (maximum exposed individual)

Ai γ = (1.14E05) (21BFI + 5BFI) DFI

Pathway: Invertebrates & Fish

Isotope	BFI	BFI	DFI	DFI	Critical Organ	Ai γ	Ai γ
	PCi/kg pCi/l (Fish)	pCi/kg pCi/l (Inver)	mrem pCi Whole Body	mrem pCi Critical Organ		hr-uCi Whole Body	mrem-ml hr-uCi Critical Organ
³ H	9.0E-01	9.0E-01	1.05E-07	1.05E-07	Whole Body	2.80E-01	2.80E-01
¹⁴ C	4.6E+03	9.1E+3	5.68E-07	2.84E-06	Bone	9.20E+03	4.60E+04
²⁴ Na	1.0E+02	2.0E+02	1.70E-06	1.70E-06	Whole Body	6.01E+02	6.01E+02
³² P	1.0E+05	2.0E+04	7.46E-06	1.93E-04	Bone	1.87E+06	4.84E+07
⁵¹ Cr	2.0E+02	2.0E+03	2.66E-09	6.69E-07	GI-LLI	4.31E+00	1.08E+03
⁵⁴ Mn	4.0E+02	9.0E+04	8.72E-07	1.40E-05	GI-LLI	4.56E+04	7.32E+05
⁵⁶ Mn	4.0E+02	9.0E+04	2.04E-08	3.67E-06	GI-LLI	1.07E+03	1.92E+05
⁵⁶ Fe	1.0E+02	3.2E+03	4.43E-07	2.75E-06	Bone	9.14E+02	5.67E+03
⁵⁹ Fe	1.0E+02	3.2E+03	3.91E-06	3.40E-05	GI-LLI	7.15E+03	7.02E+04
⁵⁸ Co	5.0E+01	2.0E+02	1.67E-06	1.51E-05	GI-LLI	3.90E+02	3.53E+03
⁶⁰ Co	5.0E+01	2.0E+02	4.72E-06	4.02E-05	GI-LLI	1.10E+03	9.39E+03
⁶³ Ni	1.0E+02	1.0E-02	4.36E-06	1.30E-04	Bone	1.29E+03	3.85E+04
⁶⁵ Ni	1.0E+02	1.0E+02	3.13E-08	1.74E-06	GI-LLI	9.28E+00	5.16E+02
⁶⁴ Cu	5.0E+01	4.0E+02	3.91E-08	7.10E-06	GI-LLI	1.36E+01	2.47E+03
⁶⁵ Zn	2.0E+03	1.0E+04	6.96E-06	1.54E-05	Liver	7.30E+04	1.62E+05
⁶⁹ Zn	2.0E+03	1.0E+04	1.37E-09	1.97E-08	Liver	1.44E+01	2.07E+02
⁸³ Br	4.2E+02	3.3E+02	4.02E-08	5.79E-08	GI-LLI	4.80E+01	6.91E+01
⁸⁴ Br	4.2E+02	3.3E+02	5.21E-08	5.21E-08	Whole Body	6.22E+01	6.22E+01
⁸⁵ Br	4.2E+02	3.3E+02	2.14E-09	2.14E-09	Whole Body	2.55E+00	2.55E+00
⁸⁶ Rb	2.0E+03	1.0E+03	9.83E-06	2.11E-05	Liver	5.27E+04	1.13E+05
⁸⁷ Rb	2.0E+03	1.0E+03	3.21E-08	6.05E-08	Liver	1.72E+02	3.24E+02

Table 2-1 Continued

Isotope	BFi	B Li	DFi	DFi	Critical	Critical	Ai γ	Ai γ
	pCi/kg pCi/l (Fish)	pCi/kg pCi/l (Inver)	mrem pCi Whole Body	mrem pCi Critical Organ			hr - uCi Whole Body	hr - uCi Critical Organ
⁸⁹ Rb	2.0E+03	1.0E+03	2.82E-08	4.01E-08	Liver	1.51E+03	2.15E+02	
⁸⁹ Sr	3.0E+01	1.0E+02	8.84E-06	3.08E-04	Bone	1.14E+03	3.97E+04	
⁹⁰ Sr	3.0E+01	1.0E+02	1.86E-03	7.58E-03	Bone	2.40E+05	9.76E+05	
⁹¹ Sr	3.0E+01	1.0E+02	2.29E-07	2.70E-05	GI-LLI	2.95E+01	3.48E+03	
⁹² Sr	3.0E+01	1.0E+02	9.30E-08	4.26E-05	GI-LLI	1.20E+01	5.49E+03	
⁹⁰ Y	2.5E+01	1.0E+03	2.58E-10	1.02E-04	GI-LLI	1.63E-01	6.42E+04	
^{91m} Y	2.5E+01	1.0E+03	3.52E-12	2.67E-10	GI-LLI	2.22E-03	1.68E-01	
⁹¹ Y	2.5E-01	1.0E+03	3.77E-09	7.76E-05	GI-LLI	2.37E+00	4.89E+04	
⁹² Y	2.5E+01	1.0E+03	2.47E-11	1.48E-05	GI-LLI	1.56E-02	9.32E+03	
⁹³ Y	2.5E+01	1.0E+03	7.40E-11	8.50E-05	GI-LLI	4.66E-02	5.35E+04	
⁹⁵ Zr	3.3E+00	6.7E+00	6.60E-09	3.09E-05	GI-LLI	7.73E-02	3.62E+02	
⁹⁷ Zr	3.3E+00	6.7E+00	1.55E-10	1.05E-04	GI-LLI	1.82E-03	1.23E+03	
⁹⁷ Nb	3.0E+04	1.0E+02	1.86E-09	2.10E-05	GI-LLI	1.34E-02	1.51E+06	
⁹⁹ Mo	1.0E+01	1.0E+01	8.70E-07	9.99E-06	GI-LLI	2.43E+01	2.96E+02	
^{99m} Tc	1.5E+01	5.0E+00	8.89E-09	4.13E-07	GI-LLI	3.45E-01	1.60E+01	
¹⁰¹ Tc	1.5E+01	5.0E+00	3.59E-09	6.59E-09	Kidney	1.39E-01	2.55E-01	
¹⁰³ Ru	1.0E+01	3.0E+02	7.97E-08	2.16E-05	GI-LLI	5.80E+00	4.21E+03	
¹⁰⁵ Ru	1.0E+01	3.0E+02	6.08E-09	9.42E-06	GI-LLI	1.19E+00	1.84E+03	
¹⁰⁶ Ru	1.0E+01	3.0E+02	3.48E-07	1.78E-04	GI-LLI	6.78E+01	3.47E+04	
^{110m} Ag	1.0	1.0	8.79E-08	6.04E-05	GI-LLI	2.61E-01	1.79E+02	
^{125m} Te	4.0E+02	6.1E+03	3.59E-07	1.09E-05	Kidney	1.59E+03	4.83E+04	
^{127m} Te	4.0E+02	6.1E+03	8.25E-07	2.75E-05	Kidney	3.66E+03	1.22E+05	
¹²⁷ Te	4.0E+02	6.1E+03	2.38E-08	8.68E-06	GI-LLI	1.06E+02	3.85E+04	
^{129m} Te	4.0E+02	6.1E+03	1.82E-06	5.79E-05	GI-LLI	8.07E+03	2.57E+05	
¹²⁹ Te	4.0E+02	6.1E+03	7.65E-09	1.32E-07	Kidney	3.39E+01	5.85E+02	

Table 2-1 Continued

Isotope	BFi	B Li	DFi	DFi	Critical Organ	Ai γ	Ai γ
	$\frac{\text{pCi/kg}}{\text{pCi/l}}$ (Fish)	$\frac{\text{pCi/kg}}{\text{pCi/l}}$ (Inver)	$\frac{\text{mrem}}{\text{pCi}}$ Whole Body	$\frac{\text{mrem}}{\text{pCi}}$ Critical Organ		$\frac{\text{mrem-ml}}{\text{hr - uCi}}$ Whole Body	$\frac{\text{mrem-ml}}{\text{hr - uCi}}$ Critical Organ
^{131m}Te	4.0E+02	6.1E+03	7.05E-07	8.40E-05	GI-LLI	3.13E+03	3.73E+05
^{131}Te	4.0E+02	6.1E+03	6.22E-09	8.63E-08	Kidney	2.76E+01	3.83E+02
^{132}Te	4.0E+02	6.1E+03	1.53E-06	7.71E-05	GI-LLI	6.78E+03	3.42E+05
^{130}I	1.5E+01	5.0E+00	8.80E-07	1.89E-04	Thyroid	3.41E+01	7.33E+03
^{131}I	2.0E+03	5.0E+00	3.41E-06	1.95E-03	Thyroid	1.63E+04	9.34E+06
^{132}I	2.0E+03	5.0E+00	1.90E-07	1.90E-05	Thyroid	9.1E+02	9.1E+04
^{133}I	2.0E+03	5.0E+00	7.53E-07	3.63E-04	Thyroid	3.6E+03	1.74E+06
^{134}I	2.0E+03	5.0E+00	1.03E-07	4.99E-06	Thyroid	4.94E+02	2.4E+04
^{135}I	2.0E+03	5.0E+00	4.28E-07	7.65E-05	Thyroid	2.1E+03	3.7E+05
^{134}Cs	1.5E+02	1.0E+03	1.21E-04	1.48E-04	Liver	1.12E+05	1.38E+05
^{136}Cs	1.5E+02	1.0E+03	1.85E-05	2.57E-05	Liver	1.72E+04	2.39E+04
^{137}Cs	1.5E+02	1.0E+03	7.14E-05	1.09E-04	Liver	6.63E+04	1.01E+05
^{138}Cs	1.5E+02	1.0E+03	5.40E-08	1.09E-07	Liver	5.02E+01	1.01E+02
^{139}Ba	4.0E+00	2.0E+02	2.84E-09	1.72E-07	GI-LLI	3.51E-01	2.13E+01
^{140}Ba	4.0E+00	2.0E+02	1.33E-06	4.18E-05	GI-LLI	1.64E+02	5.17E+03
^{141}Ba	4.0E+00	2.0E+02	1.59E-09	4.71E-08	Bone	1.96E-01	5.82E+00
^{142}Ba	4.0E+00	2.0E+02	1.34E-09	2.13E-08	Bone	1.66E-01	2.63E+00
^{140}La	2.5E+01	1.0E+03	3.33E-10	9.25E-05	GI-LLI	2.10E-01	5.83E+04
^{142}La	2.5E+01	1.0E+03	1.45E-11	4.25E-07	GI-LLI	9.13E-03	2.68E+02
^{141}Ce	1.0E+00	1.0E+03	7.18E-10	2.42E-05	GI-LLI	4.11E-01	1.39E+04
^{143}Ce	1.0E+00	1.0E+03	1.35E-10	4.56E-05	GI-LLI	7.73E-02	2.61E+04
^{144}Ce	1.0E+00	1.0E+03	2.62E-08	1.65E-04	GI-LLI	1.50E+01	9.44E+04
^{143}Pr	2.5E+01	1.0E+03	4.56E-10	4.03E-05	GI-LLI	2.87E-01	2.54E+04
^{144}Pr	2.5E+01	1.0E+03	1.52E-12	3.01E-11	GI-LLI	9.57E-04	1.90E-02
^{147}Nd	2.5E+01	1.0E+03	4.35E-10	3.49E-05	Bone	2.74E-01	2.20E+04
^{147}W	1.2E+03	1.0E+01	3.01E-08	2.82E-05	GI-LLI	8.66E+01	8.12E+04
^{239}Np	1.0E+01	4.0E+02	6.45E-11	2.40E-05	Liver	1.63E-02	6.05E+03

3.0 GASEOUS EFFLUENTS

3.1 Gaseous Effluent Releases - General Information

- 3.1.1 The surveillance and lower limit of detection requirements for gaseous radioactive effluents are contained in section 4.11.2 of the Technical Specifications. All releases at IP3NPP are assumed to be ground level so there are no elevated releases.
- 3.1.2 A completed and properly authorized Airborne Radioactive Waste Release Permit shall be issued prior to the release of airborne activity from the waste gas holding system, containment purge, and containment pressure relief. The unit shall maintain its own Airborne Radioactive Release Permit book for the life of the plant. The site meteorology indicated in the control room shall be recorded on the Release Permit on an hourly basis during these discharges.
- 3.1.3 All activity determinations for gaseous effluent releases shall be performed in such a manner as to be representative of the activity released from the site. In general, one half of the derived Ci/sec limits delineated in section 3.2 are applicable to IP3NPP since it is a two unit site.
- 3.1.4 During normal operations without a primary to secondary leak, all gaseous ground level releases occur through the main plant vent. However, in the event of a leak, the blowdown flash tank vent and condenser air ejector releases shall be added to those from the main plant vent for the purpose of determining if total release criteria are met.
- 3.1.5 For releases that are expected to continue for periods over two days a new release permit shall be issued each day. Containment purge release permits may be terminated at the discretion of the RESS and be considered as a continuous release until the purge is terminated. However, when plant conditions change that will cause the activity in containment to significantly change a new permit shall be issued.
- 3.1.6 Assurance that the combined gaseous releases from Units 2 and 3 do not exceed section 3.2 limits for the site is provided by administrative controls agreed to in the Memorandum of Understanding (#16) between Con Edison and the Power Authority concerning gaseous effluent discharge and the requirements of the document.
- 3.1.7 By mutual agreement with Con Edison's IP2NPP Watch Supervisor and the Power Authority's IP3NPP Shift Supervisor, one unit can reduce or eliminate discharges for a period of time to allow the other unit to use the full site permissible discharge rate, or a specific portion thereof, for a discharge when necessary.

3.1.8 The annual average limit shall be used for calculating limitations on discharge. If this limit restricts operating flexibility the quarterly average limit may be used by the Shift Supervisor as long as releases for the calendar month stay within the quarterly average and the Operations Superintendent is in agreement. The Shift Supervisor may use the instantaneous limit for release if the Superintendent of Power is in agreement. The instantaneous limit should be checked by the Radiological and Environmental Services department when applied.

3.2 Gaseous Effluent Dose Calculation Requirements

3.2.1 Section 3.11.2.1 of the Technical Specifications requires that the dose rate due to radioactive materials released in gaseous effluents from the site shall be limited to the following:

- a) For noble gases: less than or equal to 500 mrem/yr to the total body and less than or equal to 3000 mrem/yr to the skin, and
- b) For all radioiodines and for all radioactive materials in particulate form and radionuclides (other than noble gases) with half lives greater than 8 days: less than or equal to 1500 mrem/yr to any organ.

3.2.2 Section 3.11.2.2. of the Technical Specifications requires that the air dose due to noble gases released in gaseous effluents, from each reactor unit, shall be limited to the following:

- a) During any calendar quarter: less than or equal to 5 mrad for gamma radiation and less than or equal to 10 mrad for beta radiation.
- b) During any calendar year: less than or equal to 10 mrad for gamma radiation and less than or equal to 20 mrad for beta radiation.

3.2.3 Section 3.11.2.3 of the Technical Specifications requires that the dose to a member of the general public from Iodine-131, tritium, and radionuclides in particulate form with half lives greater than 8 days in gaseous effluents released from each reactor unit shall be limited to the following:

- a) During any calendar quarter: less than or equal to 7.5 mrem to any organ and
- b) During any calendar year; less than or equal to 15 mrem to any organ.

Cumulative dose contributions for the current calendar quarter and current calendar year shall be determined at least once every 31 days.

3.2.4 Section 3.11.2.4 of the Technical Specifications requires that for each reactor unit, the appropriate portions of the gaseous radwaste treatment system shall be used to reduce radioactive effluents in gaseous waste prior to their discharge when projected gaseous effluent air dose at the site boundary when averaged over 31 days, would exceed 0.2 mrad for gamma radiation, 0.4 mrad for beta radiation. The appropriate portions of the ventilation exhaust treatment system shall be used to reduce radioactive materials in gaseous releases when the projected doses when averaged over 31 days, would not exceed 0.3 mrem to any organ (at nearest residence).

Doses due to gaseous release from the site shall be calculated at least once every 31 days.

Section 2.3.3 addresses how projected doses from effluent releases can be evaluated.

3.3 Theoretical Dose Rate Methodology

3.3.1 Theoretical Instantaneous - Noble Gas Releases

3.3.1.1 The equations developed in this section are used to meet the calculational requirements of paragraph 3.2.1. The magnitude of this pathway is the same for all age groups so there is no critical group. Based on a previous agreement with Consolidated Edison, IP3NPP utilizes 50% of the site release limit as measured in Ci/sec which translates to 71% of the applicable dose rate limit. Each unit has different dispersion factors due to their relative positions to the critical sector of the unrestricted area boundary. A calculation showing the relationship between Ci/sec released and dose rates from Units 2 and 3 is shown in Attachment 4-1. The equations for calculating the dose rate limitaitons are obtained from NUREG 0133 (ref. 1, section 5.1). Utilizing the above assumption, these equations reduce to the following:

$$\begin{aligned} \sum_i (K_i) (\overline{X/Q})_v (\dot{Q}_{iv}) &< 357 \text{ mrem/yr} && \text{whole body} \\ \sum_i (L_i + 1.1M_i) (\overline{X/Q})_v (\dot{Q}_{iv}) &= \text{mrem/yr} && \text{skin} \\ \sum_i (s_i) (\overline{X/Q})_v (\dot{Q}_{iv}) &< 2143 \text{ mrem/yr} && \text{to the skin} \end{aligned}$$

Where:

K_i = the total body dose factor due to gamma emissions for each identified noble gas radionuclide, in mrem/yr per uCi/m^3 .

L_i = The skin dose factor due to beta emissions for each identified noble gas radionuclide, in mrem/yr per uCi/m^3 .

M_i = The air dose factor due to gamma emissions for each identified noble gas radionuclide, in mrad/yr per uCi/m^3 (unit conversion constant of 1.1 mrem/mrad converts air dose to skin dose).

N_i = The air dose factor due to beta emissions for each identified noble gas radionuclide, in mrad/yr per uCi/m^3 .

S_i = $(L_i + 1.1M_i)$ in mrem/yr per uCi/m^3 .

Q_{iv} = The release rate of radionuclides, i , in gaseous effluent from the release, in Ci/sec.

$(\overline{X/Q})_v$ = For all vent releases, the highest calculated annual average relative concentration for any area at the unrestricted area boundary, $1.4 \text{ E-}05 \text{ sec/m}^3$ in the SW sector at 350 meters.

The K_i , L_i , M_i , N_i and S_i factors were obtained from Table B-1 of Regulatory Guide 1.109 and are included in this document as Tables 3-4, 3-5, 3-6, 3-7, and 3-8 respectively.

3.3.1.2 These equations can also be expressed in the following manner:

$$\bar{K} (\dot{Q}_{tv}) < 357 \text{ mrem/yr} \quad - \text{ dose to whole body}$$

$$(\bar{L} + 1.1 \bar{M}) (\dot{Q}_{tv}) =$$

$$(\bar{S}) (\dot{Q}_{tv}) < 2143 \text{ mrem/yr} \quad \text{dose to the skin}$$

where:

\dot{Q}_{tv} = The release rate of all noble gases summed together, in uCi/sec

$$\dot{Q}_{tv} = \sum_i \dot{Q}_{iv}$$

$$\bar{K} = (1/\dot{Q}_{tv}) \sum_i \dot{Q}_{iv} \bar{K}_i$$

$$\bar{K}_i = K_i (\bar{X}/Q)_v$$

$$\bar{L} = (1/\dot{Q}_{tv}) \sum_i \dot{Q}_{iv} \bar{L}_i$$

$$\bar{L}_i = L_i (\bar{X}/Q)_v$$

$$\bar{M} = (1/\dot{Q}_{tv}) \sum_i \dot{Q}_{iv} \bar{M}_i$$

$$\bar{M}_i = M_i (\bar{X}/Q)_v$$

$$\bar{N} = (1/\dot{Q}_{tv}) \sum_i \dot{Q}_{iv} \bar{N}_i$$

$$\bar{N}_i = N_i (\bar{X}/Q)_v$$

$$\bar{S} = (1/\dot{Q}_{tv}) \sum_i \dot{Q}_{iv} \bar{S}_i$$

$$\bar{S}_i = S_i (\bar{X}/Q)_v$$

The values of \bar{K}_i , \bar{L}_i , \bar{M}_i , \bar{N}_i and \bar{S}_i have been listed in Table 3-9 for the unrestricted area boundary and Table 3-19 for the nearest residence.

3.3.2 Theoretical Instantaneous - Radioiodines and Particulate Releases

3.3.2.1 The equations developed in this section are used to meet the calculational requirements of paragraph 3.2.1. The critical age group is considered to be the infant as recommended in NUREG-0133 (ref.1, section 5.2.1 pg. 25). Based on a previous agreement with Consolidated Edison, IP3NPP utilizes 50% of the site release limit as measured in Ci/sec which translates to 65% of the applicable dose rate limit. This is a result of the different dispersion factors for each unit due to their relative positions to the critical sector of the unrestricted area boundary. A calculation showing the relationship between Ci/sec released and dose rates from units 2 and 3 is shown in Attachment 4-1. The equation for calculating the dose rate limitation is obtained from NUREG-0133 (ref. 1, section 5.2.1, pg. 25). Utilizing the above assumptions this equation reduces to the following:

$$\sum_k P_i \cdot (W_v \cdot Q_{iv}) \leq 975 \text{ mrem/yr (to any organ) (1500 x 0.65)}$$

where:

P_i = The dose parameter for radionuclides other than noble gases for the inhalation pathway in mrem/yr_2 per uCi/m^3 and for food and ground plane pathways in m^2 mrem/yr per pCi/second . The dose factors are based on the critical individual organ and most restrictive age group:

Paragraph 3.3.2.a, of Gaseous Effluents - Calculation of P_i (inhalation), contains the bases and models for calculation of P_i (inhalation) and its tabulated values. Designated P_i (in).

Paragraph 3.3.2.b, of this manual, Gaseous Effluents - calculation of P_i (ground plane) contains the bases and models for calculation of P_i (ground plane) and its tabulated values. Designated P_i (gp).

