NUS-4679

PRELIMINARY PREOPERATIONAL SUMMARY REPORT

OF THE

RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM AT THE PERRY NUCLEAR POWER PLANT

Prepared for
The Cleveland Electric Illuminating Company

by
Carl R. Yates

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NUS Corporation
910 Clopper Road
Gaithersburg, MD 20878

David K. Dougherty, Manager
Radiological Programs Department

A. Edgar Mitchell, Jr.
Project Manager

Preface

This report presents the results of the Perry Nuclear Power Plant (PNPP) Radiological Environmental Monitoring Program (REMP) through the fall of 1984. It is a preliminary report of the preoperational REMP. After Perry Unit 1 goes critical, additional data will be incorporated into a final preoperational summary report.

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1.0 INTRODUCTION

The preoperational radiological environmental monitoring program (REMP) for the Perry Nuclear Power Plant (PNPP) was initiated in March 1981 and is ongoing. Pressurized Ionization Chamber (PIC) readings were made on March 24, 1981 as an initial environmental characterization and to detect gross anomalies. The first REMP samples (fish and sediment) were collected on May 20, 1981. This is the Preliminary Preoperational Summary Report for the radiological environmental monitoring program. This report covers the period March 24, 1981 through October 2, 1984 and summarizes the results of measurements and analyses of data obtained from samples collected during this interval. This program was conducted by NUS Corporation under contract with The Cleveland Electric Illuminating Company (CEI) until October 1984. This report will be reissued in final form when all data, through the date of criticality, (expected mid 1985) are available.

A. Site and Station Description

PNPP will consist of two BWR units, each designed to operate at a power level of about 1205 megawatts-electric with the main condenser circulating water cooled by a system of closed-loop natural draft cooling towers. The plant is located on Lake Erie, on approximately 1100 acres, about thirty-five (35) miles northeast of Cleveland, Ohio and about seven (7) miles northeast of Painesville, Ohio. PNPP is situated in North Perry Village in northeastern Lake County, Ohio.

B. Objectives and Overview of PNPP Monitoring Program

United States Nuclear Regulatory Commission (USNRC) regulations require that nuclear power plants be designed, constructed, and operated to keep levels of radioactive material in effluents to unrestricted areas as low as reasonably achievable (ALARA) (10 CFR 50.34). To ensure that these criteria are met, each license authorizing reactor operation includes technical specifications (10 CFR 50.36a) governing the release of radioactive effluents.

In-plant monitoring will be used to assure that these predetermined release limits are not exceeded. However, as a precaution against unexpected and undefined processes which might allow undue accumulation of radioactivity in any sector of man's environment, a program for monitoring the plant environs is also included.

The regulations governing the quantities of radioactivity in reactor effluents allow nuclear power plants to contribute, at most, only a few percent increase above normal background radioactivity. Background levels at any one location are not constant but vary with time as they are influenced by external events such as cosmic ray bombardment, weapons test fallout, and seasonal variations. These levels also can vary spatially within relatively short distances reflecting variations in geological composition. Because of these spatial and temporal variations, the radiological surveys of the plant environs are divided into preoperational and operational phases. The preoperational phase of the program of sampling and measuring radioactivity in various media permits a general characterization of the radiation levels and concentrations prevailing prior to plant operation, along with an indication of the degree of natural variation to be expected. The operational phase of the program obtains data which, when considered along with the data obtained in the preoperational phase, assist in the evaluation of the radiological impact of plant operation.

Implementation of the preoperational monitoring program fulfills the following objectives:

1. Evaluation of procedures, equipment and techniques.

2. Identification of potentially important pathways to be monitored after the plant is in operation.

3. Measurement of background levels of radioactivity and radiation and their variations along potentially important pathways in the area surrounding the plant.

4 Provision of baseline data for statistical comparison with future operational analytical results.

Sampling locations were selected on the basis of local ecology, meteorology, physical characteristics of the region, and demographic and land use features of the site vicinity. The preoperational program was designed based on the USNRC Radiological Assessment Branch Technical Position on radiological environmental monitoring as revised in Revision 1 November 1979 (reference 1).