Paragraph 3.3.2.c, of this manual, Gaseous Effluents Calculation of P_i (food) contains the bases and models for P_i (food) and its tabulated values. Designated P_i (f).

Q_{iv} = the release rate of radionuclides, i , in gaseous effluents from the release in uCi sec .

W_V = The highest calculated annual average dispersion parameter for estimating the dose to an individual at the controlling location due to all vent releases (see section 3.5.)

$W_V(\text{in})$ = $1.4\text{E-}05 \text{ sec/m}^3$, for the inhalation pathway release. The location is the unrestricted area boundary in the SW sector, at 350 meters.

$W_V(\text{gp})$ = $8.13 \text{ E-}08 \text{ m}^{-2}$, for the ground plane pathway, vent release

The location is the unrestricted area boundary in the SSW sector, at 380 meters.

$W_V(\text{F})$ = $6.7\text{E-}11 \text{ M}^{-2}$, for the food pathway release. The location is in the SSW sector at 8.9 miles. For tritium in the food pathway, use $W_V(\text{in})$ at this location, $1.5\text{E-}08 \text{ sec/m}^3$.

3.3.2.2. To estimate the dose rate for radioiodines and radioactive materials in particulate form other than noble gases, and with half lives greater than 8 days, the following relationships shall be used.

$$(\text{Pi}(\text{in}) W_V(\text{in}) Q_{\text{iv}} + \text{Pi}(\text{gp}) Q_{\text{iv}} + \text{Pi}(\text{food}) W_V(\text{f}) Q_{\text{iv}} + \text{Pi}(\text{Food-H-3}) W_V(\text{in})) = \text{mrem/yr (to any organ)}$$

3.3.2.a Gaseous Effluents - Calculation of Pi (Inhalation Dose Factor)

The Pi parameter contained in the radioiodine and particulates Specification represents the transport pathway of the ith radionuclide, the receptors usage of the pathway media, and dosimetry of the exposure. Pathway usage rates and the internal dosimetry are functions of the receptor's age; however, the youngest age group, the infant, will always receive the maximum dose under the exposure conditions for the Specification delineated in paragraph 3.2.1.

$$Pi \text{ (inhalation)} = K' (BR) DFAi \text{ (mrem/yr per } \mu\text{Ci/m}^3\text{)}$$

where:

K' = a constant of conversion, 10^6 pCi/uCi

BR = the breathing rate of the infant age group ($1400\text{m}^3/\text{yr}$) from Table E-5 of Regulatory Guide 1.109.

DFAi = the maximum organ inhalation dose factor for the infant age group for the ith radionuclide, in mrem/pCi. Taken from Table E-10 of Regulatory Guide 1.109.

Resolution of units yields:

$$Pi \text{ (inhalation)} = 1.4E09 DFAi$$

All Pi (in) factors for the infant age group have been calculated using the above equation and as listed in Table 3-1.

3.3.2.b Gaseous Effluents - Calculation of Pi (Ground Plane)

The factor Pi (ground plane) represents the dose parameter contained in the radioiodine and particulates Specification for the ground plane pathway. This dose factor is based on the critical individual organ (skin or total body), and the most restrictive age groups (infant).

$$P_i = \frac{K'K''DFG_i (1 - e^{-\lambda_i t})}{\lambda_i} \quad (\text{m}^2 \text{mrem/yr per uCi/sec})$$

where:

K' = Constant of unit conversion, 10^6 pCi/uCi

K'' = Constant of unit conversion, 8760 hr/yr

λ_i = Decay constant for the ith radionuclide sec^{-1}

t = Exposure period, 3.15×10^7 sec (1 year)

Resolution of units yields:

$$P_i (\text{ground plane}) = 8.76E09 DFG_i (1 - e^{-\lambda_i t}) / \lambda_i$$

The deposition rate onto the ground plane results in a ground plane concentration that is assumed to persist over a year with radiological decay the only operating removal mechanism for each radionuclide. The ground plane dose conversion factors for the ith radionuclide, DFG_i , are taken from Regulatory Guide 1.109, Table E-6. All Pi (gP) factors have been calculated using the above equations and are listed in Table 3-2.

3.3.2.c Gaseous Effluents Calculation of Pi (Food Dose Factor)

The factor Pi (food) represents the dose parameter contained in the radioiodine and particulate Specification for the food pathway. The organ with the maximum ingestion dose factor will be the limiting organ, and the infant, the limiting age group.

$$Pi \text{ (food)} = K'r \left[\frac{Q_F (U_{ap})}{Y_p (\lambda_i + \lambda_w)} \right] F_m DFL_i \left[e^{-\lambda_i t_f} \right]$$

(m² mrem/yr per uCi/sec)

where:

- K' = Constant of conversion, 10⁶ pCi/uCi
- Q_F = The cow's consumption rate, in Kg/day (wet weight)
- U_{ap} = The infant's milk consumption rate, in liters/yr
- Y_p = The agricultural productivity by unit area, in Kg/m²
- F_m = The stable element transfer coefficients, in days/liter
- r = Fraction of deposited activity retained on cow's feed grass.
- DFLi = The maximum organ ingestion dose factor for the ith radionuclide, i mrem/pCi.
- λ_i = The decay constant for the ith radionuclide, in sec⁻¹
- λ_w = The decay constant for removal of activity on leaf and plant surfaces by weathering, 5.73 x 10⁷ sec⁻¹ (corresponding to a 14 day half-time)
- t_f = The transport time from pasture to cow, to milk, to infant, in sec.

A fraction of the airborne deposition is captured by the ground plant vegetation cover. The captured material is removed from the vegetation (grass) by both radiological decay and weathering processes.

Regulatory Guide 1.109 provides the following parameters:

1. $Q_F = 50\text{Kg/day}$ (Table E-3)
2. $U_{ap} = 330\text{ liters/yr}$ (Table E-5)
3. $Y_p = 0.7\text{ Kg/m}^2$ (Table E-15)
4. $t_f = 2\text{ days}$ ($1.73 \times 10^5\text{ sec}$) (Table E-15)
5. $r = 1.0$ for radioiodines; $r = 0.2$ for particulates (Table I-15)
6. F_m values - Table E-1
7. $DFLi$ values - Table E-14

Resolution of units yields (all radionuclides except H-3):

$$P_i(\text{food}) = 2.4 \times 10^{10} \frac{r F_m}{\lambda_i + \lambda_w} DFLi [e^{-\lambda_i t_f}]$$

($\text{m}^2 \cdot \text{mrem/yr}$ per uCi/sec)

The concentration of tritium in milk is based on its airborne concentration rather than the deposition rate.

$$P_i = K' K'' F_m Q_F U_{ap} DFLi [0.75 (0.5/H)]$$

where:

- $K'' =$ Constant of conversion, 10^3 gm/kg
- $H =$ Absolute humidity of the atmosphere in gm/m^3
- $0.75 =$ Fraction of total feed that is water
- $0.5 =$ The ratio of the specific activity of the feed grass water to the atmospheric water.

Regulatory Guide 1.109 provides the following parameters:

1. $F_m = 1.0 \times 10^{-2}\text{ day/liter}$ (Table E-1)
2. $DFLi = 3.08 \times 10^{-7}\text{ mrem/pCi}$ (Table E-14)

Assuming an average absolute humidity of 8 grams/m^3 , the resolution of units yields (H-3 only):

$$P_i(\text{food}) = 2.4 \times 10^3\text{ mrem/yr per uCi/m}^3$$

all P_i (f) factors have been calculated using the above equations and are listed in Table 3-3.

3.3.3 Time Average Dose - Noble Gas Release

3.3.3.1 The equations in this section are used to meet the calculational requirements of paragraphs 3.2.2 and 3.2.4. All releases at IP3NNP are assumed to be ground level so there are no elevated releases. The magnitude for this pathway is the same for all age groups so there is not critical group. (1978 - 1979 meteorological data)

3.3.3.2 The equations for calculating the dose limitations are obtained from NUREG 0133 (ref. 1 section 5.3) The doses are evaluated at the nearest residence in the unrestricted area in the worst meteorological sector. This is the worst location for which it is reasonable to assume a 100% occupancy factor for a full year. These equations reduce to the following:

a) during any calendar quarter, for gamma radiation:

$$3.17 \times 10^{-8} \sum_i M_i (\bar{X}/Q)_v \tilde{Q}_{iv} + (\bar{x}/q)_v \tilde{q}_{iv} \leq 5 \text{ mrad}$$

during any calendar quarter for the beta radiation:

$$3.17 \times 10^{-8} \sum_i N_i (\bar{X}/Q)_v \tilde{Q}_{iv} + (\bar{x}/q)_v \tilde{q}_{iv} \leq 10 \text{ mrad}$$

b) During any calendar year for gamma radiation:

$$3.17 \times 10^{-8} \sum_i M_i (\bar{X}/Q)_v \tilde{Q}_{iv} + (\bar{x}/q)_v \tilde{q}_{iv} \leq 10 \text{ mrad}$$

during any calendar year for beta radiations:

$$3.17 \times 10^{-8} \sum_i N_i (\bar{X}/Q)_v \tilde{Q}_{iv} + (\bar{x}/q)_v \tilde{q}_{iv} \leq 20 \text{ mrad.}$$

where:

$(\bar{X}/Q)_v$ = For vent releases, the highest calculated annual average relative concentration for the area beyond the unrestricted area boundary in the SSW sector at 1526 meters for long term releases (greater than 500 hrs/years), $1.2E-06 \text{ sec/m}^3$.

$(\bar{x}/q)_v$ = For vent releases, the relative concentration for the areas beyond the unrestricted area boundary for short term releases (equal to or less than 500 hrs/year) in the SSW sector at 1526 meters. This value is calculated as per Section 3.5.

M_i = the air dose factor due to gamma emission for each identified noble gas radionuclide in mrad/yr per uCi/m^3

N_i = the air dose factor due to beta emissions for each identified noble gas radionuclide, in mrad/yr per uCi/m^3 .

\tilde{Q}_{iv} = The average release of noble gas radionuclides in gaseous effluents, i , for short term releases (equal to or less than 500 hrs/yr) from all vents, in uCi. Releases shall be cumulative over the calendar quarter or year as appropriate.

\tilde{Q}_{iv} = The average release of noble gas radionuclides in gaseous effluents, i , for long term releases (greater than 500 hrs/yr) from all vents, in uCi. Releases shall be cumulative over the calendar quarter or year as appropriate.

3.17×10^{-8} = The inverse of the number of seconds in a year.

The air dose factors M_i and N_i were obtained from Table B1 of Regulatory Guide 1.109¹ and are listed in Tables 3-6 and 3-7 respectively.

3.3.4 Theoretical Time Averaged Dose - Radioiodines and Particulates

3.3.4.1 The equations in this section are used to meet the calculational requirements of paragraphs 3.2.3 and 3.2.4. All releases at IP3NPP are assumed to be ground level so there are no elevated releases. Only the infant and child factors are calculated for the purpose of this manual, since they are the most restrictive age groups, NUREG 0133 (ref. 1, section 5.3.1, p. 31).

3.3.4.2 The pathways considered in this analysis are the inhalation, ground plane, vegetable ingestion and milk ingestion. The meat ingestion pathway is not considered because of the high degree of commercial, industrial and residential land usage in the area, and the fact that this pathway was not indicated within ten miles of the plant. The inhalation, ground plane and vegetation ingestion pathways are assumed to exist at the nearest residence in the worst meteorological sector, which is the SSW sector at 1526 meters. The individual at this location is considered to ingest milk from the closest actual dairy farm located in the worst meteorological sector within ten miles of the plant, which is the ESE sector at 8.9 miles. This is believed to be a conservative calculation of dose to the maximum individual.

3.3.4.3 The equations for calculating the dose limitations are obtained from NUREG 0133 (ref. 1, section 5.3.). These equations reduce to the following:

During any calendar quarter:

$$3.17 \times 10^8 \sum_i R_i (W_v \tilde{Q}_{iv} + wv\tilde{q}_{iv}) \leq 7.5 \text{ mrem}$$

During any calendar year:

$$3.17 \times 10^8 \sum_i R_i (W_v \tilde{Q}_{iv} + wv\tilde{q}_{iv}) \leq 15 \text{ mrem}$$

Where:

\tilde{Q}_{iv} = The plant vent releases of radioiodines and radioactive materials in particulate form with half lives greater than eight days, for long term releases greater than 500 hr/yr, in uCi. Releases shall be cumulative over the calendar quarter or year as appropriate.

\tilde{q}_{iv} = The plant vent releases of radioiodines and radioactive materials in particulate form with half lives greater than eight days, for short term releases equal to or less than 500 hrs/yr, in uCi. Releases shall be cumulative over the calendar quarter or year as appropriate.

Wv = The vent dispersion or deposition parameter (based on 1978-79 data meteorological data) for estimating the dose to an individual at the controlling location for long term releases (greater than 500 hrs/yr):

Wv(in) = The highest calculated annual average dispersion parameter for the inhalation pathway for the nearest residence in the unrestricted area located in₃ the SSW sector at 1526 meters, $1.2E-06 \text{ sec/m}^3$.

Wv(dep) = The highest calculated annual average deposition parameter for the ground plane pathway for the nearest residence in the unrestricted area located₂ in the S sector at 1279 meters, $8.8E-09 \text{ m}^{-2}$.

Wv(f) = The highest calculated annual average deposition parameter for the food pathway for existing dairy in the unrestricted area located in₂ the ESE sector at 8.9 miles, $6.7E-11 \text{ m}^{-2}$. For tritium in the food pathway use Wv(in) at this location $1.5E-08 \text{ sec/m}^3$.

wv = The vent dispersion or deposition parameter for estimating the dose to an individual at the controlling location for short term releases (equal or less than 500 hrs/yr) calculated as in Section 3.5.

wv(in) = The highest calculated annual average short term dispersion parameters for the inhalation pathway for the nearest residence in the unrestricted area located in the SSW sector at 1526 meters, in sec/m^3 .

wv(dep) = The highest calculated annual average deposition parameter for the ground plane pathway for the nearest residence in the unrestricted area₂ located in the S sector at 1279 meters in m^{-2} .

wv(f) = The highest calculated annual average short term deposition parameter for the food pathway for existing dairy farms in the unrestricted area located in the ESE sector at 8.9 miles, in m^{-2} . For tritium in the food pathway use wv(in) at this location in sec/m^3 .

3.17×10^{-8} = The inverse number of seconds in a year.

R_i = The dose factor for each identified pathway, organ and radionuclide, i , in m^2 . mrem/yr per uCi/sec or mrem/yr per uCi/ m^3 . (Tables 3-11 - 3-16)

3.3.4.4 Utilizing the assumptions contained in section 3.3.1.2, these equations reduce to the following:

$$3.17E-08 \sum \left\{ R_i^I (Wv(in) \tilde{Q}_{iv} + wv(in) \tilde{q}_{iv}) + (R_i^G + R_i^V) (Wv(dep) \tilde{Q}_{iv} + wv(dep) \tilde{q}_{iv}) + R_I^C (Wv(milk) \tilde{Q}_{iv} + wv(milk) \tilde{q}_{iv}) \right\}$$

$$\leq 7.5 \text{ mrem} \quad \text{Quarterly}$$

$$\leq 15 \text{ mrem} \quad \text{Annual}$$

3.3.4.a Calculation of R_i^I (X/Q) Inhalation Pathway Factor

$$R_i^I (X/Q) = K' (BR)_a (DFAi)_a \quad (\text{mrem/yr per uCi/m}^3)$$

Where:

K' = constant of unit conversion, 10^6 pCi/uCi

$(BR)_a$ = breathing rate of the receptor of age group (a) in m^3 /yr.

$(DFAi)_a$ = The maximum organ inhalation dose factor for the receptor of age group (a) for the i^{th} radionuclide, in mrem/pCi. The total body is considered as an organ in the selection of $(DFAi)_a$.

Only the infant and the child R factors are calculated for the purpose of this manual, since they are the most restrictive age groups. These values are listed in Table 4-11 and 4-12 respectively.

Breathing rates:

Infant = 1400 (m^3 /yr) *

Child = 3700 (m^3 /yr) *

The values of $(BR)_a$ and $(DFAi)_a$ were obtained from Tables E-5 and E-10 respectively of Regulatory Guide 1.109.

3.3.4.b Calculation of R_i^G (D/Q) Ground Plane Pathway Factor.

$$R_i^G \text{ (D/Q)} = K' K'' \text{ (SF)} \text{ (DFG}_i \text{ (} 1 - e^{-\lambda_i t} / \lambda_i \text{))}$$

(m^2 : mrem/yr per uCi/sec)

where:

K' = a constant of conversion, 10^6 pCi/uCi

K'' = a constant of conversion, 8760 hr/yr

λ_i = Decay constant for the i th radionuclide sec^{-1} .

t = The exposure time, 4.73×10^8 sec (15 years)

DFG_i = The ground plane dose conversion factor for the i th radionuclide (mrem/hr per pCi/ m^2)

SF = Shielding factor (dimensionless) = 0.7 from Table E-15 of Regulatory Guide 1.109.

The values of DFG_i were obtained from Table E-6 of Regulatory Guide 1.109. These values were used to calculate R_i^G , which is the same for all age groups and is listed in Table 3-13.

3.3.4.c Calculation of R_i^C (D/Q) - Grass-Cow-Milk Pathway Factor.

$$R_i^C (D/Q) = \frac{\kappa' Q_F (Uap) F_m (r) (DFL_i)_a}{\lambda_i + \lambda_w} \times \left[\frac{fpfs}{Y_P} + \frac{(1-fpfs)e^{-\lambda_i t_h}}{Y_S} \right] e^{-\lambda_i t_f}$$

where:

- κ' = constant of conversion, 10^6 pCi/uCi
- Q_F = Cow's consumption rate, in Kg/day (wet weight)
- Uap = receptor's milk consumption rate for age (a), in liters/yr.
- Y_P = Agricultural₂ productivity by unit area of pasture grass, in Kg/m²
- Y_S = Agricultural₂ productivity by unit area of stored feed, in Kg/m²
- F_m = Stable element transfer coefficients, in days/liter
- r = Fraction of deposited activity retrained on cow's feed grass.
- $(DFL_i)_a$ = The maximum organ ingestion dose factor for the ith radionuclides for the receptor in age group (a) in mrem/pCi.
- λ_i = Decay constant for the ith radionuclide, in sec⁻¹
- λ_w = Decay constant for removal of activity on leaf and plant surfaces by weathering, 5.73×10^{-7} sec⁻¹ (corresponding to a 14 day half-life)
- t_f = The transport time from pasture, to cow, to milk, to receptor in sec.
- t_h = The transport time from pasture, to harvest, to cow, to milk, to receptor, in sec.
- f_p = Fraction of the year that the cow is on pasture.
- f_s = Fraction of the cow feed that is pasture grass while the cow is on pasture.

The concentration of tritium in milk is based on the airborne concentration rather than the deposition. Therefore, the R_i^C is based on X/Q:

$$R_i^C (X/Q) = K' K'' F_m Q_a U_{ap} (DFL_i)_a 0.75 (0.5/H) \quad (\text{mrem/yr per } \mu\text{Ci/m}^3)$$

where:

K'' = a constant of unit conversion, 10^3 gm/kg.

H = absolute humidity of the atmosphere, in gm/m^3 .

0.75 = the fraction of total feed that is water.

0.5 = the ratio of the specific activity of the feed grass water to the atmospheric water.

and other parameters and values are given above. The value of H may be considered as 8 grams/meter³, in lieu of site specific information.

R_i^C Parameters are taken from the following sources:

<u>Parameter</u>	<u>Value</u>	<u>Table (R.G. 1.109)</u>
r (dimensionless)	1.0 for radioiodine	E-15
	0.2 for particulates	E-15
F_m (days/liter)	Each stable element	E-1
U_{ap} (liters/yr) - infant	330	E-5
- child	330	E-5
- teen	400	E-5
- adult	310	E-5
$(DFL_i)_a$ (mrem/pCi)	Each radionuclide	E-11 to E-14
Y_p (kg/m ²)	0.7	E-15
Y_s (kg/m ²)	2.0	E-15
t_f (seconds)	1.73×10^5 (2 days)	E-15
t_h (seconds)	7.78×10^6 (90 days)	E-15
Q_f (kg/day)	50	E-3
f_s *		
f_p *		

* f_s and f_p are assumed to be unity

Only the R_i^C values for the infant and the child are calculated for the purposes of this manual as they are the most restrictive age groups. These values are listed in Table 3-14 and 3-15 respectively.

3.3.4.d. Calculation of $Ri^V [D/Q]$ - Vegetation Pathway Factor

$$Ri^V [D/Q] = K' \left[\frac{(r)}{Y_V (\lambda i + \lambda w)} \right] (DFL_i)_a \left[U_a^L f_{Le}^{-\lambda i t_L} + U_a^S f_{ge}^{-\lambda i t_h} \right]$$

$$= (m^2 \cdot mrem/yr \text{ per } \mu Ci/sec)$$

Where:

- K' = constant of conversion, 10^6 pCi/ μ Ci
- U_a^L = consumption rate of fresh leafy vegetation by the receptor in age group (a), in Kg/yr.
- f_L = fraction of annual intake of fresh leafy vegetation grown locally.
- f_g = the fraction of the annual intake of stored vegetation grown locally.
- t_L = the average time between harvest of leafy vegetation and its consumption, in seconds.
- t_h = the average time between harvest of stored vegetation and its consumption, in seconds.
- Y_V = the vegetation area density, in kg/m².

all other factors are defined in the Calculation of Grass-Cow-Milk Pathway Factor section 3.3.4.c of this manual.

R_i^V Parameters Are From The Following Sources:

<u>Parameter</u>	<u>Value</u>	<u>Table (R.G. 1.109)</u>
r (dimensionless)	1.0 for radioiodines 0.2 for particulates	E-1
$(DFL_i)_a$ (mrem/pCi)	Each radionuclide	E-11 to E-14
U_a^L (kg/yr) - infant	0	E-5
- child	26	E-5
- teen	42	E-5
- adult	64	E-5
U_a^S (kg/yr) - infant	0	E-5
- child	520	E-5
- teen	630	E-5
- adult	520	E-5
f_L (dimensionless)	site specific (default = 1.0)	
f_g (dimensionless)	site specific (default = 0.76) (see Ref. 6, pg.28)	
t_L (seconds)	8.6×10^4 (1 day)	E-15
t_h (seconds)	5.18×10^6 (60 days)	E-15
Y_v (kg/m ²)	2.0	E-15

The concentration of tritium in vegetation is based on the airborne concentration rather than the deposition. Therefore, the R_i^V is based on χ/Q :

$$R_i^V \chi/Q = K'K'' \left[U_a^L f_L + U_a^S f_g \right] (DFL_i)_a [0.75(0.5/H)] \text{ (mrem/yr per } \mu\text{Ci/m}^3 \text{)}$$

where all terms have been defined above and in the grass-cow-milk pathway calculation section of this manual.

Since the infant consumption rate is zero, only the child R_i^V values are calculated. These values are listed in Table 3-16.

3.4 Operational Dose Methodology

3.4.1 Operational Instantaneous - Noble Gas Releases

- 3.4.1.1 This section describes an alternative calculational method to meet the requirements of paragraph 3.2.1. The purpose of this method is to provide a calculational technique which is readily amenable to hand calculation and yields conservative results.
- 3.4.1.2 To determine an acceptable noble gas instantaneous release rate, a standard isotopic mixture of noble gases is assumed. This isotopic mixture was measured for a mixture of isotopics typical of the condenser air ejector with a steam generator tube leak. This requirement is evaluated at the worst sector of the unrestricted area boundary. Based on this isotopic mixture standard \bar{K}_S , \bar{L}_S , \bar{M}_S , \bar{N}_S , and \bar{S}_S (Subscripts denotes weighted sum see Table 3-10) can be determined using the technique presented in paragraph 3.3.1.2 and the \bar{K}_i , \bar{L}_i , \bar{M}_i , \bar{N}_i , and \bar{S}_i values from Table 3-9. The data and results of this calculation are shown in Table 3-10.
- 3.4.1.3 The isotopic mixture chosen was obtained from a condenser air ejector sample during a past primary to secondary leak. Table 3-10 contains the mixture data and the fractional relative abundance of each isotope.

These standard factors can be used with the equations and limits presented in Section 3.3.1. The instantaneous dose rate equations then reduce to the following:

dose to whole body:

$$\bar{K}_S \cdot (Q_{tv}) \leq 357 \text{ mrem/yr}$$

dose to skin:

$$\bar{S}_S \cdot (Q_{tv}) \leq 2143 \text{ mrem/yr}$$

- 3.4.1.4 Utilizing the equations from paragraph 3.4.1.3 and the values from Table 3-10 and 3-10A maximum release limits for all noble gases in uCi/sec can be calculated as follows:

These equations can be solved to yield a maximum instantaneous release rate as follows:

$$Q_{tv} = \frac{357}{\bar{K}} = \frac{357}{3.63E-2} = 9.84 \text{ E03 } \frac{\text{uCi}}{\text{Sec}} \text{ (Whole Body)}$$

$$Q_{tv} = \frac{2143}{\bar{S}_S} = \frac{2143}{6.34E-2} = 3.38 \text{ E04 } \frac{\text{uCi}}{\text{Sec}} \text{ (Skin)}$$

3.4.2 Operational Instantaneous - Radioiodines and Particulates

- 3.4.2.1 This section describes an alternative calculational method to meet the requirements of paragraph 3.2.1. The purposes of this method is to provide a calculational technique which is readily amenable to hand calculation and yields conservative results.
- 3.4.2.2 To determine an acceptable iodine and particulate release rate it is assumed that the limit on these releases shall be met if the total noble gas concentration in the VC is at least a factor of 20,000 more than the concentration of radioiodine and long lived particulates. This has historically been the case and this assures that the noble gas activity will be limiting.
- 3.4.2.3 The thyroid is the critical organ for gaseous releases of iodine and particulates typical of IP3NPP, based on analysis performed in reference 4.
- 3.4.2.4 In performing this analysis it is assumed that the inhalation and ground plane pathways occur at the worst X/Q and D/Q unrestricted area boundary sectors for the instantaneous limit and at the nearest residence in the worst X/Q and D/Q sector for the annual and quarterly limits. The milk pathway is assumed to occur at 8.9 miles in the ESE direction, which is the closest location to the site at which cows are currently kept. In reviewing the dose factors from section 3.3.2, it was noted that for I-131 the dose from the ground plane pathway is approximately a factor of 100 less than the inhalation pathway so it is neglected in this calculation.

3.4.2.5 All iodines and particulates detected are assumed to be I-131 for the purpose of these calculations, which is a conservative assumption since this isotope has the highest thyroid dose factor of all iodines and particulates.

3.4.2.6 The assumptions presented in the previous paragraphs can be used with the equations presented in section 3.3.2 to determine the instantaneous dose rate to the maximum organ of the maximum individual for iodine. However, for the purpose of this operational calculation only 65% of the applicable dose limit will apply as explained in paragraph 3.3.2.1 the instantaneous dose equation reduces to the following:

$$D = (P(\text{in}) Wv(\text{in}) + P(\text{f}) Wv(\text{f})) \dot{Q}_v < 975 \text{ mrem/yr to the thyroid}$$

Where:

D = the dose in mrem/yr

P(in) = The dose parameter of I-131 for the inhalation pathway, $1.48E07 \text{ mrem/yr per } \mu\text{Ci/m}^3$.

P(f) = The dose parameter of I-131 for the milk ingestion pathway, $(1.08E12 \text{ m})$.

Wv(in) = The highest calculated annual average dispersion parameter, for the inhalation pathway at the unrestricted area boundary in the SW sector at 350 meters, $1.4E-05 \text{ sec/m}^3$.

Wv(f) = the highest calculated annual average deposition parameter for the food pathway for existing dairy farms in the unrestricted area located in the ESE sector at 8.9 miles, $6.7E-11 \text{ m}^{-2}$. For tritium in the food pathway use Wv(in) at this location, $1.5E-08 \text{ sec/m}^3$.

\dot{Q}_v = The vent release rate of all iodines and particulates summed together in $\mu\text{Ci/sec}$.

3.4.2.7 These equations can then be solved to yield an estimate of the maximum allowable release rate as follows:

$$\dot{Q}_v = \frac{D}{(P(\text{in}) \cdot Wv(\text{in}) + P(\text{f}) \cdot Wv(\text{f}))}, \text{ where}$$

D = 975 mrem/yr, and the denominator equals $280 \frac{\text{mrem s}}{\mu\text{Ci yr}}$ (See Attach. 4-1) instantaneous:

$$\dot{Q}_v = \frac{975}{2.80E02} = 3.48 \mu\text{Ci/sec}$$

3.4.3 Operational Time Averaged Dose - Noble Gas Releases

3.4.3.1 This section describes the operational method of meeting the requirements of paragraphs 3.2.2 and 3.2.4 and the operational method of implementing the calculation techniques presented in section 3.3.3.

3.4.3.2 On a monthly basis collect the analytical results of all noble gas samples required by the surveillance requirements for IP3NPP.

3.4.3.3 A value of \bar{K}_t , \bar{L}_t , \bar{M}_t , \bar{N}_t and \bar{S}_t is determined for each release using the dispersion parameter for the nearest residence in the worst sector. The calculation is as follows:

$$\bar{K}_i = K_i (\bar{X}/Q)v$$

$$\bar{L}_i = L_i (\bar{X}/Q)v$$

$$\bar{M}_i = M_i (\bar{X}/Q)v$$

$$\bar{N}_i = N_i (\bar{X}/Q)v$$

$$\bar{S}_i = S_i (\bar{X}/Q)v$$

where:

K_i = The total body dose factor due to gamma emissions for each identified noble gas radionuclide, in mrem/yr per uCi/m^3 .

L_i = The skin dose factor due to beta emissions for each identified noble gas radionuclide in mrem/yr per uCi/m^3 .

M_i = The air dose factor due to gamma emissions for each identified noble gas radionuclide, in mrem/yr per uCi/m^3 .

N_i = The air dose factor due to beta emissions for each identified noble gas radionuclide, in mrad/yr per uCi/m^3 .

S_i = The skin dose factor due to beta and gamma emissions for each identified noble gas radionuclide, ($L_i + 1.1 M_i$) in mrem/yr per uCi/m^3 .

$(\bar{X}/Q)v$ = The highest calculated annual average dispersion parameter for the noble gas pathway, at the closest residence in the unrestricted area located in the SSW sector at 1526 meters, $1.2 \text{ E-}06 \text{ sec}/\text{m}^3$; or at the unrestricted area boundary, $1.4\text{E-}05 \text{ sec}/\text{m}^3$.

All values of \bar{K}_i , \bar{L}_i , \bar{M}_i , \bar{N}_i , and \bar{S}_i are shown in Table 3-19 for the worst residence in the unrestricted area.

$$C_t = \sum_i C_i$$

$$\bar{K}_t = (1/C_t) \sum_i \bar{K}_i C_i$$

$$\bar{L}_t = (1/C_t) \sum_i \bar{L}_i C_i$$

$$\bar{M}_t = (1/C_t) \sum_i \bar{M}_i C_i$$

$$\bar{N}_t = (1/C_t) \sum_i \bar{N}_i C_i$$

$$\bar{S}_t = (1/C_t) \sum_i \bar{S}_i C_i$$

Where:

C_i = Concentration of isotope i ($\mu\text{Ci/cc}$) in analysis, t

C_t = Concentration of all noble gas isotopes ($\mu\text{Ci/cc}$) for a specific analysis, t .

- 3.4.3.4 Considering both the continuous and batch releases, determine the total weighted average annual N factors for the calendar month. Utilizing the highest calculated $(\bar{X}/\bar{Q})_v$ for the site boundary; add the resulting value of:

$$3.17 \text{ E-8 } \frac{\text{yr}}{\text{s}} \times \text{total } \mu\text{Ci released} \times (\bar{M}_t (\bar{X}/\bar{Q})_v \text{ and } \bar{N}_t (\bar{X}/\bar{Q})_v),$$

to the appropriate values for the current calendar quarter or calendar year. Compare these sums to the limits of section 3.2.2 and 3.2.4.

3.4.4 Operational Time Averaged Dose - Iodines and Particulates

- 3.4.4.1 This section describes the operational method of meeting the requirements of paragraph 3.2.3 and 3.2.4 and the operational method of implementing the calculational techniques presented in Section 3.3.4.
- 3.4.4.2 On a monthly basis collect the analytical results of iodines and particulates samples required by the surveillance requirements, for IP3NPP.
- 3.4.4.3 The activity of I-131 and particulate released for each weekly sampling period are summed together to get the total activity released for the month, prorating when time periods overlap the monthly periods. This value is then divided by the time in seconds for the month to find Q_t in uCi/sec, the average release rate for the month.

3.4.4.4 $P(\text{in}) = 1.48\text{E}07 \text{ mrem/yr per uCi/m}^3$

$W_v(\text{in}) = 1.2\text{E}-06 \text{ sec/m}^3$
 (highest calculated annual average inhalation dispersion parameter for the nearest residence; 1526 meters SSW)

$P(\text{f}) = 1.08\text{E}12 \text{ m.mrem/yr per uCi/sec}$
 $W_v(\text{f}) = 6.7\text{E}-11 \text{ m}^2$

- 3.4.4.5 Determine the monthly dose and monthly time averaged fraction of the quarterly dose requirements in paragraph 3.2.3. The assumptions utilized for this calculation are the same as those delineated in paragraph 3.4. The inhalation and groundplane pathways are assumed to take place at the nearest residence, when it is reasonable to assume a 100% occupancy time and the cow-milk pathway takes place at the worst actual dairy farm in the vicinity of IP3NPP. The equations from Section 3.3.4 are simplified as follows:

thyroid dose:

$$D = (R^I W_v(\text{in}) + R^C W_v(\text{f})) Q_t \frac{(1 \text{ yr})}{12 \text{ months}} = \text{mrem per month}$$

$$D = ((1.48 \text{ E}07)(1.2 \text{ E}-06) + (1.08 \text{ E}12)(6.7 \text{ E}-11)) Q_t \frac{(1 \text{ yr})}{12 \text{ mos per month}} = \text{mrem}$$

$$D = (7.51 \text{ mrem-sec/uCi-month})Q_t = \text{mrem per month}$$

Compare this thyroid dose to the limits in paragraph 3.2.4. Add this calculated thyroid dose to the calculated values for the prior time period in the calendar quarter and calendar year. Compare these sums to the limits of paragraph 3.2.3.

where:

D = The dose in mrem/month

R^I = The dose parameter of I-131 for the inhalation pathway,
1.48 E07 mrem/yr per uCi/m³.

R^C = The dose parameter of I-131 for the milk ingestion pathway,
1.08 E12 mrem/yr per uCi/sec.

Wv(in) = The highest calculated annual average dispersion parameter
for the inhalation pathway for the nearest residence in the
unrestricted area located in the SSW sector at 1526 meters,
1.2 E-06 sec/m³.

Wv(f) = The highest calculated annual average deposition parameter
for the food pathway for existing dairy farms in the un-
restricted area located in the ESE sector at 8.9 mile, 6.7
E-11 m².

Qt = Average total iodine and particulate release rate for the month
from paragraph 3.4.4.3, uCi/sec.

3.5

Calculation of Meteorological Dispersion Factors

- 3.5.1 For the purpose of these calculations the site boundary was taken to be the unrestricted area boundary. The distances to the site boundary as measured from the center of IP3NPP containment are shown in Table 3-18 for each of the 16 major compass sectors. The distances to the nearest residence in each of these sectors is also shown on this table. In the sectors where the Hudson River is the site boundary, the opposite shore is assumed as the boundary of the unrestricted area. This is based on the definition of unrestricted area in NUREG 0133 (ref. 1, section 22, page 6), which states that the unrestricted area boundary does not include areas over bodies of water. The nearest opposite shore distances is five times that of the closest land restricted area boundary. Therefore, these locations are unimportant when evaluating the maximum unrestricted area boundary concentrations.
- 3.5.2 The atmospheric transport and diffusion model used in the evaluation of dispersion and deposition factors is the straight line flow model presented by Sagendorf in NUREG 0324 (ref. 5). All releases were treated as ground level with credit taken for building wake dilution as applicable and no credit was taken for plume depletion or decay during travel time. Values of sigma Y and sigma Z were defined by onsite measurements of temperature differential which determine the atmosphere stability classes of Regulatory Guide 1.23. These measurements were taken from the onsite meteorological tower; wind data were taken at the 33 foot elevation and temperature differentials between the 200 foot and 33 foot levels. Data recovery for the two years used (1978-1979) was 96.3% and 98.2% respectively. Calms were assigned to the lowest windspeed class and to wind directions in proportion to the directional distribution of the lowest windspeed within an atmospheric stability class. Comparison of these meteorological data with the previous data in the Indian Point area shows that these data are representative of long term conditions at the IP3NPP site. The program of meteorological monitoring and data acquisition is in accordance with Regulatory Guide 1.23.
- 3.5.3 To meet the calculational requirements of paragraph 3.2.1.a the annual average dispersion and deposition factors were calculated for each compass sector at the site unrestricted area boundary, except in the cases where the river was the boundary, to be used for the inhalation and ground plane pathways. For the food pathway the annual average dispersion and deposition factors were calculated for each compass sector at 7 miles which is the closest cows have been kept to the site. In fact, cows are now no longer present this close to the site. The most restrictive compass sector values were chosen and are as follows:

$W_v(\text{in})$ = The highest calculated annual average dispersion parameter for the inhalation pathway at the unrestrictive area boundary in the SW sector at 350 meters, $1.4\text{E-}05 \text{ sec/m}^3$.

Wv(gp) = The highest calculated annual deposition parameter for the ground plane pathway at the unrestricted area boundary in the SSW sector at 380 meters, $8.1E-08 \text{ m}^2$.

Wv(f) = The highest calculated annual average desposition parameter for the food pathway located in the SSW sector at 8.9 miles $6.7E-11 \text{ m}^2$. For tritium in the food pathway use Wv(in) at this location, $1.5E-08 \text{ sec/m}^3$.

3.5.4 To meet the calculational requirements of paragraph 3.2.1.b the annual average coverage dispersion factors were calculated for each compass sector at the site unrestricted area boundary except in the cases where the river was the boundary. The most restrictive compass sector value was chosen as follows:

$(\bar{X}/Q)v$ = The highest calculated annual average dispersion parameter, for the noble gas pathway at the unrestricted area boundary in the SW sector at 350 meters, $1.4E-05 \text{ sec/m}^3$.

3.5.5 To meet the calculational requirements of paragraphs 3.2.3 for iodines and particulates, the annual average deposition and dispersion parameters were calculated for the nearest residence in each of the compass sectors. In addition, the dispersion and deposition parameters for all dairies within ten miles of the site were calculated. These locations and distances are shown in Table 3-18. The most restrictive compass sector values were chosen and are as follows:

Wv(in) = The highest calculated annual average dispersion parameters for the inhalation pathway for the nearest residence in the unrestricted area located in the SSW sector at 1526 meters, $1.2E-06 \text{ sec/m}^3$.

Wv(dep) = The highest calculated annual average deposition parameters for the ground plane pathway for the nearest residence in the unrestricted area located in S sector at 1279 meters, $8.8E-09 \text{ m}^2$.

Wv(f) = The highest calculated annual average depostion paramter for the food pathway for existing dairy farms in the unrestricted area located in the ESE sector at 8.9 miles, $6.7E-11 \text{ m}^2$. For tritium in the food pathway use Wv(in) at this location, $1.5E-08 \text{ sec/m}^3$.

3.5.6 To meet the calculational requirements of paragraphs 3.2.2 and 3.2.4 for noble gases, the annual average dispersion parameters were calculated for the nearest residence in each of the compass sectors, since these are the worst locations for which it is reasonable to assume a 100% occupancy factor. The most restrictive compass sector value was chosen as follows:

$(\overline{X/Q})v$ = The highest calculated annual average dispersion parameters for the noble gas pathway, at the closest residence in the unrestricted area located in the SSW sector at 1526 meters, $1.2E-06 \text{ sec/m}^3$.

3.5.7 To meet the calculational requirements of paragraphs 3.2.2, 3.2.3, and 3.2.4 and the calculation methodologies described in Sections 3.3.4 and 3.3.3 short term release dispersion and deposition factors need to be calculated. For this document short term release dispersion and deposition factors are determined from the long term annual average parameters. The method utilized is that presented by Sagendorf in NUREG 0324 (ref. 5) as recommended by NUREG 0133 (ref. 5 section 3.3, page 8). The short term release calculations assume that the plume uniformly distributes in the horizontal within a $22\frac{1}{2}$ degree sector as recommended in NUREG 0324 (ref. 5, page 22) for many short period releases. All releases are assumed to be ground level, and no credit is taken for plume depletion or decay during plume travel time, and all short term releases are cumulative over the calendar year or quarter as appropriate, NUREG 0133 (ref. 1, section 5.3.1., p. 29). Utilizing the following equation a factor (F) is developed for a particular compass sector and distance which is simply multiplied against the annual average for the same sector and distance to develop the short term dispersion or deposition factor:

$$F = \left(\frac{NTOTAL}{8760} \right) \exp \left[\frac{\log (ANMX/F 15 MX)}{\log 8760} \right]$$

where:

F = The non-dimensional correction factor used to convert annual average dispersion or deposition factors to short term dispersion or deposition factors.

NTOTAL = The total number of intermittent releases in hours.

8760 = The total number of hours in a year.

ANMX = The calculated annual average dispersion (sec/m^3) or deposition (m^{-2}) factor for the compass sector and distance of interest.

F15MX = The short term dispersion (sec/m^3) or deposition (m^{-2}) factor for the Compass sector and distance of interest. This is the 15th percentile value such that worse weather conditions can only exist 15% of the time and better weather conditions 85% of the time.

3.5.8 The short term 15th percentile dispersion or deposition factor for use in the equation of the preceding paragraphs and the simplified F factor equations are as follows:

Paragraph 3.5.5

a) $F_{15MX} (Wv(in)) = 1.38 \text{ E-}05$

$$F(Wv(in)) = \left(\frac{NTOTAL}{8760} \right) \exp \left[\frac{\log (1.2 \text{ E-}06 / 1.38 \text{ E-}05)}{\log 8760} \right]$$

$$F(Wv(in)) = \left(\frac{NTOTAL}{8760} \right) \exp (-0.269)$$

b) $F_{15MX} (Wv(gp)) = 1.6 \text{ E-}05$

$$F(Wv(gp)) = \left(\frac{NTOTAL}{8760} \right) \exp \left[\frac{\log (1.0 \text{ E-}06 / 1.6 \text{ E-}05)}{\log 8760} \right]$$

$$F(Wv(gp)) = \left(\frac{NTOTAL}{8760} \right) \exp (-0.305)$$

c) $F_{15MX} (Wv(f)) = 6.43 \text{ E-}07$

$$F(Wv(f)) = \left(\frac{NTOTAL}{8760} \right) \exp \left[\frac{\log (1.5 \text{ E-}08 / 6.43 \text{ E-}07)}{\log 8760} \right]$$

$$F(Wv(f)) = \left(\frac{NTOTAL}{8760} \right) \exp (-0.414)$$

d) $F_{15MX} ((\overline{X/Q})v) = 1.38 \text{ E-}05$

$$F((\overline{X/Q})v) = \left(\frac{NTOTAL}{8760} \right) \exp \left[\frac{\log (1.2 \text{ E-}06 / 1.38 \text{ E-}05)}{\log 8760} \right]$$

$$F((\overline{X/Q})v) = \left(\frac{NTOTAL}{8760} \right) \exp (-0.269)$$

Pi (inhalation)
 INHALATION DOSE FACTORS

TABLE 3-1

NUCLIDE	CONSTANT (pCi/μCi)	DFAi (mrem/pCi)	ORGAN	Pi (mrem/yr, per μCi/m ³)
H-3	1.4E09	4.62E-07	Total body	6.47E02
Cr-51		9.17E-06	Lung	1.28E04
Mn-54		7.14E-04	Lung	1.00E06
Fe-59		7.25E-04	Lung	1.02E06
Co-58		5.55E-04	Lung	7.77E05
Co-60		3.22E-03	Lung	4.51E06
Zn-65		4.62E-04	Lung	6.47E05
Sr-89		1.45E-03	Lung	1.03E06
Sr-90		2.92E-02	Bone	4.09E07
Zr-95		1.25E-03	Lung	1.75E06
I-131		1.06E-02	Thyroid	1.48E07
I-133		2.54E-03	Thyroid	3.56E06
Cs-134		5.02E-04	Liver	7.03E05
Cs-136		9.61E-05	Liver	1.35E05
Cs-137		4.37E-04	Liver	6.12E05
Ba-140		1.14E-03	Lung	1.60E06
Ce-141		3.69E-04	Lung	5.17E05
P-32		1.45E-03	Bone	2.03E06
Fe-55		6.21E-05	Lung	9.25E04
C-14		1.89E-05	Bone	2.65E04

NUCLIDE	CONSTANT	DFGi (mrem/hr per pCi/m ²)	λ_i (sec ⁻¹)	Pi (m ² mrem/yr per μ Ci/sec)
H-3	8.76E09	0	1.78E-09	0
Cr-51		2.60E-10	2.89E-07	7.88E06
Mn-54		6.80E-09	2.57E-08	1.29E10
Fe-59		9.4E-09	1.80E-07	4.56E08
Co-58		8.20E-09	1.13E-07	6.18E08
Co-60		2.00E-08	4.18E-09	5.17E09
Zn-65		4.60E-09	3.29E-08	7.90E08
Sr-89		6.50E-13	1.58E-07	3.58E04
Sr-90		not given	7.60E-10	0
Zr-95		5.80E-09	1.22E-07	4.08E08
I-131		3.40E-09	9.95E-07	2.98E07
I-133		4.50E-09	9.26E-06	4.26E06
Cs-134		1.40E-08	1.07E-08	3.27E09
Cs-136		1.70E-08	6.17E-07	2.41E08
Cs-137		4.90E-09	7.28E-10	1.34E09
Ba-140		2.40E-09	6.27E-07	3.35E07
Ce-141		6.20E-10	2.48E-07	2.19E07
P-32		0	5.61E-07	0
Fe-55		0	8.14E-09	0
C-14		0	3.84E-12	0

	CONSTANT	r	Fm	λ_i	λ_w	DFLi	tf	Pi
Cr-51	2.4E10	0.2	2.2E-03	2.89E-07	5.73E-07	4.11E-07	1.73E05	4.78E06
Mn-54			2.5E-04	2.57E-08		1.99E-05		3.97E07
Fe-59			1.2E-03	1.80E-07		5.38E-05		3.99E08
Co-58			1.0E-03	1.13E-07		8.98E-06		6.17E07
Co-60			1.0E-03	4.18E-09		2.57E-05		2.14E08
Zn-65			3.9E-02	3.29E-08		6.31E-05		1.94E10
Sr-89			8.0E-04	1.58E-07		2.51E-03		1.28E10
Sr-90			8.0E-04	7.60E-10		1.85E-02		1.24E11
Zr-95			5.0E-06	1.22E-07		2.50E-05		8.46E05
I-131			6.0E-03	9.95E-07		1.39E-02		1.08E+12
I-133			6.0E-03	9.26E-06		3.31E-03		9.74E09
Cs-134			1.2E-02	1.07E-08		7.03E-04		6.92E10
Cs-136			1.2E-02	6.17E-07		1.35E-04		5.88E09
Cs-137			1.2E-02	7.28E-10		6.11E-04		6.13E10
Ba-140			4.0E-04	6.27E-07		1.71E-04		2.46E08
Ce-141			1.0E-04	2.48E-07		2.48E-05		1.39E07
P-32			2.5E-02	5.61E-07		1.70E-03		1.63E11
Fe-55			1.2E-03	8.14E-09		1.39E-05		1.38E08
C-14			1.2E-02	3.84E-12		2.37E-05		2.38E09

TOTAL BODY DOSE FACTORSKiFROM NOBLE GASES (GAMMA)

<u>NUCLIDE</u>	<u>γ - BODY *</u>		<u>10⁶(pCi/μCi)</u>	<u>Ki **</u>
Kr-83m	7.56x10 ⁻⁸	X	10 ⁶	7.56x10 ⁻²
Kr-85m	1.17x10 ⁻³	X	10 ⁶	1.17x10 ³
Kr-85	1.61x10 ⁻⁵	X	10 ⁶	1.61x10 ¹
Kr-87	5.92x10 ⁻³	X	10 ⁶	5.92x10 ³
Kr-88	1.47x10 ⁻²	X	10 ⁶	1.47x10 ⁴
Kr-89	1.66x10 ⁻²	X	10 ⁶	1.66x10 ⁴
Kr-90	1.56x10 ⁻²	X	10 ⁶	1.56x10 ⁴
Xe-131m	9.15x10 ⁻⁵	X	10 ⁶	9.15x10 ¹
Xe-133m	2.51x10 ⁻⁴	X	10 ⁶	2.51x10 ¹
Xe-133	2.94x10 ⁻⁴	X	10 ⁶	2.94x10 ²
Xe-135m	3.12x10 ⁻³	X	10 ⁶	3.12x10 ³
Xe-135	1.81x10 ⁻³	X	10 ⁶	1.81x10 ³
Xe-137	1.42x10 ⁻³	X	10 ⁶	1.42x10 ³
Xe-138	8.83x10 ⁻³	X	10 ⁶	8.83x10 ³
Ar-41	8.84x10 ⁻³	X	10 ⁶	8.84x10 ³

* from Regulatory Guide 1.109, Table B-1 (mrem/yr per uCi/cc)

** Ki (mrem/yr per μCi/m³)

SKIN DOSE FACTORSLiFROM NOBLE GASES (BETA)

<u>NUCLIDE</u>	<u>β - SKIN. *</u>		<u>10^6 (pCi/μCi)</u>	<u>Li **</u>
Kr-83m		X	10^6	
Kr-85m	1.46×10^{-3}	X	10^6	1.46×10^3
Kr-85	1.34×10^{-3}	X	10^6	1.34×10^3
Kr-87	9.73×10^{-3}	X	10^6	9.73×10^3
Kr-88	2.37×10^{-3}	X	10^6	2.37×10^3
Kr-89	1.01×10^{-2}	X	10^6	1.01×10^4
Kr-90	7.29×10^{-3}	X	10^6	7.29×10^3
Xe-131m	4.76×10^{-4}	X	10^6	4.76×10^2
Xe-133m	9.94×10^{-4}	X	10^6	9.94×10^2
Xe-133	3.06×10^{-4}	X	10^6	3.06×10^2
Xe-135m	7.11×10^{-4}	X	10^6	7.11×10^2
Xe-135	1.86×10^{-3}	X	10^6	1.86×10^3
Xe-137	1.22×10^{-2}	X	10^6	1.22×10^4
Xe-138	4.13×10^{-3}	X	10^6	4.13×10^3
Ar-41	2.69×10^{-3}	X	10^6	2.69×10^3

* from Regulatory Guide 1.109, Table B-1 (mrem/yr per pCi/m³)

** Li (mrem/yr per μ Ci/m³)

AIR DOSE FACTORSMiFROM NOBLE GASES (GAMMA)

<u>NUCLIDE</u>	<u>γ - Air *</u>		<u>10^6 (pCi/μCi)</u>	<u>Mi **</u>
Kr-83m	1.93×10^{-5}	X	10^6	1.93×10^1
Kr-85m	1.23×10^{-3}	X	10^6	1.23×10^3
Kr-85	1.72×10^{-5}	X	10^6	1.72×10^1
Kr-87	6.17×10^{-5}	X	10^6	6.17×10^3
Kr-88	1.52×10^{-2}	X	10^6	1.52×10^4
Kr-89	1.73×10^{-2}	X	10^6	1.73×10^4
Kr-90	1.63×10^{-2}	X	10^6	1.63×10^4
Xe-131m	1.56×10^{-4}	X	10^6	1.56×10^2
Xe-133m	3.27×10^{-4}	X	10^6	3.27×10^2
Xe-133	3.53×10^{-4}	X	10^6	3.53×10^2
Xe-135m	3.36×10^{-3}	X	10^6	3.36×10^3
Xe-135	1.92×10^{-3}	X	10^6	1.92×10^3
Xe-137	1.51×10^{-3}	X	10^6	1.51×10^3
Xe-138	9.21×10^{-3}	X	10^6	9.21×10^3
Ar-41	9.30×10^{-3}	X	10^6	9.30×10^3

* from Regulatory Guide 1.109, Table B-1

** Mi (mrad/yr per μ Ci/ m^3)

Table 3-7

Air Dose Factors (Ni) From Noble Gases (Beta)

Nuclide	*Beta Air	10^6 (pCi/uCi)	Ni**
Kr-83m	2.88E-04	10^6	2.88E02
Kr-85m	1.97E-03	10^6	1.97E03
Kr-85	1.95E-03	10^6	1.95E03
Kr-87	1.03E-02	10^6	1.03E04
Kr-88	2.93E-03	10^6	2.93E03
Kr-89	1.06E-02	10^6	1.06E04
Kr-90	7.83E-03	10^6	7.83E03
Xe-131m	1.11E-03	10^6	1.11E03
Xe-133m	1.48E-03	10^6	1.48E03
Xe-133	1.05E-03	10^6	1.05E03
Xe-135m	7.39E-04	10^6	7.39E02
Xe-135	2.46E-03	10^6	2.46E03
Xe-137	1.27E-02	10^6	1.27E04
Xe-138	4.75E-03	10^6	4.75E03
Ar-41	3.28E-03	10^6	3.28E03

* From Regulatory Guide 1.109, Table B-1

** Ni (mrad/yr per uCi/m³)

SKIN DOSE FACTORS FROM NOBLE GASES (BETA-GAMMA)

$$Si = (Li + 1.1Mi)$$

NUCLIDE	* <u>Li</u>	** <u>Mi</u>	*** <u>Si = (Li + 1.1Mi)</u>
Kr-83m		1.93×10^1	2.12×10^3
Kr-85m	1.46×10^3	1.23×10^3	2.81×10^3
Kr-85	1.34×10^3	1.72×10^1	1.36×10^3
Kr-87	9.73×10^3	6.17×10^3	1.62×10^4
Kr-88	2.37×10^3	1.52×10^4	1.91×10^4
Kr-89	1.01×10^4	1.73×10^4	2.91×10^4
Kr-90	7.29×10^3	1.63×10^4	2.52×10^4
Xe-131m	4.76×10^2	1.56×10^2	6.48×10^2
Xe-133m	9.94×10^2	3.27×10^2	1.35×10^3
Xe-133	3.06×10^2	3.53×10^2	6.94×10^2
Xe-135m	7.11×10^2	3.36×10^3	4.41×10^3
Xe-135	1.86×10^3	1.92×10^3	3.97×10^3
Xe-137	1.22×10^4	1.51×10^3	1.39×10^3
Xe-138	4.13×10^3	9.21×10^3	1.43×10^4
Ar-41	2.69×10^3	9.30×10^3	1.29×10^4

* From Table NG-2 (mrad/yr per $\mu\text{Ci}/\text{m}^3$)

** From Table NG-3 (mrad/yr per $\mu\text{Ci}/\text{m}^3$)

*** Si (mrem/yr per $\mu\text{Ci}/\text{m}^3$)

Table 3-9 Dose Factors for Site Boundary

Nuclide	$\overline{\text{Ki}}$	$\overline{\text{Li}}$	$\overline{\text{Mi}}$	$\overline{\text{Ni}}$	$\overline{\text{Si}}$
Kr-83m	1.06E-06		2.70E-04	4.03E-03	2.97E-02
Kr-85m	1.64E-02	2.04E-02	1.72E-02	2.76E-02	3.93E-02
Kr-85	2.25E-04	1.88E-02	2.41E-04	2.73E-02	1.90E-02
Kr-87	8.29E-02	1.36E-01	8.64E-02	1.44E-01	2.31E-01
Kr-88	2.06E-01	3.32E-02	2.13E-01	4.10E-02	2.67E-01
Kr-89	2.32E-01	1.41E-01	2.42E-01	1.48E-01	4.07E-01
Kr-90	2.18E-01	1.02E-01	2.28E-01	1.10E-01	3.53E-01
Xe-131m	1.28E-04	6.66E-03	2.18E-03	1.55E-02	9.07E-03
Xe-133m	3.51E-03	1.39E-02	4.58E-03	2.07E-02	1.89E-02
Xe-133	4.12E-03	4.28E-03	4.94E-03	1.47E-02	9.72E-03
Xe-135m	4.37E-02	9.95E-03	4.70E-02	1.03E-02	6.17E-02
Xe-135	2.53E-02	2.60E-02	2.69E-02	3.44E-02	5.56E-02
Xe-137	1.99E-02	1.71E-01	2.11E-02	1.78E-01	1.95E-02
Xe-138	1.24E-01	5.78E-02	1.29E-01	6.65E-02	2.00E-01
Ar-41	1.24E-01	3.77E-02	1.30E-01	4.59E-02	1.81E-01

$$(\overline{\text{X/Q}})_v = 1.4\text{E-}05 \text{ sec/m}^3$$

* $\overline{\text{Ki}}, \overline{\text{Li}}, \overline{\text{Si}}$, (mrem.sec per uCi.yr)

** $\overline{\text{Mi}}, \overline{\text{Ni}}$, (mrad.sec per uCi.yr)

TABLE 3-10

DOSE FACTORS FOR SITE BOUNDARY
FOR STANDARD ISOTOPIC MIXTURE

Nuclide	Relative Abundance (Q _{iv})	Q _{iv} \bar{K}_i	Q _{iv} \bar{L}_i	Q _{iv} \bar{M}_i	Q _{iv} \bar{N}_i	Q _{iv} \bar{S}_i
Kr-85M	4.06 E-2	6.66 E-4	8.28 E-4	6.98 E-4	1.12 E-3	1.60 E-3
Kr-87	4.36 E-2	3.61 E-3	5.93 E-3	3.77 E-3	6.28 E-3	1.01 E-2
Kr-88	8.25 E-2	1.70 E-2	2.74 E-3	1.76 E-2	3.38 E-3	2.20 E-2
Xe-131M	1.09 E-1	1.40 E-5	7.26 E-4	2.38 E-4	1.69 E-3	9.89 E-4
Xe-133M	1.23 E-2	4.32 E-5	1.71 E-4	5.63 E-5	2.55 E-4	2.32 E-4
Xe-133	4.11 E-1	1.69 E-3	1.76 E-3	2.03 E-3	6.04 E-3	3.99 E-3
Xe-135M	2.88 E-2	1.26 E-3	2.87 E-4	1.35 E-3	2.97 E-4	1.78 E-3
Xe-135	2.21 E-1	5.39 E-3	5.75 E-3	5.94 E-3	7.60 E-3	1.23 E-2
Xe-138	5.18 E-2	6.62 E-3	2.99 E-3	6.68 E-3	3.44 E-3	1.04 E-2
Total	1.00	3.63 E-2	1.94 E-2	3.84 E-2	3.01 E-2	6.34 E-2

* $\bar{K}_s = 3.63 \text{ E-2}$
 $\bar{L}_s = 1.94 \text{ E-2}$
 $\bar{M}_s = 3.84 \text{ E-2}$
 $\bar{N}_s = 3.01 \text{ E-2}$
 $\bar{S}_s = 6.34 \text{ E-2}$

$\bar{K}_s, \bar{L}_s, \bar{S}_s$ (mrem - sec per uCi-yr)

\bar{M}_s, \bar{N}_s (mrad - sec per uCi-yr)

K_i, L_i, M_i, N_i, S_i from Table 3-9

* The subscript, s, denotes a weighted sum; for example:

$$\bar{K}_s = \sum_i Q_{iv} \bar{K}_i \quad (\bar{K}_i \text{ can be found in Table 3-9}).$$

TABLE 3-10A

DOSE FACTORS AT NEAREST RESIDENCE
FOR STANDARD ISOTOPIC MIXTURE

Nuclide	Relative Abundance (Qiv)	\bar{Q}_{ivKi}	\bar{Q}_{ivLi}	\bar{Q}_{ivMi}	\bar{Q}_{ivNi}	\bar{Q}_{ivSi}
Kr-85M	4.06 E-2	5.68 E-5	7.11 E-5	6.01 E-5	9.58 E-5	1.37 E-4
Kr-87	4.36 E-2	3.10 E-4	5.10 E-4	3.23 E-4	5.41 E-4	8.63 E-4
Kr-88	8.25 E-2	1.39 E-3	2.34 E-4	1.50 E-3	2.90 E-4	1.89 E-3
Xe-131M	1.09 E-1	1.20 E-5	6.22 E-5	2.04 E-5	1.45 E-4	8.48 E-5
Xe-133M	1.23 E-2	3.70 E-7	1.46 E-5	4.82 E-6	2.19 E-5	1.99 E-5
Xe-133	4.11 E-1	1.45 E-4	1.51 E-4	1.74 E-4	5.18 E-4	3.42 E-4
Xe-135M	2.88 E-2	1.08 E-4	2.46 E-5	1.16 E-4	2.55 E-5	1.52 E-4
Xe-135	2.21 E-1	4.80 E-4	4.93 E-4	5.09 E-4	6.52 E-4	1.05 E-3
Xe-138	5.18 E-2	5.49 E-4	2.57 E-4	5.75 E-4	2.95 E-4	8.91 E-4
Total	1.00	3.05 E-3	1.82 E-3	3.28 E-3	2.58 E-3	5.43 E-3

$$\bar{Ks} = 3.05 \text{ E-3}$$

$$\bar{Ls} = 1.82 \text{ E-3}$$

$$\bar{Ms} = 3.28 \text{ E-3}$$

$$\bar{Ns} = 2.58 \text{ E-3}$$

$$\bar{Ss} = 5.43 \text{ E-3}$$

$\bar{Ks}, \bar{Ls}, \bar{Ss}$ (mrem - sec per uCi - yr)

\bar{Ms}, \bar{Ns} (mrad - sec per uCi-yr)

$\bar{Ki}, \bar{Li}, \bar{Mi}, \bar{Ni}, \bar{Si}$ from Table 3-19

INFANT INHALATION DOSE FACTORS

I
R_i Infant

TABLE 3-11

Radionuclide	(pCi/μCi) K'	(m ³ /yr) BR	mrem/Pci* DFAi	Organ	I R _i mrem/yr per μCi/m ³
Cr-51	10 ⁶	1.4E03	9.17E-06	Lung	1.28E04
Mn-54	↓	↓	7.14E-04	Lung	1.00E06
Fe-59	↓	↓	7.25E-04	Lung	1.02E06
Co-58	↓	↓	5.55E-04	Lung	7.77E05
Co-60	↓	↓	3.22E-03	Lung	4.51E06
Zn-65	↓	↓	4.62E-04	Lung	6.47E07
Sr-89	↓	↓	1.45E-03	Lung	2.03E06
Sr-90	↓	↓	2.92E-02	Bone	4.09E07
Zr-95	↓	↓	1.25E-03	Lung	1.75E06
I-131	↓	↓	1.06E-02	Thyroid	1.48E07
I-133	↓	↓	2.54E-03	Thyroid	3.56E06
Cs-134	↓	↓	5.02E-04	Liver	7.03E05
Cs-136	↓	↓	9.61E-05	Liver	1.35E05
Cs-137	↓	↓	4.37E-04	Liver	6.12E05
Ba-140	↓	↓	1.14E-03	Lung	1.60E06
Ce-141	↓	↓	3.69E-04	Lung	5.17E05
H-3	↓	↓	4.62E-07	Body	6.47E02
P-32	↓	↓	1.45E-03	Bone	2.03E06
Fe-55	↓	↓	6.21E-05	Lung	8.69E04
C-14	↓	↓	1.89E-05	Bone	2.65E04

* From Table E-10, Regulatory Guide 1.109

CHILD INHALATION DOSE FACTORS

I
R_i Child

Table 3-12

Radionuclide	(pCi/μCi) K'	(m ³ /yr) BR	mrem/Pci* DFAi	Organ	I R _i mrem/yr per μCi/m ³
Cr-51	10 ⁶	3.7E03	4.59E-06	Lung	1.70E04
Mn-54			4.26E-04	Lung	1.58E06
Fe-59			3.43E-04	Lung	1.27E06
Co-58			2.99E-04	Lung	1.11E06
Co-60			1.91E-03	Lung	7.07E06
Zn-65			2.69E-04	Lung	9.95E05
Sr-89			5.83E-04	Lung	2.16E06
Sr-90			2.73E-02	Bone	1.01E08
Zr-95			6.03E-04	Lung	2.23E06
I-131			4.39E-03	Thyroid	1.62E07
I-133			1.04E-03	Thyroid	3.85E06
Cs-134			2.74E-04	Liver	1.01E06
Cs-136			4.62E-05	Liver	1.71E05
Cs-137			2.45E-04	Bone	9.07E05
Ba-140			4.71E-04	Lung	1.74E06
Ce-141			1.47E-04	Lung	5.44E05
H-3			3.04E-07	Body	1.12E03
P-32			7.04E-04	Bone	2.60E06
Fe-55			3.00E-05	Lung	1.11E05
C-14			9.70E-06	Bone	3.59E04

* From Table E-9, Regulatory Guide 1.109

INFANT GROUND PLANE DOSE FACTORS

G
R_i

Table 3-13

Nuclide	(pCi/μCi) K'	hr/yr K''	* SF	** DFG _i	(sec) t	(sec ⁻¹) λ _i	G R _i
Cr-51	10 ⁶	8.76E03	7.0E-01	2.6E-10	4.73E08	2.89E-07	5.52E06
Mn-54				6.8E-09		2.57E-08	1.62E09
Fe-59				9.4E-09		1.80E-07	3.20E08
Co-58				8.2E-09		1.13E-07	4.45E08
Co-60				2.00E-08		4.18E-09	2.53E10
Zn-65				4.6E-09		3.29E-08	8.57E08
Sr-89				6.5E-13		1.58E-07	2.52E04
Sr-90				not given		7.60E-10	0
Zr-95				5.8E-09		1.22E-07	2.92E08
I-131				3.4E-09		9.95E-07	2.10E07
I-133				4.5E-09		9.26E-06	2.98E06
Cs-134				1.4E-08		1.07E-08	7.97E09
Cs-136				1.7E-08		6.17E-07	1.69E08
Cs-137				4.9E-09		7.28E-10	1.20E10
Ba-140				2.4E-09		6.27E-07	2.35E07
Ce-141				6.2E-10		2.48E-07	1.53E07
H-3				0		1.78E-09	0
P-32				0		5.61E-07	0
Fe-55				0		3.14E-09	0
C-14				0		3.84E-12	0

* From Table E-15 Regulatory Guide 1.109

** From Table E-6 Regulatory Guide 1.109

C
 Ri [D/Q] Grass-Cow-Milk Pathway Factor (infant)

TABLE 14

Nucl.	K'	QF	Uap	Yp	Ys	Fm	r	DFL ⁱ	Organ	λ_i	λ_w	tf	th	fp	fs	^C Ri
Cr-51	10 ⁶	50	330	0.7	2.0	2.2E-03	0.2	4.11E-07	GI-LLI	2.89E-7	5.73E-7	1.73E5	7.78E6	1	1	4.71E06
Mn-54						2.5E-04	0.2	1.99E-05	Liver	2.57E-8						3.90E07
Fe-59						1.2E-03	0.2	5.38E-05	Liver	1.8E-7						3.92E08
Co-58						1.0E-03	0.2	8.98E-06	Body	1.13E-7						6.06E07
Co-60						1.0E-03	0.2	2.57E-05	GI-LLI	4.18E-9						2.10E08
Zn-65						3.9E-02	0.2	6.31E-05	Liver	3.29E-8						1.91E10
Sr-89						8.0E-04	0.2	2.51E-03	Bone	1.58E-7						1.26E10
Sr-90						8.0E-04	0.2	1.85E-02	Bone	7.6E-10						1.22E11
Zr-95						5.0E-06	0.2	2.50E-05	GI-LLI	1.22E-7						8.31E05
I-131						6.0E-03	1.0	1.39E-02	Thyroid	9.95E-7						1.06E12
I-133						6.0E-03	1.0	3.31E-03	Thyroid	9.26E-6						9.60E09
Cs-134						1.2E-02	0.2	7.03E-04	Liver	1.07E-8						6.81E10
Cs-136						1.2E-02	0.2	1.35E-04	Liver	6.17E-7						5.77E09
Cs-137						1.2E-02	0.2	6.11E-04	Liver	7.28E-10						6.03E10
Ba-140						4.0E-04	0.2	1.71E-04	Bone	6.27E-7						2.41E08
Ce-141						1.0E-04	0.2	2.48E-05	GI-LLI	2.48E-7						1.37E07
H-3						1.0E-02	0.2	3.08E-07	Body	1.78E-9						2.38E03
P-32						2.5E-02	0.2	1.70E-03	Bone	5.61E-7						1.61E11
Fe-55						1.2E-03	0.2	1.39E-05	Bone	8.14E-9						1.35E08
C-14						1.2E-02	0.2	2.37E-05	Bone	3.84E-12						2.34E09

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C
 Ri $\sqrt{D/Q}$ Grass-Cow-Milk Pathway Factor (child)

Nucl.	K'	QF	Uap	Yp	Ys	Fm	r	DFLi	Organ	λ_i	λ_w	tf	th	fp	fs	$\frac{C}{Ri}$
Cr-51	10 ⁶	50	330	0.7	2.0	2.2E-03	0.2	4.72E-7	GI-LLI	2.89E-7	5.73E-7	1.73E5	7.78E6	1	1	5.41E00
Mn-54						2.5E-04	0.2	1.07E-5	Liver	2.57E-8						2.10E00
Fe-59						1.2E-03	0.2	2.78E-5	GI-LLI	1.8E-7						2.03E00
Co-58						1.0E-03	0.2	1.05E-5	GI-LLI	1.13E-7						7.08E00
Co-60						1.0E-03	0.2	2.93E-5	GI-LLI	4.18E-9						2.39E00
Zn-65						3.9E-02	0.2	3.65E-5	Liver	3.29E-8						1.10E10
Sr-89						8.0E-04	0.2	1.32E-3	Bone	1.58E-7						6.63E09
Sr-90						8.0E-04	0.2	1.70E-2	Bone	7.6E-10						1.12E11
Zr-95						5.0E-06	0.2	2.66E-5	GI-LLI	1.22E-7						8.84E09
I-131						6.0E-03	1.0	5.72E-3	Thyroid	9.95E-7						4.35E11
I-133						6.0E-03	1.0	1.36E-3	Thyroid	9.26E-6						3.95E09
Cs-134						1.2E-02	0.2	3.84E-4	Liver	1.07E-8						3.72E10
Cs-136						1.2E-02	0.2	6.46E-5	Liver	6.17E-7						2.76E09
Cs-137						1.2E-02	0.2	3.27E-4	Bone	7.28E-10						3.23E10
Ba-140						4.0E-04	0.2	8.31E-5	Bone	6.27E-7						1.17E08
Ce-141						1.0E-04	0.2	2.47E-5	GI-LLI	2.48E-7						1.36E07
H-3						1.0E-02	0.2	2.03E-7	Body	1.78E-9						3.52E02
P-32						2.5E-02	0.2	8.25E-4	Bone	5.61E-7						7.79E10
Fe-55						1.2E-03	0.2	1.15E-5	Bone	8.14E-9						1.12E08
C-14						1.2E-02	0.2	1.21E-5	Bone	3.84E-12						1.20E09

Table 3-16
Vegetation Primary Dose Factors (Child)

$R_i^v [D/Q]$

Nucl.	K'	$\frac{L}{Ua}$	$\frac{S}{Ua}$	Yv	λ_w	r	DFLi	λ_i	f1	fg	t1	th	$\frac{v}{R_i}$
Cr-51	10 ⁶	26	520	2.0	5.73E-07	0.2	4.27E-07	2.89E-07	1.0	0.76	8.6E4	5.18E6	6.23E06
Mn-54						0.2	1.07E-05	2.57E-08					6.65E08
Fe-59						0.2	2.78E-05	1.8E-07					6.69E08
Co-58						0.2	1.05E-05	1.13E-07					3.76E08
Co-60						0.2	2.93E-05	4.18E-09					1.71E09
Zn-65						0.2	3.65E-05	3.29E-08					2.16E09
Sr-89						0.2	1.32E-03	1.58E-07					3.61E10
Sr-90						0.2	1.70E-02	7.6E-10					1.24E12
Zr-95						0.2	2.66E-05	1.22E-07					9.02E08
I-131						1.0	5.72E-03	9.95E-07					4.77E10
I-133						1.0	1.36E-03	9.2E-06					8.20E08
Cs-134						0.2	3.84E-04	1.07E-08					2.63E10
Cs-136						0.2	6.46E-05	6.17E-07					2.22E08
Cs-137						0.2	3.27E-04	7.28E-10					2.39E10
Ba-140						0.2	8.31E-05	6.27E-07					2.77E08
Ce-141						0.2	2.47E-05	2.48E-07					4.06E08
H-3						0.2	2.03E-07	1.78E-09					4.01E03
P-32						0.2	8.25E-04	5.61E-07					3.38E09
Fe-55						0.2	1.15E-05	8.14E-09					8.01E08
C-14						0.2	1.21E-05	3.84E-12					8.89E08

TABLE 3-18

Locations of Site Boundary, Residences, Dairy Cows

<u>Sector</u>	<u>Distance*</u> <u>Nearest Point of</u> <u>Site Boundary</u> (Meters)	<u>Distance*</u> <u>Nearest Residence</u> (Meters)	<u>Distance*</u> <u>Nearest Cow</u> (Miles)
N	River	1950	
NNW	River	1740	
NW	River	1830	
WNW	River	1830	
W	River	1890	
WSW	River	2135	
SW	350	2745	
SSW	380	1525	
S	580	1280	
SSE	595	1220	
SE	580	1100	
ESE	580	1070	8.9
E	625	730	
ENE	760	1370	10.0
NE	790	1525	
NNE	River	3050	19.6

* Measured from Indian Point 3.

Dose Factors for Nearest Residence

Table 3-19

Nuclide	\bar{K}_i	\bar{L}_i	\bar{M}_i	\bar{N}_i	\bar{S}_i
Kr-83m	9.07E-08		2.32E-05	3.46E-04	2.54E-03
Kr-85m	1.40E-03	1.75E-03	1.48E-03	2.36E-03	3.37E-03
Kr-85	1.93E-05	1.61E-03	2.06E-05	2.34E-03	1.63E-03
Kr-87	7.10E-03	1.17E-02	7.40E-03	1.24E-02	1.98E-02
Kr-88	1.68E-02	2.84E-03	1.82E-02	3.52E-03	2.29E-02
Kr-89	1.99E-02	1.21E-02	2.08E-02	1.27E-02	3.49E-02
Kr-90	1.87E-02	8.75E-03	1.96E-02	9.40E-03	3.02E-02
Xe-131m	1.10E-04	5.71E-04	1.87E-04	1.33E-03	7.78E-04
Xe-133m	3.01E-05	1.19E-03	3.92E-04	1.78E-03	1.62E-03
Xe-133	3.53E-04	3.67E-04	4.24E-04	1.26E-03	8.33E-04
Xe-135m	3.74E-03	8.53E-04	4.03E-03	8.87E-04	5.29E-03
Xe-135	2.17E-03	2.23E-03	2.30E-03	2.95E-03	4.76E-03
Xe-137	1.70E-03	1.46E-02	1.81E-03	1.52E-02	1.67E-03
Xe-138	1.06E-02	4.96E-03	1.11E-02	5.70E-03	1.72E-02
Ar-41	1.06E-02	3.23E-03	1.12E-02	3.94E-03	1.95E-01

$(\bar{X}/\bar{Q})_v = 1.2E-06 \text{ sec/m}^3$

* $\bar{K}_i, \bar{L}_i, \bar{S}_i$ (mrem.sec per uCi/yr)

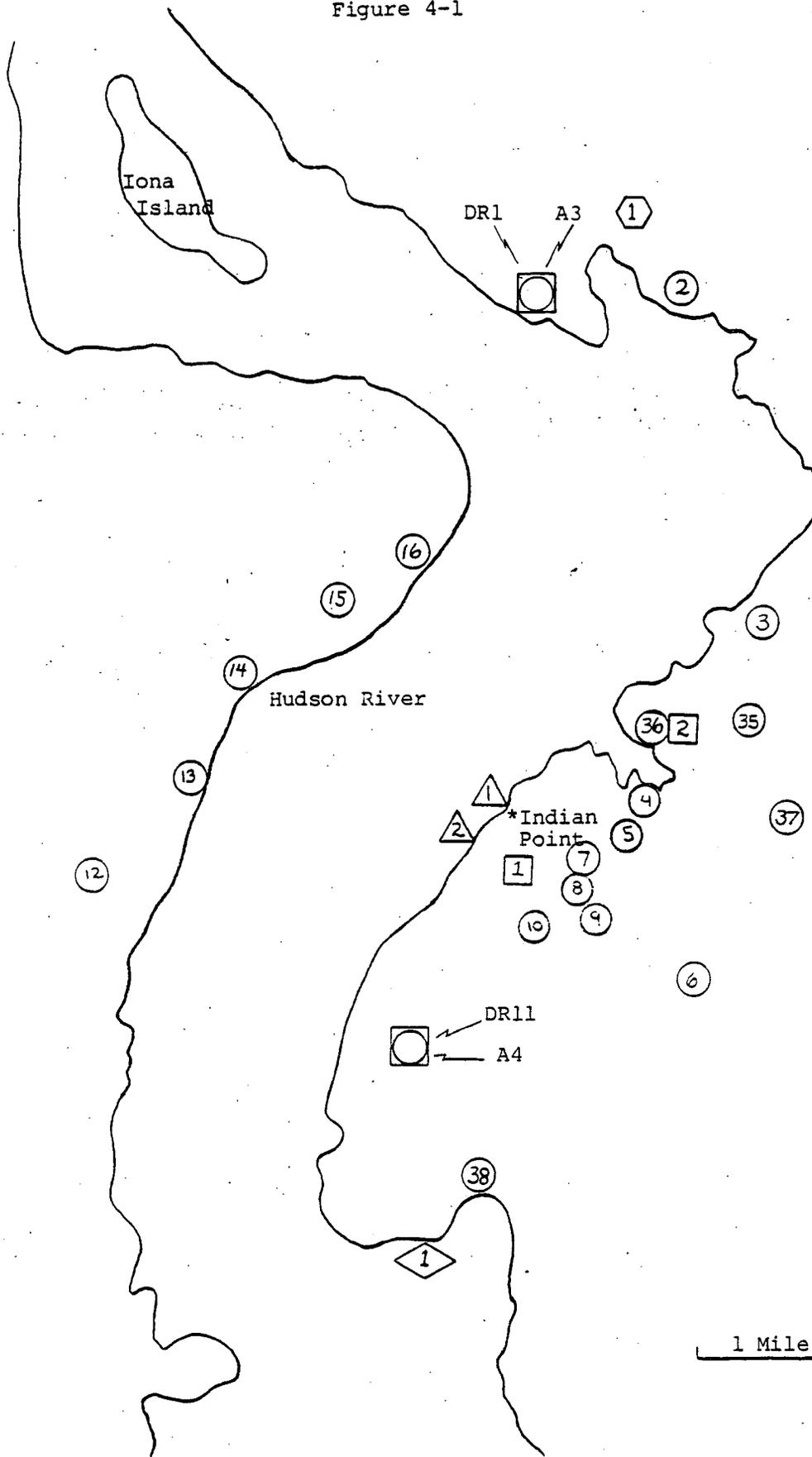
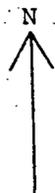
** \bar{M}_i/\bar{N}_i (mrad.sec per uCi/yr)

4.0 SAMPLE LOCATIONS

Figure 4.1 is a map which shows the location of environmental sampling points within 2.5 miles of the Indian Point Plant and Figure 4.2 is a map providing the same information for points at greater distances from the plant. Table 4.1 provides a description of environmental sample locations and the sample types collected at each of these locations.

The locations listed in Table 4.1 are the RETS designated locations only. The air sample locations were chosen considering the highest average annual D/Q sectors and the practicality of locating continuous air samples. There are backup sample locations not listed in Table 4.1 that may be maintained to provide the program with additional supporting information.

Radiological Environmental Monitoring - Sampling Stations
Figure 4-1

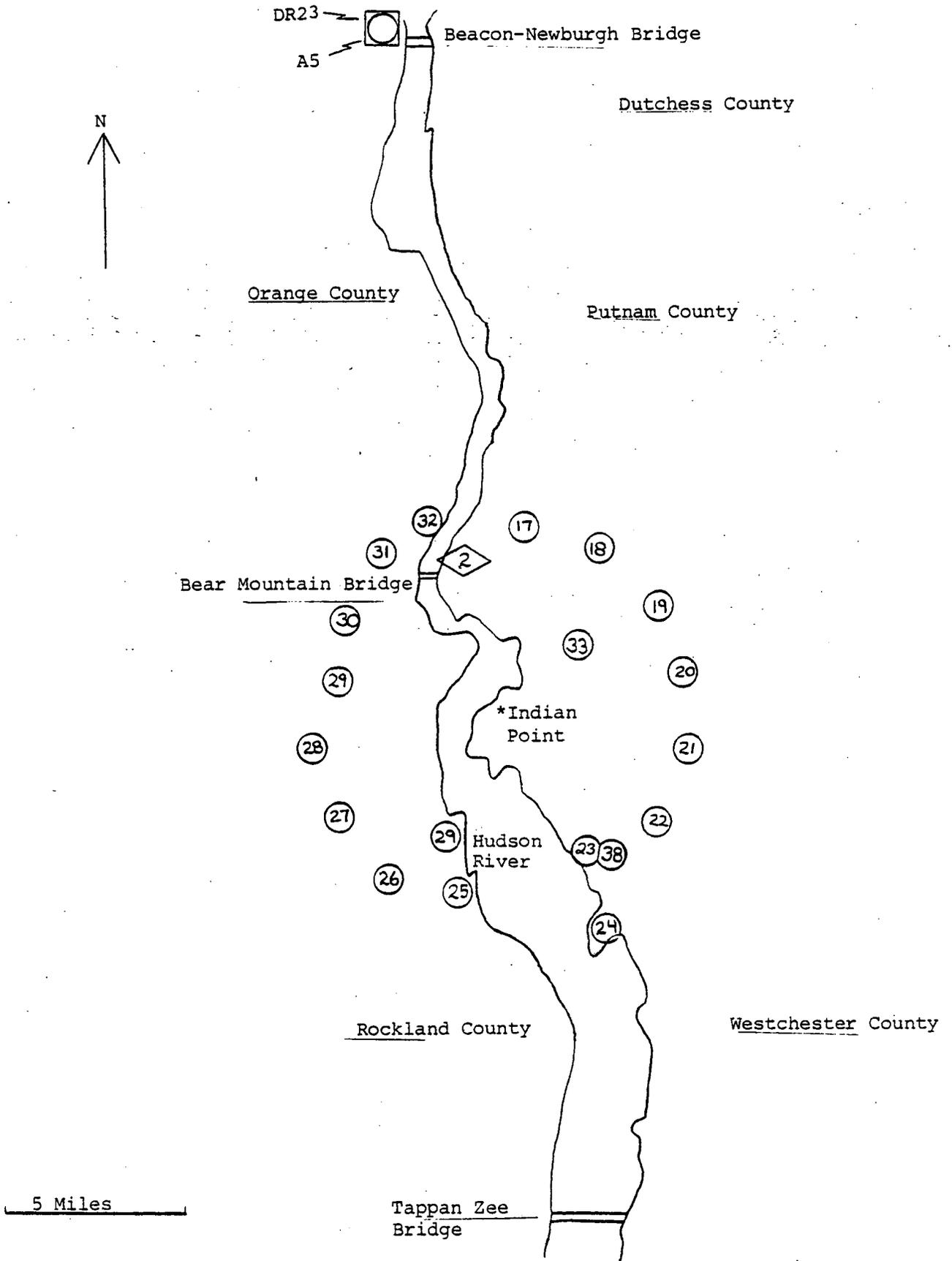


KEY:

- △ - Waterborne Surface Wa#
- - Direct Radiation Sample Location DR#
- - Airborne Sample Location A#
- ◻ - Direct Radiation/Airborne

- ⬡ - Waterborne Drinking Wb#
- ◇ - Shoreline Sediment Wc#

Radiological Environmental Monitoring - Sampling Stations
 Figure 4-2



- KEY:
- - Direct Radiation Sample Location DR#
 - ◻ - Direct Radiation/Airborne
 - ◊ - Shoreline Sediment Wc#

Table 4.1

Indian Point Station
Environmental Sampling Station Points

Exposure Pathway/Sample: Direct Radiation

<u>RETS</u> <u>Sample Designation</u>	<u>Location</u>	<u>Distance</u>
DR1	Cortlandt Sanitary Dept.	2 mi - N
DR2	Old Permart Ave.	2 mi - NNE
DR3	Lower South St. and Franklin	1.5 mi - NE
DR4	Old Dump	0.5 mi - ENE
DR5	Broadway and Bleakley	0.4 mi - E
DR6	Tate Ave. Buchanan	1 mi - SE
DR7	Water Meter House	0.3 mi - E
DR8	Service Center Building	0.4 mi - SSE
DR9	SE Corner	0.9 mi - SE
DR10	Onsite Pole	0.8 mi - S
DR11	NYU Tower	1 mi - SSE
DR12	Gays Hill Road South	1.5 mi - WSW
DR13	Gays Hill Road North	1 mi - W
DR14	Rt. 9W Pirates Cove	1 mi - WNW
DR15	Rt. 9W South of Ayers Road	1 mi - NW
DR16	Ayer Road	1 mi - NNW
DR17	Rt. 9D Garrison	5 mi - N
DR18	Gallows Hill Road	5 mi - NNE
DR19	Westbrook Drive	5 mi - NE
DR20	Pine Road - Cortlandt	5 mi - ENE
DR21	Croton Ave. - Cortlandt	5 mi - E
DR22	Colabaugh Pond Road Cortlandt	5 mi - SSE
DR23	Mt. Airy & Windsor Road	5 mi - SE
DR24	Croton Point	7.5 mi - SSE
DR25	Warren Ave. Haverstraw	5 mi - S
DR26	Railroad Ave. & 9W	5 mi - SSW
DR27	Willow Grove Road & Birch Drive	5 mi - SW
DR28	Palisades Parkway Exit 14A	5 mi - WSW
DR29	Palisades Parkway	4 mi - W
DR30	Anthony Wayne Park	4.5 mi - WNW
DR31	Palisades Pkwy Lake Welch Exit	5 mi - NW
DR32	Rt. 9W Fort Montgomery	5 mi - NNW
DR33	Hamilton St.	3 mi - NNE
DR34	Furnace Dock	3.5 mi - SE
DR35	Lower South St. & Louisa St.	1 mi - ENE
DR36	Standard Brands	0.6 mi - NNE
DR37	Welcher Ave. Peekskill	1 mi - E
DR38	Montrose Marina	1.5 mi - S
DR39	Grassy Point	3 mi - S
DR40	Roseton*	20 mi - N

*Control Station Location

TABLE 4.1 CONT'D

Exposure Pathway/Sample: Airborne

<u>RETS Designation</u>	<u>Location</u>	<u>Distance</u>
A1	Algonquin Gas Line	0.25 mi - S
A2	Standard Brands	0.6 mi - NNE
A3	Cortlandt Sanitary Station	2 mi - N
A4	NYU Tower	1 mi - SSE
A5	*Roseton	20 mi - N

Exposure Pathway/Sample: Waterborne-Surface (Hudson River Water)

Wa1	Plant Inlet	N/A
Wa2	Discharge Canal	N/A

Exposure Pathway/Sample: Waterborne-Drinking

Wb1	Camp Smith	2.5 mi - NNE
-----	------------	--------------

Exposure Pathway/Sample: Sediment from Shoreline

Wc1	White Beach	0.9 mi - SSW
Wc2	*Monitor Inlet	4.5 mi - NNW

* Control Station Location

Exposure Pathway/Sample: Milk

There are no milch animals within 8 km distance of Indian Point; therefore, no milk samples are taken.

Exposure Pathway/Sample: Ingestion-Fish and Invertebrates

The RETS designate two required sample locations labeled Ib1 and Ib2. The downstream Ib1 location and samples will be chosen where it is likely to be effected by plant discharge. Ib2 will be a location up-stream that is not likely to be effected by plant discharge. The following fish species are considered acceptable sample species:

Striped Bass	Bluegill Sunfish
White Perch	Pumpkin Seed Sunfish
White Catfish	Blueback Herring
American Eel	

TABLE 4.1 CONT'D

Exposure Pathway/Sample: Ingestion: Food Products

As required by the RETS the locations for the samples will be as follows:

Ic10 - Ic13: Between site boundary and 1 mile, SW & SSW sectors.
(These sectors are highest annual D/Q)

Ic20 - Ic23: These will be sampled around the Roseton location
and are treated as control locations. (20 mi-N)

5.0 Basis of Radiological Effluent Technical Specifications

Certain sections of the Radiological Effluent Technical Specifications (RETS) require certain explanations or backup information. Where the additional information does not fit in with other sections of the ODCM, it is supplied in this section. Format will be keyed to the specific sections referenced in the RETS.

5/Table 3.3-12

There are no continuous composite samples for steam generator blowdown. The method of determining release concentrations is shown below:

Blowdown flowrate (by flowmeter or by flow curves) multiplied by samples blowdown concentration equals composite activity being released. In addition, R-19 monitors the composite steam generator blowdown released.

5/Table 3.3-12

The service water radioactivity monitor listed in Table 3.3-12 is defined as the process radiation monitors which monitor components which discharge into or are cooled by the service water system. These process radiation monitors are component cooling radiation monitor (R-17 A/B), Liquid Waste Release Monitor (R-18) Steam Generator Blowdown Monitor (R-19), Vapor Containment Fan Coolers, and Vapor Containment FCU Motor Coolers (R-23).

If any of these monitors are taken out of service and the removal of that monitor from service is not specifically addressed in the Radiological Environmental Technical Specification samples shall be taken every 12 hours or releases may not continue via this pathway. Samples may be taken on the affected monitored stream or on the service water system.

5/Table 3.3-13

The ventilation flow rate utilized to monitor environmental releases from the Administrative Building Controlled Area and the Radioactive Machine Shop shall be the system's design flow rate. The system design flowrate for the Administration Building and the Radioactive Machine Shop is 12,500 and 33,750 cubic feet per minute respectively. Using the system design flowrate will result in a conservative quantification of releases as the flowrate can not exceed design.

5/Table 3.3-13

The activity released via the blowdown flash tank vent is determined as follows. The release rate of radioactivity from the steam generator blowdown is determined. The partition factors for the blowdown flash tank vent as listed in Regulatory Guide 1.42 "Interim Licensing Policy On As Low As Practicable for Gaseous Radioiodine Releases from Light Water Cooled Nuclear Power Reactors" are then applied to determine how much activity is being released via the blowdown flash tank vent.

In the event of a purge while above cold shutdown, the alarm set-point for R-12 would be set as per Section 1.2 of the ODCM. The monitor calibration factor would be determined prior to release by taking a VC air sample. The plant vent noble gas monitor would be used to verify these calculations.

5/3.11.1.1

Liquid Effluent Concentrations are limited to 10CFR20 limits, as calculated under 20.106a. This permits averaging of effluent concentrations over one year. This is appropriate since doses from the liquid pathway are the result of total curies released and are not greatly influenced by instantaneous concentrations. In any case, the total dose per quarter and per year must be within the limitations of 3.11.1.2 of the RETS.

5/3.11.1.2.a

There are no drinking water intakes within 3 miles of the site on the Hudson River.

5/3/11/2/6

Gas Storage Tank Activity Limit:

The noble gas activity limit of 50,000 Ci in the gas storage tanks was calculated using the equation from section 5.6.1 of NUREG 0133 and the following parameters:

$$K_i = 294 \frac{\text{mrem} \cdot \text{m}^3}{\text{uCi} \cdot \text{yr}}, \text{ Xe-133 equivalent Table B-1 Reg. Guide 1.109}$$

$$X/Q = 1.03 \times 10^{-3} \text{ s} \cdot \text{m}^{-3}, \text{ Indian Point 3 FSAR}$$

$$\sum Q_{it} \leq 500 \text{ mrem} \frac{(3.15 \times 10^7 \text{ sec/year})}{10^6 \text{ uCi/Ci} (294 \frac{\text{mrem} \cdot \text{m}^3}{\text{uCi} \cdot \text{yr}}) 1.03 \times 10^{-3} \frac{\text{s}}{\text{m}^3}}$$

$$Q_{it} = 52,011 \text{ Ci} \sim 50,000 \text{ Ci}$$

5/4.11.2.6

Gas Storage Tank Activity - Surveillance Requirements

There are two methods available to ensure that the activity in the gas storage tank is within the 50,000 Ci, Xe-133 equivalent concentration:

1. Gas samples of the tanks contents which are less than 430 uCi·cc⁻¹ will ensure that there are less than 50,000 Ci in the tank.
2. The waste gas line monitor R-20 will have an exposure rate to activity concentration conversion factor which will also allow for activity determinations.

5/4.11.4.2

Cumulative dose contributions from direct radiation would be determined by evaluation of existing parameter and environmental TLDs if this evaluation was necessary per Specification 3.11.4.a.

5/Table 4.11-2

Containment Pressure Reliefs:

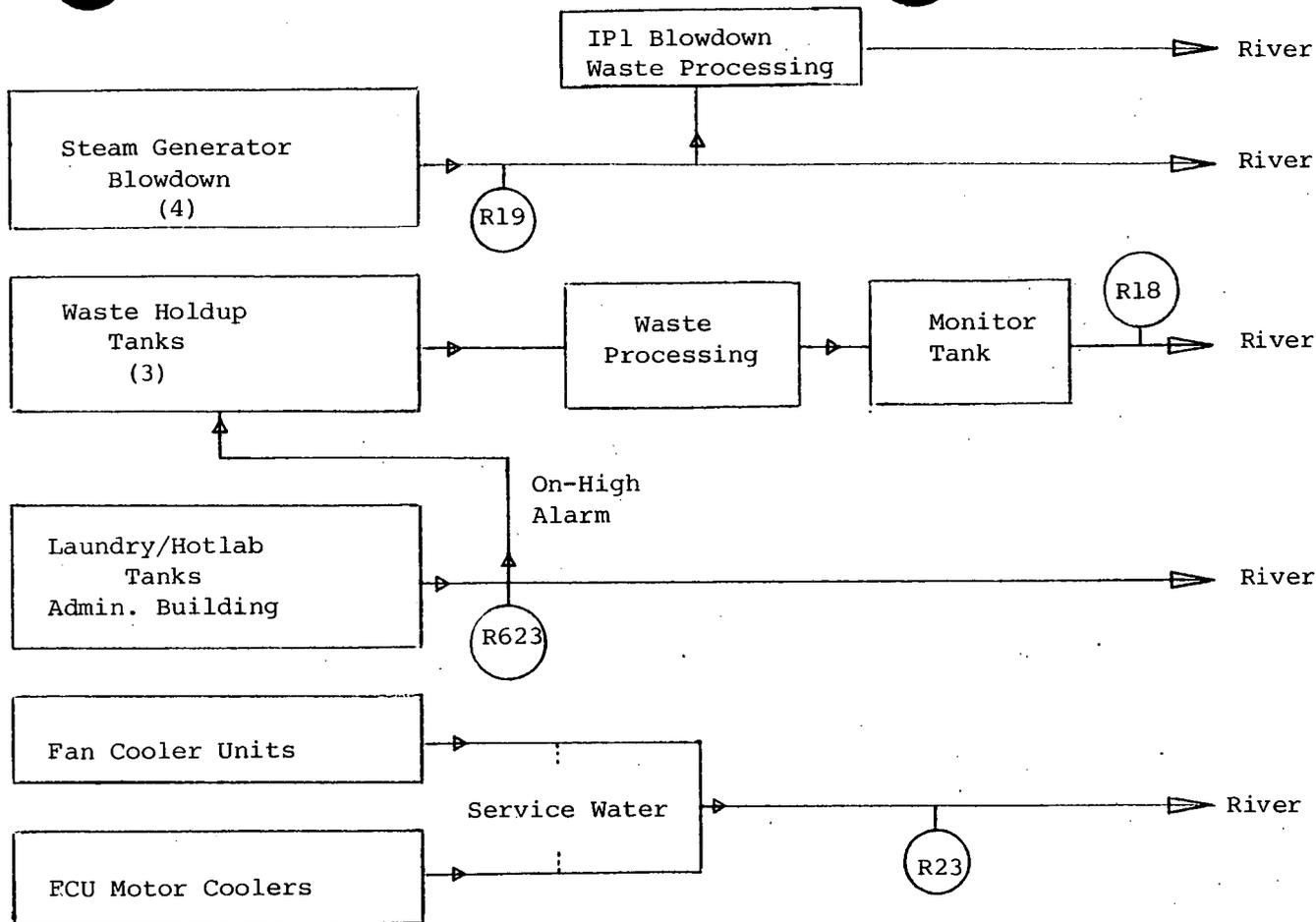
Containment pressure reliefs occur on a frequent enough basis to be considered continuous and are sampled as part of the plant vent release path. However, to ensure that the release rate will not be exceeded, the containment noble gas monitor (R-12) and the expected flow rate are used to calculate a release rate. The effluent noble gas monitor in the plant vent is used to verify these calculations.

5/Table 4.11-2

Composite Particulate Samples:

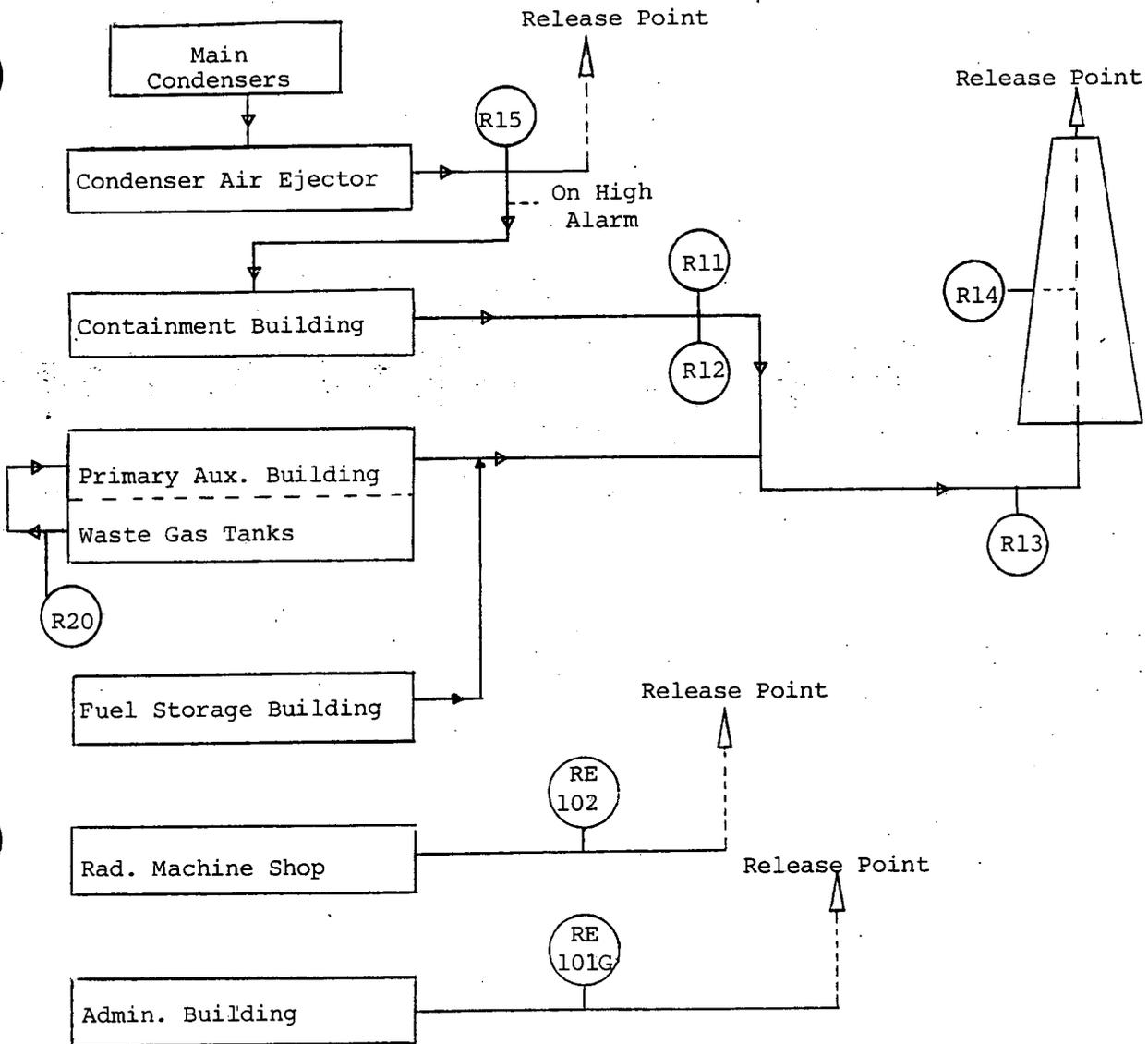
One of these methods will be used to obtain a composite sample:

1. Samples will be taken weekly and averaged monthly, or
2. Samples will be taken weekly and counted together once per month.



Liquid Radioactive Waste Effluent System
Flow Diagram

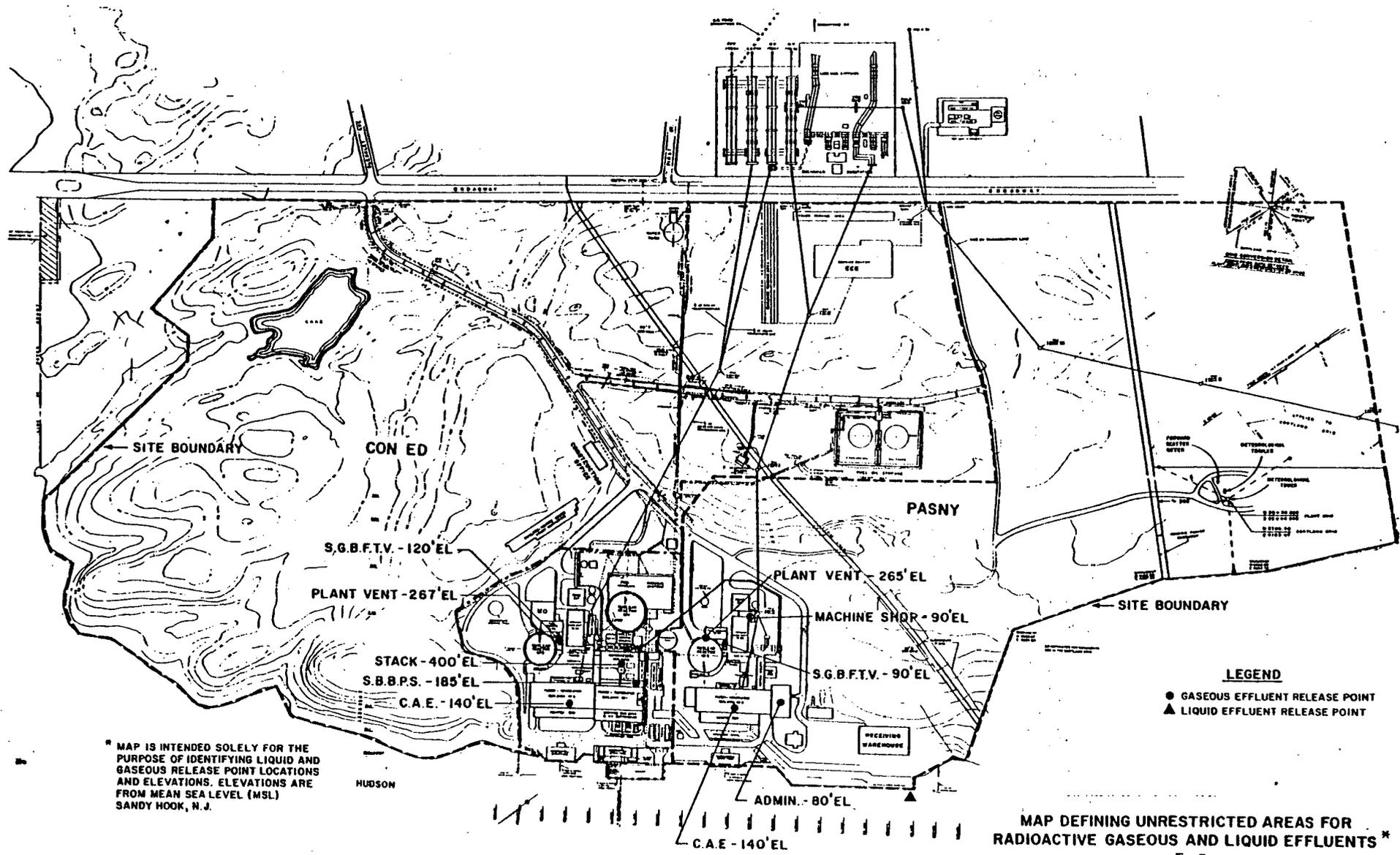
Figure 5-1



(xxx) - Radiation Monitor

Gaseous Radioactive Waste Effluent System
Flow Diagram

Figure 5-2



MAP IS INTENDED SOLELY FOR THE PURPOSE OF IDENTIFYING LIQUID AND GASEOUS RELEASE POINT LOCATIONS AND ELEVATIONS. ELEVATIONS ARE FROM MEAN SEA LEVEL (MSL) SANDY HOOK, N.J.

LEGEND
 ● GASEOUS EFFLUENT RELEASE POINT
 ▲ LIQUID EFFLUENT RELEASE POINT

MAP DEFINING UNRESTRICTED AREAS FOR RADIOACTIVE GASEOUS AND LIQUID EFFLUENTS *
 FIGURE 5-3

ATTACHMENT 4-1

CALCULATION SHOWING RELEASE RATE
VS.
DOSE RATE FOR UNITS 2 & 3

Primary Assumptions:

1. Unit 3 and Unit 2 effective dose factor K_{eff} , values are equivalent,
2. Each unit shares 50% of the total allowable release rate, Q , in $Ci\ s^{-1}$. Therefore $Q_3 = Q_2$.

Given:

	<u>Location</u>	<u>Unit 3</u>	<u>Unit 2</u>	<u>Location</u>
W_V (in) Annual Average Site Boundary X/Q	(SW350m)	$1.4 \times 10^{-5} \text{ sm}^{-3}$	5.6×10^{-6}	(579m)
W_V (gp) Annual Ave. Ground Plane Site Boundary Deposition	(SSW380m)	$8.1 \times 10^{-8} \text{ m}^{-2}$	2.5×10^{-8}	(579m)
W_V (f) Food Pathway Dispersion Parameter	(SSW8.9mi)	$6.7 \times 10^{-11} \text{ m}^{-2}$	6.7×10^{-11}	(8.9 m)
W_V (in) Food Pathway Tritium (Inhal. Parameter)	(SSW8.9 mi)	$1.5 \times 10^{-8} \text{ m}^{-2}$	1.5×10^{-8}	(8.9 m)
W_V (in) Inhalation Pathway Nearest Residence	(SSW1526m)	$1.2 \times 10^{-6} \text{ sm}^{-3}$	1.2×10^{-6}	(1526m)
W_V (gp) Annual Ave. Ground Plane Depos Parameter Nearest Residence	(S 1279 m)	$8.8 \times 10^{-9} \text{ m}^{-2}$	8.8×10^{-9}	(1279m)
From Table 3-10 $\bar{K}s = 0.0363 \text{ mrem-sec per uCi-yr} = 8.22 \times 10^{-5} \frac{\text{mrem-m}^3}{\text{uCi-s}} = K \text{ effective}$				

A. Instantaneous Dose Rate - Noble Gas Release

Calculation of Allowable Release Rate and Percent of Dose Commitment for Each Unit.

$$(K_i) (\overline{X/Q}_v) (Q_{iv}) \quad 500 \text{ mrem yr}^{-1} \quad \text{whole body}$$

$$(L_i + 1.1 \text{ Mi}) (\overline{X/Q})_v (Q_{iv}) \quad 3000 \text{ mrem Yr}^{-1} \quad \text{skin}$$

$$\text{Unit 3: } \overline{X/Q}_v = 1.4 \times 10^{-5} \text{ sm}^{-3} \quad @ \quad \text{SB 350m SW}$$

$$\text{Unit 2: } \overline{X/Q}_v = 5.6 \times 10^{-6} \text{ sm}^{-3} \quad @ \quad \text{SB 579m SW}$$

$$500 \text{ mrem yr}^{-1} = 1.585 \times 10^{-5} \text{ mrem s}^{-1}; \quad 3000 \text{ mrem yr}^{-1} = 9.512 \times 10^{-5} \text{ mrem s}^{-1}$$

Let $Q_3 = Q_2 = Q$ so,

$$Q_{iv} (K_i) (\overline{X/Q})_v \quad 500 \text{ mrem yr}^{-1} \quad (\text{See Section 3.3.1})$$

$$Q (8.22 \times 10^{-5}) (1.4 \times 10^{-5}) + (8.22 \times 10^{-5}) (5.6 \times 10^{-6}) = 1.585 \times 10^{-5} \text{ mrem s}^{-1}$$

$$Q = 9.84 \times 10^3 \text{ uCi s}^{-1}$$

Dose Commitments for $Q = 9.84 \times 10^3 \text{ uCi s}^{-1}$

$$\text{Unit 3: } 9.84 \times 10^3 \text{ uCi s}^{-1} \cdot 8.22 \times 10^{-5} \frac{\text{mrem}}{\text{uCi}} \cdot 1.4 \times 10^{-5} \text{ sm}^{-3} = 357 \text{ mrem yr}^{-1}$$

$$\text{Unit 2: } 9.84 \times 10^3 \text{ uCi s}^{-1} \cdot 8.22 \times 10^{-5} \frac{\text{mrem}}{\text{uCi}} \cdot 5.6 \times 10^{-6} \text{ sm}^{-3} = 143 \text{ mrem yr}^{-1}$$

Unit 3 has 71% and Unit 2 has 29% of the dose rate limit.

Skin:

$$(L_i + 1.1 \text{ Mi}) = 1.43 \times 10^{-4} \frac{\text{mrem}}{\text{uCi}} \frac{\text{m}^3}{\text{s}}$$

$$\sum Q_{iv} (L_i + 1.1 \text{ Mi}) (\overline{X/Q})_v \leq 3000 \text{ mrem yr}^{-1}$$

$$Q \left\{ (1.436 \times 10^{-4} \frac{\text{mrem}}{\text{uCi}} \frac{\text{m}^3}{\text{s}}) \cdot (1.4 \times 10^{-5} \frac{\text{s}}{\text{m}^3}) + (1.436 \times 10^{-4} \frac{\text{mrem}}{\text{uCi}} \frac{\text{m}^3}{\text{s}}) \cdot (5.6 \times 10^{-6}) \right\} \leq 9.51 \times 10^{-5} \text{ mrem s}^{-1}$$

$$Q = 3.38 \times 10^4 \text{ uCi s}^{-1}$$

B. Instantaneous Dose Rate - Iodines/Particulates*

$$P_i (W_v Q_{i_v}) 1500 \text{ mrem/yr to any organ}$$

where P_i = dose factor for radionuclides other than noble gases for the food pathway.

considering I-131 and H-3 as the radionuclides of interest:

$$P_{I-131} = 1.48 \times 10^7 \text{ mrem/yr per uCi/m}^3 \text{ inhalation}$$

$$** P_{H-3} = 6.47 \times 10^2 \text{ mrem/yr per uCi/m}^3 \text{ inhalation}$$

$$P_{I-131} = 2.98 \times 10^7 \text{ m}^2 \text{ mrem/yr per uCi/sec ground plane}$$

$$P_{I-131} = 1.08 \times 10^{12} \text{ m}^2 \text{ mrem/yr per uCi/sec food pathway.}$$

$$P_i(\text{in}) \cdot W_v(\text{in}) \cdot Q_{i_v} + P_i(\text{gp}) \cdot W_v(\text{gp}) \cdot Q_{i_v} + P_i(\text{food}) \cdot W_v(\text{f}) \cdot Q_{i_v} + P_i(\text{Food H-3}) W_v(\text{in}) = \text{mrem yr}^{-1} \text{ to any organ.}$$

See Section 3.3.2.2.

$$Q_3 = Q_2 = Q$$

$$\text{Unit 3: } P_i(\text{in}) W_v(\text{in}) Q = (1.48 \times 10^7 \frac{\text{mrem m}^3}{\text{yr uCi}}) (1.4 \times 10^{-5} \text{ sm}^{-3}) Q = 207.2 Q$$

$$\text{Unit 3: } P_i(\text{gp}) W_v(\text{gp}) Q = (2.98 \times 10^7 \text{ m}^2 \frac{\text{mrem s}}{\text{yr uCi}}) (8.8 \times 10^{-9} \text{ m}^{-2}) Q = 0.3 Q$$

$$\text{Unit 3: } P_i(\text{food}) W_v(\text{f}) Q = (1.08 \times 10^{12} \text{ m}^2 \frac{\text{mrem s}}{\text{yr uCi}}) (6.7 \times 10^{-11} \text{ m}^{-2}) = 72.4 Q$$

$$\frac{280.0 Q \text{ mrem s}}{\text{yr uCi}}$$

$$\text{Unit 2: See equats above} = 1.48 \times 10^7 (5.6 \times 10^{-6}) Q = 82.9 Q$$

$$\text{Unit 2: " " " } = 2.98 \times 10^7 (8.8 \times 10^{-9}) Q = 0.3 Q$$

$$\text{Unit 2: " " " } = 1.08 \times 10^{12} (6.7 \times 10^{-11}) Q = 72.4 Q$$

$$156 Q \frac{\text{mrem s}}{\text{yr uCi}}$$

Percent of Dose Commitment to critical organ for each unit:

$$\text{Unit 3} = \frac{280}{280+156} \times 100 = 65\%$$

$$\text{Unit 2} = \frac{156}{280+156} \times 100 = 35\%$$

* $t_{1/2} > 8$ days

**Because the dose factor for H-3 is approximately 4 orders of magnitude less than the dose factors for iodine its contribution to the total dose is considered negligible.

LOWER LIMIT OF DETECTION

ATTACHMENT 4-2

The LLD is the smallest concentration of radioactive material in a sample that will be detected with 95% probability with 5% probability of falsely concluding that a blank observation represents a "real" signal.

For a particular measurement system (which may include radiochemical separation):

$$\text{LLD} = \frac{4.66s_b}{\text{EVY} (2.22 \times 10^6) \exp(-\lambda\Delta t)}$$

where

LLD is the "a priori" lower limit of detection as defined above (as uCi per unit mass or volume):

s_b is the standard deviation of the background counting rate or of the counting rate of a blank sample as appropriate (as counts per minute):

E is the counting efficiency (as counts per transformation);

V is the sample size (in units of mass or volume);

2.22×10^6 is the number of transformations per minute per microcurie;

Y is the fractional radiochemical yield (when applicable);

λ is the radioactive decay constant for the particular radionuclide;

Δt is the elapsed time between sample collection and time of counting.

The value of s_b used in the calculation of the LLD for a detection system shall be used on the actual observed variance of the background counting rate or of the counting rate of the blank samples (as appropriate) rather than on an unverified theoretically predicted variance. Typical values of E, L, V, Y and Δt shall be used in the calculation.

The value of s_b used in the calculation of the LLD for a detection system shall be used on the actual observed variance of the background counting rate or of the counting rate of the blank samples (as appropriate) rather than on an unverified theoretically predicted variance: Typical values of E, L, V, Y and t shall be used in the calculation.

PROCESS CONTROL PROGRAM

1.0 PURPOSE

The purpose of the Process Control Program (PCP) is to provide reasonable assurance of the complete solidification of processed wet radioactive waste. The PCP shall assure the absence of free standing water in the processed wet radioactive waste within the limits as set forth in Federal Guidelines for transportation and burial of radioactive waste.

2.0 APPLICABILITY

At all times.

3.0 DESCRIPTION OF SOLIDIFICATION SYSTEM

- a) The Indian Point 3 solidification system description and operating procedures are contained in IP3 procedure number RE-HPI-9.22 (rev. 0) entitled, "Solidification". Briefly, the system consists of a mixing tank, pumps and associated hoses for cement slurry transfer.
- b) Indian Point III may contract for insitu solidification of resin, oil or other waste streams as needed to meet future regulatory requirements for burial. Contractors will be required to provide written procedures and a PCP for approval by the Authority prior to solidification.

4.0 QUALITY ASSURANCE/AUDITS/SURVEILLANCE

- a) Audits of this PCP will be conducted on an annual basis as per Nuclear Generation Procedures 16.3.1 and 16.3.2.
- b) As per Indian Point 3 procedure RE-HPI-9.22, a "Solidification Process Control Data Sheet" must be filled out for each processed batch. As per section 7.4.2 of RE-HPI-9.22, a sample from each batch solidified will be tested to verify that the solidification medium has cured before the shipment can be released.
- c) Contractor surveillance of radioactive waste solidification will be conducted in accordance with written procedures submitted by the contractor and approved by Indian Point III. Verification of solidification must be assured prior to shipment.
- d) Quality assurance for this PCP is provided by the surveillance procedures as outlined in 3.0(b) above with the maintenance of appropriate documentation for each batch solidified showing conformance with the established parameters. The Power Authority shall also maintain administration control over contractor activities by having responsible plant personnel verify solidification process records before shipment of material is approved.

5.0 ADMINISTRATIVE CONTROLS

- a) Any changes in solidification procedures or in this Process Control Program must be PORC approved before they can be initiated.

Justification of the Fish Bioaccumulation Factor Used in
the IP3 ODCM Submittal

Section 2.4.3 of the Indian Point 3 ODCM submittal gives a bioaccumulation factor of 150 for Cesium instead of the value listed for fresh water in Reg. Guide 1.109. The justification for this value comes from a Doctoral thesis from New York University by J. W. Lentsch.

The value of 150 for the Cesium bioaccumulation factor in soft tissue is considered appropriate in soft tissue during typical mean saline conditions in the estuary (ie., ~1% Cl⁻) around Indian Point.

The appropriate table (Table IX-5) and the section entitled Detailed Distributions in Fish are provided as supporting documents. The entire thesis is not attached due to its length, approximately 600 pages.

THE FATE OF GAMMA-EMITTING RADIONUCLIDES
RELEASED INTO THE HUDSON RIVER ESTUARY AND
AN EVALUATION OF THEIR ENVIRONMENTAL SIGNIFICANCE

by
JACK W. LENTSCH

New York
December, 1974

Submitted to the Graduate Division of the School of Engineering and
Science in partial fulfillment of the requirements for the degree of
Doctor of Philosophy at New York University.

Summary of Biological Concentration Factors for Biota from the Indian Point Study Area.
Dissolved, Wet Weight Values Averaged over all Species Analyzed.

Nuclide	Fraction ^(a) Dissolved	Fish ^(b)		Molluscs		Crustacea ^(e)		Rooted Plants
		Whole	Flesh ^(c)	Whole	Flesh ^(d)	Whole	Flesh	
Mn-54	0.46	240	160	19,000	60,000	5,000	8,000	19,000
Fe-55,-59	0.01	8,800	3,700	NA	80,000	NA	5,000	69,000
Co-58,-60	0.41	200	140	2,900	1,100	810	700	4,300
Zn-65	0.45	3,100	2,200	27,000	180,000	4,200	6,000	2,800
Zr-95	0.11	190	190	7,600	1,000 ⁽ⁱ⁾	6,000 ^(h)	100 ⁽ⁱ⁾	5,500
I-131	1.0	NA	25 ^(g)	NA	700	NA	700	100 ^(j)
Cs-134,-137	0.74	140 ^(f)	150	320	60	480	60	160
Ce-144	0.36	96	96	6,000 ^(h)	1,000 ⁽ⁱ⁾	2,000 ^(h)	600 ⁽ⁱ⁾	2,100

(a) Average fraction of nuclide that is dissolved in water

(b) Indigenous species only

(c) Based on average ratio of flesh to whole fish concentrations given in Table V-28.
Flesh and whole concentrations assumed to be equal for Zr-95 and Ce-144.

(d) Estimated upper limit based on stable element concentrations in Indian Point Study Area water and concentrations in molluscs reported in the literature (See Table IX-6 and -8).

(e) Estimated upper limit based on stable element concentrations in Indian Point Study Area water and concentrations in crustacea reported in the literature (See Tables IX-7 and -8).

(f) Based on the measured value of 97 with correction for an estimated 30% loss of Cs during sample preservation and ashing.

(g) Maximum value reported in the literature for either marine or fresh water (Jinks and Eisenbud 1972, Chapman et al. 1969, Lowman et al. 1971, Freke 1967, Bowen et al. 1971, IAEA 1971, Fletcher and Dotson 1971).

(h) Upper limit values derived from detection limits.

(i) Maximum value reported in the literature for either marine or fresh water (Jinks and Eisenbud 1972, Freke 1967, Bryan, Preston and Templeton 1966, Lowman, Rice and Richards 1971).

(j) Estimated freshwater value from Chapman et al. (1968) and Eisenbud and Jinks (1972).

that the concentration factor of Cs and radiocesium in these plants is inversely proportional to the dissolved Cs content of water. This necessarily implies that the estimated 24-fold higher concentration of Cs in water at Indian Point than in fresh Hudson water is primarily due to the leaching of Cs from bottom sediment by saline water.

Detailed Distributions in Fish

Concentrations of radiocesium in whole fish collected at Indian Point and at upstream locations during 1969-1970 are given in Tables VIII-12 through -16. Concentrations of radiocesium in fillets of anadromous fish samples collected during 1970 are given in Table VIII-18. From these data, it is seen that the concentration of Cs-137 in fish at both Indian Point and at upstream locations, as well as in anadromous species from the Atlantic, were consistently higher than concentrations of any other manmade radionuclide. This fact, together with the importance of fish in the human diet and the relatively high release of radiocesium in reactor effluents is an immediate indication of the relevance of the radiocesium content of fish in dosimetric evaluations.

Data previously presented in Chapter V (see Table V-28) has been used to show that there is no significant difference in the concentration of Cs-137 in whole fish or in fish flesh. Data previously presented in this chapter (see Table VIII-24) does not reveal a consistent or significant dependence of Cs-137 concentration in fish on fish size. Limited experimentation indicates that a possible loss of approximately 25-35 percent of the radiocesium content of fish may have occurred in the preservation and ashing technique employed (see Table V-27).

A total of 22 different fish species were analyzed during 1969-1970 at all sampling locations. The limited number of samples of each species that could be obtained for analysis on each collection date and the variable concentrations of radiocesium in water on the different collection dates preclude accurate evaluation of interspecies differences in radiocesium concentrations. The magnitude of such interspecies differences has been estimated by normalizing the Cs-137 concentrations in each species analyzed each month at Indian Point and at upstream locations to the concentration of Cs-137 in white perch (the most common

species analyzed) each month. There were six monthly sampling dates during 1969-1970 when a white perch sample was obtained together with at least one other fish species at the upstream locations, and seven sampling dates at Indian Point, for a total of 13 sets of normalized radiocesium concentrations in the various fish species. The mean, standard deviation and range of the normalized Cs-137 concentrations in 19 different species of fish determined in this manner are given in Table VIII-51, together with the total number of monthly samples which included each of the indicated species. On the individual sampling dates, the Cs-137 concentrations in the various species ranged from a factor of approximately 3 less than the concentration in white perch to a factor of approximately 2 greater than the concentration in white perch. The average relative concentrations of Cs-137 in 11 of the 19 species for which two or more samples were analyzed was not significantly different from unity at the 5-percent level. Within the precision of these data, it is therefore concluded that there is no difference in the relative concentrations of Cs-137 in at least 11 of the species which were analyzed. There is also no clear trend in the relative concentration data of Table VIII-51 which would indicate that a trophic-level effect exists for the accumulation of radiocesium by the different species. This observation for Hudson River fish conflicts with studies by numerous other investigators, including Kolehmainen et al. (1966), Pendleton (1962) and Gustafson (1966, 1969) who have shown that in certain freshwater environments the concentration of Cs-137 in fish increases with trophic level, with predacious fish accumulating the highest Cs-137 concentrations. Other investigators, including Nelson (1969) and Harvey (1964), studying different freshwater environments, have found that no apparent relationship exists between trophic level and radiocesium accumulation in fish.

During April-August, 1970, the following average radiocesium concentrations were measured in indigenous fish species at Indian Point and at upstream locations, and in anadromous species caught by commercial fishermen in Haverstraw Bay during their upstream migration:

		<u>Cs-134</u>	<u>Cs-137</u>
Indigenous Fish			
Indian Point	(n=14 species)	27.1 \pm 2.5 pCi/kg	34.2 \pm 2.7 pCi/kg
Upstream	(n= 7 species)	5.7 \pm 2.1	16.9 \pm 1.2
Anadromous Fish	(n= 4 species)	NA/ND	16.5 \pm 2.8

Equal weight has been given to the average radiocesium concentration of each fish species which was analyzed during this time period in arriving at the above average concentrations. Cesium-134 was not present at detectable levels in either upstream fish or in anadromous species. At Indian Point, the average Cs-134/Cs-137 ratio in continuous water samples during this period of time was 0.92 ± 0.11 , which, at the 5-percent level, is the same Cs-134/Cs-137 ratio as found in Indian Point fish (0.79 ± 0.10). At least at Indian Point, fish rather definitely acquire radiocesium either directly from water or from another source whose radiocesium content is proportional to the radiocesium concentration in water (surficial bottom sediment, plankton, plants, etc.).

It is a well-known fact that the concentration factor of cesium in freshwater fish is substantially higher than in marine fish. A literature survey by Jinks and Eisenbud (1972) revealed an average cesium concentration factor of 3700 (range: 120-22,000) in freshwater fish and 48 (range: 5-244) in marine fish. A similar study by Chapman et al. (1968) produced values of 3000 for freshwater fish and 30 for marine fish. In view of these results, it is somewhat surprising to have found almost identical Cs-137 concentrations in freshwater Hudson River fish and in anadromous fish of recent marine origin (16.9 ± 1.2 and 16.5 ± 2.8 pCi/kg, respectively). As mentioned previously, Riel (1970) found an average Cs-137 concentration in Atlantic coastal water of 0.16 pCi/l in 1969 and Volchok et al. (1971) found an average Cs-137 concentration in Atlantic surface waters of 0.14 pCi/l during 1967 (both investigators measured only the dissolved Cs-137 concentration, which for sea water has been shown to account for 97-100 percent of the total concentration in water (Robertson et al., 1968, Templeton and Preston, 1966)). Assuming that the anadromous fish analyzed here acquired all of their Cs-137 content while residing in the Atlantic prior to migrating into the Hudson, the dissolved concentration factor of Cs-137 in these anadromous species is calculated from Riel's and Volchok's water analyses

to be approximately 100. Based on the average Cs-137 concentrations in continuous water samples from Chelsea during the period April-August, 1970, and an average dissolved percentage of 31 percent, the total concentration factor of Cs-137 in freshwater upstream Hudson River fish is estimated to be 219 ± 30 and the dissolved concentration factor is estimated to be 706 ± 97 . These data show that the dissolved Cs-137 concentration factor is more than 7-fold higher in Hudson fish from freshwater locations than in marine fish. It is, therefore, coincidental that the anadromous and freshwater fish had the same approximate Cs-137 concentration; i.e., the higher concentration factor of Cs-137 in freshwater than in marine fish is compensated for by the higher dissolved concentration of Cs-137 in coastal and surface marine water which existed during 1970.

Adequate simultaneous characterization of radiocesium concentrations in both water and fish at Indian Point was achieved only during May, June and July, 1970. The concentrations of Cs-134 and Cs-137 in fish and water during each of these three months, the average water chlorosity, and the radiocesium concentration factors computed from these monthly data are given in Table VIII-52. In calculating the monthly average concentrations in fish, equal weight has been given to the radiocesium concentration of each species analyzed each month. During May-June, 1970, at least four major variables underwent significant change which could affect the concentration of radiocesium in fish: 1) water temperature; 2) water chlorosity; 3) radiocesium concentration in water; and 4) percentage of dissolved radiocesium in water. It is virtually impossible to attribute the changes seen in the concentration and concentration factors of Cs-134 and Cs-137 in fish on each of the three months to any single environmental variable. As discussed previously, numerous other investigators as well as this study have shown that the radiocesium concentration factor in fish is lower in saline water than in fresh water. Studies by Gallegos (1971) indicate an inverse proportionality between the biological half-life of radiocesium in fish and water temperature, which, together with the lower expected feeding rate of fish at low water temperatures, might explain why an approximate three-fold lower concentration factor was found in fish during May than in June or July (Table VIII-52). However, the salinity during May was

substantially less than in June or July, which would be expected to increase the concentration factor of fish during May compared to June or July. Thus, the difficulty of interpreting differences in these monthly concentration factors is quite apparent.

The average water chlorosity and surface water temperature at Indian Point during May-June, 1970, was 0.62 g/l and 18°C, respectively. The annual average water chlorosity and surface water temperature at Indian Point during 1969-1970 was 0.68 g/l and 14°C, respectively. The average water chlorosity and water temperature during May-July, 1970 was therefore, fairly similar to the annual average values at Indian Point. Assuming that water temperature and chlorosity are the principal variables affecting accumulation of radiocesium by fish, the average concentration factor of radiocesium in fish during May-July, 1970, should be a fairly accurate estimate of the annual average value for Indian Point fish. From Table VIII-52, the average dissolved radiocesium concentration factor in fish at Indian Point is estimated to be 97±18 and the average total radiocesium concentration factor is estimated to be 64±13.

The dissolved concentration factor in fish at Indian Point of 97±18 is approximately the same as the value of 100 which was previously estimated for anadromous fish species, and is a factor of 7.3 less than the corresponding value of 706±97 for freshwater (upstream) Hudson River fish which were analyzed during the same period of time. The following average concentrations of chloride and K were measured at Indian Point and upstream at Chelsea for the periods when the above radiocesium concentration factors in fish were determined:

	<u>Chlorosity</u>	<u>Potassium</u>
Chelsea	0.011 g/l	1.8 pCi/l K-40
Indian Point	0.62	12.9
Ratio (Indian Point/Chelsea)	56	7.2

From these results, it would appear that the concentration factor of radiocesium in Hudson fish is almost exactly inversely proportional to the K concentration of water; i.e., the concentration of K at Indian Point is 7.2-fold higher than fresh Hudson River water, while the dissolved radiocesium concentration factor at Indian Point is 7.3-fold

lower in Indian Point fish than in Hudson River fish from freshwater locations.

The concentration of K in fish is very definitely regulated at a relatively constant value which is independent of the K concentration of water. This is illustrated from the following average concentrations of K-40 which were measured in upstream and Indian Point fish during 1968-1970:

	<u>pCi/kg of K-40</u>			
	<u>1968</u>	<u>1969</u>	<u>1970</u>	
Upstream	1340	1360	1190	(Table VIII-13)
Indian Point	----	1360	1340	(Table VIII-16)

The dissolved concentration factors of K in fish during 1970 at Indian Point and upstream locations (104 and 661, respectively) are almost identical to those found for radiocesium at Indian Point and at upstream locations (97 and 706, respectively). The dissolved concentration factor of K in fish is inversely proportional to the dissolved concentration of K in water, as also found for radiocesium. Other investigators (Kolehmainen and Nelson, 1969, Preston et al., 1967) have also reported an inverse proportionality between the concentration factor of K in fish and the concentration of K in water.

The inverse proportionality between concentration factors of radiocesium and K in fish and the concentration of K in water leads one to hypothesize that fish regulate constant concentrations of Cs in tissue as well as K, and that the concentration of dissolved Cs in water is directly proportional to the concentration of K in water.

A summary of the concentrations of Cs in fish and water (dissolved) from freshwater and marine environments which have been reported by other investigators is given in Table VIII-53. Also shown in this table are the dissolved Cs concentration factors which can be computed from these measurements. A plot of these dissolved Cs concentration factors against the concentration of dissolved Cs in water is given in Figure VIII-73. It is quite apparent from this plot that the concentration of Cs in fish is regulated, and that as a result, the dissolved concentration factor of Cs in fish is inversely proportional to the Cs concentration

of water. In spite of the tremendous numbers of studies of radiocesium in aquatic and marine environments, and an equally large number of theories to explain the orders of magnitude differences in radiocesium concentration factors in fish from various bodies of water, this general conclusion has not been heretofore stated.

It is interesting to note from Table VIII-53 and Figure VIII-73, that the previously estimated concentration factor of 100 for anadromous fish agrees well with the average marine fish concentration factor of 82 (range: 68-110).

The dissolved Cs concentration in Hudson River water can be estimated by making the following two assumptions:

1. Manmade Cs-137 and naturally occurring Cs are identically distributed in fish and water; i.e., the specific activity of Cs-137 is the same in fish as in water.
2. Cesium is regulated by fish and the average concentration of Cs in the fish species analyzed is the same as the average Cs concentration in fish that has been reported by other investigators.

From Table VIII-53, the average reported concentration of Cs in freshwater fish is 18.6 $\mu\text{g}/\text{kg}$ wet and in marine fish is 24.4 $\mu\text{g}/\text{kg}$ wet, giving an average concentration in both freshwater and marine fish of approximately 22 $\mu\text{g}/\text{kg}$ wet. Using this concentration, the average specific activity of Cs-137 in fish at Indian Point and at upstream locations during the late spring and summer of 1970 were:

$$\begin{aligned} \text{Indian Point: } & (31.2 \text{ pCi/kg}) / (22 \text{ } \mu\text{g}/\text{kg}) = 1.4 \text{ pCi}/\mu\text{g} \\ \text{Upstream: } & (16.9 \text{ pCi/kg}) / (22 \text{ } \mu\text{g}/\text{kg}) = 0.77 \text{ pCi}/\mu\text{g}. \end{aligned}$$

The average dissolved concentrations of Cs-137 in water at Indian Point and at Chelsea (upstream) during this period were 0.34 pCi/l and 0.024 pCi/l, respectively. Making use of assumption (1) above, the dissolved concentrations of Cs in water at Indian Point and at upstream locations

are then estimated to be:

$$\text{Indian Point: } (0.34 \text{ pCi/l}) / (1.4 \text{ pCi}/\mu\text{g}) = 0.24 \mu\text{g/l}$$

$$\text{Upstream: } (0.024 \text{ pCi/l}) / (0.77 \text{ pCi}/\mu\text{g}) = 0.031 \mu\text{g/l}.$$

The resulting dissolved concentration factors of Cs are computed to be 92 at Indian Point and 710 at upstream locations. These two values are plotted against the estimated concentration of stable Cs in water in Figure VIII-73. The good agreement with the functional relationship defined by other investigators' measurements of Cs concentrations and concentration factors validates the assumptions made above; namely, that manmade Cs-137 and naturally occurring stable Cs are identically distributed in fish and water, and that the concentration of Cs in fish is regulated at a relatively constant value independent of the concentration of Cs in water.

The above-estimated dissolved concentrations of Cs in water for the period May-July, 1970, are a factor of 7.7 higher at Indian Point than at Chelsea (upstream). For the average water chlorosity of 0.62 g/l at Indian Point during this period, simple mixing between sea water having a Cs concentration of 0.3 ppb and fresh Hudson water having a dissolved Cs concentration of 0.031 ppb predicts a dissolved Cs concentration in water at Indian Point of 0.040 ppb. Hence, water at Indian Point during this period is estimated to have had a 6-fold higher dissolved Cs concentration than expected from a simple mixing phenomena between sea water and fresh water. The source of the estimated high concentrations of Cs in water at Indian Point may be the leaching of Cs from bottom sediment by saline water.

The concentration of K in water at Indian Point (12.9 pCi/l as K-40) was almost exactly as expected for simple mixing between sea water (335 pCi/l of K-40) and fresh Hudson River water (1.8 pCi/l of K-40), with the "mixing" value being 12.7 pCi/l of K-40. It is probably fortuitous that the estimated 7.7-fold higher concentration of Cs in water at Indian Point than at Chelsea was so similar to the 7.2-fold higher concentration of K at Indian Point than at Chelsea, since different mechanisms are thought to account for the higher measured concentration of K and higher estimated concentration of Cs at Indian Point.

A similar interpretation has been forwarded in the previous section on aquatic plants. For plants, which were collected from June-September, 1970, when the average water chlorosity at Indian Point was 1.5 g/l, it was estimated that the concentration of Cs in water at Indian Point was a factor of 24 higher than at upstream locations, or approximately $(24)(0.031 \text{ ppb}) = 0.74 \text{ ppb}$. This concentration is a factor of 14 higher than expected from mixing between sea water and fresh Hudson water, and a factor of 3.1 higher than is estimated to have existed at Indian Point during May-July, 1970. The ratio of water chlorosities for the June-September, 1970 period to the May-July, 1970 period was 2.4 compared to the ratio of Cs concentrations of 3.1. The concentration of Cs in water as a result of leaching from bottom sediment would, therefore, appear to be almost directly proportional to water salinity for salinities less than about 2 g/l.

Since the concentration factors of radiocesium and K in fish are almost identical, it is tempting to conclude that the source of radiocesium and K in fish is the dissolved radiocesium and K in water. As seen from Table VIII-54, wherein the Cs-137/K-40 ratio of fish, water, rooted aquatic plants, plankton and bottom sediment at Indian Point and upstream locations are given for 1970, similar Cs-137/K ratios were found only for fish and water. If the principal source of radiocesium and K in fish was consumption of either plankton or rooted aquatic plants, fish would have to have a mechanism for selectively accumulating K over Cs to account for the lower Cs-137/K-40 ratio in fish than in plankton or plants. While possible, it is considered unlikely that the resulting lower Cs-137/K-40 ratio in fish would be nearly identical to the ratio in water; i.e., fish would have to selectively accumulate K over Cs in quantitatively the same proportion as aquatic plants have been shown to selectively accumulate Cs over K.

The Cs-137/K-40 ratios given in Table VIII-54 for bottom sediment are given for the total Cs-137 and K-40 content of bottom sediment, as well as for the exchangeable and the acid-soluble fractions of Cs-137 and K-40 (see Table V-19). The Cs-137/K-40 ratio of both the exchangeable and the acid-soluble content of Cs-137 and K-40 in bottom sediment are similar. In all likelihood, fish would only be able to assimilate the exchangeable or acid-soluble constituents of sediment. The fact that

the Cs-137/K-40 ratio of bottom sediment is a factor of approximately 40 higher than in fish or water at Indian Point, and a factor of approximately 80 higher in bottom sediment than in fish or water at upstream locations would certainly seem to indicate that fish do not acquire significant radiocesium or K by ingesting bottom sediment, as has been suggested by Gallegos (1971). The similar Cs-134/K-40 ratio in bottom sediment at Indian Point and at upstream locations, and the two-fold higher ratio in fish and water at Indian Point than at upstream locations is further evidence that fish do not acquire Cs or K from bottom sediment. Since an even higher Cs-137/K-40 ratio is expected in surficial bottom sediment, the hypothesis of a significant direct bottom sediment source in fish is quite untenable.

A sequence of somewhat circumstantial evidence, including the above discussion of Cs-137/K-40 ratios, the previous discussions of trends in Cs-134/Cs-137 ratios, and the previously identified inverse proportionality between the radiocesium concentration factor in fish and the concentration of Cs in water, leads this investigator to believe that Hudson River fish acquire radiocesium and K either primarily by direct uptake from water or from consumption of dietary items whose radiocesium content is closely proportional to the radiocesium content of water. In any event, the concept of concentration factors is quite valid for determining radiocesium concentrations in fish, as long as the value for the concentration factor is determined for the body of water of interest.

From Table VIII-14, the average concentration of Cs-137 in upstream fish averaged 20.5 ± 1.9 pCi/kg in 1969 (n=5 months of data) and 14.8 ± 1.4 pCi/kg in 1970 (n=5 months of data). This difference is significant at the 5-percent level but not at the 2-percent level. The cumulative deposition and average monthly deposition of fallout Cs-137 were nearly identical in 1969 and 1970 (see Tables IV-1 and VII-1). The freshwater discharges into the Hudson during 1969 and 1970 were also nearly identical (see Table VI-1). The model developed in the section on radionuclides of fallout origin (see equation (52)) predicts almost identical concentrations of fallout Cs-137 in water during 1969 and 1970. Hence, it is expected that concentrations of fallout Cs-137 in upstream fish should have been the same during 1969 and 1970.

At Indian Point, the average concentrations of Cs-134 and Cs-137 in fish were 50.1 ± 6.9 and 52.9 ± 3.9 pCi/kg, respectively, during June-December, 1969 (n=5 months of data), and 25.4 ± 2.9 and 27.1 ± 4.2 pCi/kg, respectively, during May-August, 1970 (n=4 months of data). The difference in Cs-134 concentrations during 1969 and 1970 is significant at the 2-percent level and the difference in the Cs-137 concentrations is significant at the 1-percent level. The average water chlorosities during the 1969 and 1970 periods were similar, being 0.61 and 0.62 g/l, respectively. The average concentration factors of radiocesium in fish during 1969 and 1970 should, therefore, be similar, and the 2-fold higher concentrations of Cs-134 and Cs-137 in fish during 1969 imply that the concentrations of Cs-134 and Cs-137 in water were also approximately 2-fold higher in 1969 than in 1970. A previous comparison of the Cs-134 and Cs-137 concentrations in rooted aquatic plants from Indian Point during these same periods of 1969 and 1970 indicated that the concentrations of Cs-134 and Cs-137 in water were factors of 1.4 and 1.8 higher in 1969 than in 1970. Based on these findings, the average concentrations of Cs-134 and Cs-137 in water at Indian Point during June-December, 1969 are estimated to have been approximately 0.7-1.0 pCi/l (dissolved).

Distributions in Plankton,
Algae and Invertebrates

Concentrations of radiocesium in a limited number of plankton, filamentous algae and invertebrate samples from the IPSA are given in Table VIII-22. Dissolved concentration factors computed for the Cs-137 data are given in Table VIII-55. Dissolved concentrations of Cs-137 in continuous water samples which were collected during the two-week period preceding the biota collections were employed. The dissolved Cs-137 concentration in these continuous water samples was estimated from the average dissolved percentage of Cs-137 in grab water samples which were collected at the start and end of the continuous water sample collection periods.

The dissolved radiocesium concentration factor in the five monthly plankton samples from April-September, 1970, ranged from 120-3100 and

Table VIII-18

Concentrations of ^{137}Cs , ^{40}K , Mn, Co, Zn and Fe in Several Anadromous Species of Fish from the Hudson. Fillets only. 1970.

Species	pCi/kg Wet		mg/kg Wet			
	^{40}K	^{137}Cs	Mn	Co	Zn	Fe
Shad	2360	13.5	0.76	0.15	3.40	18.3
	2530	14.2	1.33	0.23	8.50	11.7
	2440	5.1	0.82	0.23	4.17	
	2200	12.8	0.57	0.20	3.89	
	<u>1630</u>	<u>6.9</u>	<u>0.37</u>	<u>0.12</u>	<u>4.61</u> ^a	
	Avg.	2230	10.5	0.77	0.19	4.91
Herring	2710	21.0	1.54	0.40	8.92	
	<u>2200</u>	<u>10.7</u>	<u>2.39</u>	<u>0.42</u>	<u>10.90</u>	
	Avg.	2460	15.9	1.97	0.41	9.91
Sturgeon	2380	21.6	0.41	0.07	2.87	
	<u>1050</u>	<u>9.7</u>	<u>1.97</u>	<u>0.37</u>	<u>4.42</u>	
	Avg.	1720	15.7	1.20	0.22	3.65
Striped Bass	2890	34.4	0.86	0.36	9.18	12.9
	2340	16.2	0.36	0.08	2.67	
	2410	20.3	0.60	0.09	2.59	
	2410	33.5	0.72	0.39	5.97	
	1870	14.6	0.78	0.35	4.92	
	2250	18.1	0.55	0.27	5.71	
	<u>2330</u>	<u>30.5</u>	<u>0.44</u>	<u>0.29</u>	<u>6.62</u>	
	Avg.	2360	23.9	0.62	0.26	5.38

Table VIII-24

Dependence of Stable Element and Radionuclide Concentrations in Fish on Fish Size. Samples Obtained at the Same Site and on the Same Date.

Species Site Date	Avg. Fish Size, g	pCi/kg Wet			mg/kg Wet		
		⁴⁰ K	⁵⁴ Mn	¹³⁷ Cs	Mn	Co	Zn
Common Sunfish IPM -15. 5/15/70	10	1550.+40.		14.3+2.1			
	20	1310.+50.		18.9+2.9			
	40	1560.+50.		14.7+2.6			
	80	1240.+50.		11.0+2.8			
White Perch IPM +2.3 5/22/70	10	580.+60.	27.6+7.8	23.9+3.5	11.2	0.68	22.7
	30	570.+50.	24.5+7.4	17.0+3.2	11.7	0.90	25.8
	60	620.+60.	21.8+7.9	18.3+3.5	10.2	1.09	26.2
White Perch IPM +5.2 6/15/70	30	500.+50.		13.1+2.8	4.95	0.88	24.1
	70	710.+60.		16.7+3.6	4.52	0.95	24.7
	120	740.+60.		18.8+3.4	4.09	1.06	25.1
	150	590.+50.		18.9+3.2	3.84	1.01	22.5
White Perch IPM +2.3 7/02/70	30	540.+60.		12.3+3.6	5.80	0.83	26.2
	50	510.+60.		18.0+3.4	4.91	1.02	26.6
	90	330.+60.		9.8+3.3	4.47	1.11	27.5
White Perch IPM 0.0 6/15/70	10	1210.+40.		42.4+2.4	4.51	0.64	24.6
	30	1380.+60.		32.1+3.1	4.01	0.98	25.5
	120	1450.+60.		41.9+3.6	3.94	1.13	25.0

Table VIII-51

Relative Concentrations of Cs-137 in
Different Species of Fish.

Species	Number of Samples (n)	Relative Concentration	
		Mean \pm s/ \sqrt{n}	Range
Alewife	7	0.74 \pm 0.19	0.32-1.51
Bluegill Sunfish	2	0.92 \pm 0.08	0.85-1.01
Catfish	1	1.59	—
Common Silversides	1	1.31	—
Common Sunfish	9	0.88 \pm 0.16	0.44-1.73
American Eel	1	2.93	—
Freshwater Killifish	5	0.87 \pm 0.19	0.37-1.36
Golden Shiner	6	0.98 \pm 0.18	0.54-1.71
Gold Fish	3	1.41 \pm 0.44	0.95-2.29
Largemouth Bass	1	1.31	—
Red-Bellied Sunfish	4	0.84 \pm 0.08	0.65-0.99
Saltwater Killifish	1	2.40	—
Spottail Shiner	9	0.91 \pm 0.15	0.39-1.68
Striped Bass	4	0.80 \pm 0.11	0.56-1.09
Sucker	1	1.51	—
Summer Herring	1	0.50	—
Tom Cod	1	0.30	—
Yellow Perch	2	1.95 \pm 0.19	1.76-2.14
White Perch	13	1.00	—

Table VIII-52

Concentration Factors of Cs-134 and Cs-137 in Whole Fish at Indian Point. Average Values over all Species Collected.

Month	Water Chlorosity (g/l)	Conc. ,pCi/kg Wet		Concentration Factor	
		Fish	Water ^a	Dissolved	Total
Cs-134					
5/70	0.33	19.4	1.04 (58) ^b	32	19
6/70	0.57	25.1	0.38 (62)	107	66
7/70	0.96	33.3	0.38 (73)	120	88
Average	0.62	25.9	0.60 (64)	67	43
Cs-137					
5/70	0.33	29.1	0.90 (58)	56	32
6/70	0.57	33.8	0.37 (62)	147	91
7/70	0.96	30.8	0.36 (73)	117	86
Average	0.62	31.2	0.54 (64)	90	58

(a)Continuous water samples from IPM +1.0. Total of suspended and dissolved fractions.

(b)Value in parenthesis is the monthly average percentage of dissolved radiocesium in grab water samples at IPM 0.0 and IPM +1.0.

Table VIII-53

Stable Cs Concentrations in Fish and Water (Dissolved) from Various Freshwater and Marine Environments.

Reference	Concentration		Diss. Conc. Factor
	Fish ($\mu\text{g}/\text{kg Wet}$)	Water ($\mu\text{g}/\text{l}$)	
Freshwater			
Nelson(1969)	9.03	0.025	360
Merlini, Girardi and Pozzi(1967)	33.8	0.016	2100
Rancitelli, Tanner and Dean(1969)	16.5	—	—
Rancitelli, Templeton and Dean(1969)	11.0	—	—
Kevern and Spigarelli(1971) ^a	16.8	0.0036	4700
	15.6	0.0029	5400
	16.3	0.0013	13000
	16.9	0.0039	4300
	13.4	0.0087	1500
Kharkar, Turekian and Bertine(1967) ^b	11.9	0.0090	1300
	—	0.017	—
Marine			
Folsom, Young and Sreekumaran(1969)	38.0	0.36	110
Robertson, Forster and Rieck(1968)	15.0	0.22	68
Robertson and Prospero(1969)	—	0.26	—
Rancitelli(1969)	23.4	0.30 ^c	78
Folsom et al (1970)	—	0.30	—
Kolehmainen and Nelson(1969)	21. ^d	0.30 ^c	70

(a) Values for six different lakes.

(b) Average value for seven eastern USA rivers.

(c) "Best estimate" value from Folsom et al. (1970).

(d) Average value found in a literature survey.

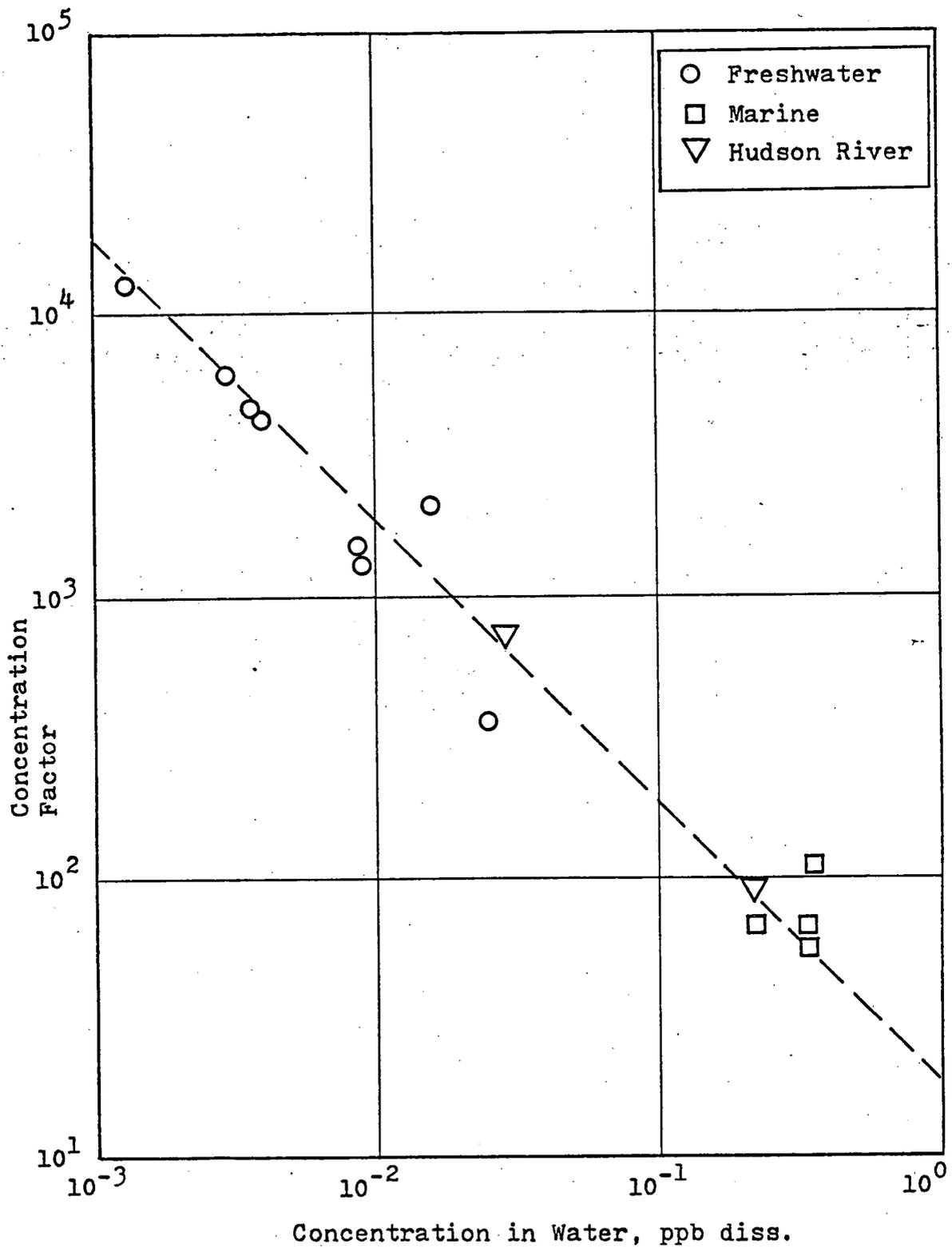


Figure VIII-73. Stable Cs Concentration Factors in Fish vs Stable Cs Concentrations in Water.