2.0 PROGRAM DESCRIPTION

As of October, 1984 there were forty locations within a radius of about 15 miles from the PNPP site included in the monitoring program. The number and location of monitoring points were determined from predictions of the highest expected offsite environmental concentrations. For these predictions, the plant effluent source terms provided the release rates of various radioisotopes. Then site hydrology, meteorology, and design parameters were used to calculate dilution and dispersion factors and probable decay times. Other factors considered were applicable regulatory guidelines (Appendix I to 10CFR50, Regulatory Guides 4.1, 4.2, and 4.8), population distribution (from environmental report), ease of access to sampling stations, security, and future program integrity (e.g., not placing TLDs near areas under construction or where the potential for vandalism is high). In addition, certain locations where PNPP operations are unlikely to affect levels of radiation or radioactivity were selected as control locations.

The PNPP radiological environmental monitoring program includes the measurement of ambient gamma radiation by thermoluminescent dosimetry; the determination of gamma emitters in shoreline sediments and fish; the determination of gross beta and gamma emitters in air particulates; the measurement of airborne I-131 in charcoal cartridges; the measurement of gross beta, gamma emitters, and tritium in water; and the determination of gamma emitters and I-131 in milk. These media and analyses were selected since they provide measurements of radiation and radioactive materials in those exposure pathways and for those radionuclides which lead to the highest potential radiation exposures of individuals resulting from station operation. In addition, beyond the minimum program requirements, fodder and food products were collected annually (starting in 1982) and analyzed for gamma emitting nuclides. Also, starting in August, 1983, sediment, water, and milk samples were analyzed for Sr-89 and Sr-90.

The preoperational radiological environmental monitoring program for Perry was initialed in 1981. The program is summarized in Table 1. Table 2 describes sample locations, associated media, approximate distance and direction from

the site, and the initial date of sampling. Figures 1 and 2 illustrate the locations of sampling stations relative to PNPP.

Table 3 presents a chronological history of the PNPP monitoring program. This table lists the various media and the sum of the control and indicator locations that were sampled during each year of the program. Figure 3 indicates the sampling media milestones for the PNPP monitoring program.

The data tables included in the preoperational summary report are for those analyses in which many positive activities have been detected. Iodine-131 in Air, iodine-131 in milk, gamma spectrometry of water, strontium-89 and strontium-90 in water, strontium-89 in milk, and strontium-89 and strontium-90 in sediment are not included in individual data tables since no or very few positive activities were detected over the course of the program. Only Lower Limits of Detection (LLDs) (see Appendix B) were reported for I-131 in air and milk, Sr-89 and Sr-90 in sediment, gamma spectrometry of water, and Sr-89 in milk and water.

Three trending figures have also been included: Figure 4 - Average Monthly Ambient Radiation Levels in the Vicinity of the PNPP, Figure 5 - Average Monthly Gross Beta Activity in Air Particulates in the Vicinity of the Perry NPP, and Figure 6 - Average Monthly Gross Beta Activity in Water in the Vicinity of the Perry NPP. Trending figure averages include both indicator and control locations.

All calculated averages in Tables 4 through 16 include both indicator and control locations. Indicator and control data are combined in the averages since there was no observable difference between the two. This is readily apparent from the indicator and control averages presented in Table 17.

A statistical summary of the results appears in Table 17. The reported averages are based only on concentrations above the limit of detection. In Table 17, the fraction (f) of the total number of analyses which were detectable follows in parenthesis. Also given in parenthesis are the minimum and maximum values of detectable activity during the reporting period.

In addition to the described analytical program, a milk animal, vegetable garden, and residence survey was performed annually. This survey identifies the nearest garden and residence in each sector and all milk animals out to 5 miles and is updated annually. Land-use survey data from 1984 is presented in Tables 18 through 20.

TABLE 1
(Page 1 of 2)

PNPP RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

Sample Media	Locations	Sampling Frequency	Type	Analysis Frequency
Airborne Radioiodine and Particulates	1, 3, 4, 5, 6, 35	Continuous sampler operation with collection weekly or as required by dust loading, whichever is more frequent	Radioiodine I-131	Weekly following canister change
			Particulates Gross Beta[a]	Weekly following filter change
			Gamma Isotopic[b]	Composite, by location quarterly
Direct Radiation (2 TLDs/location)	1 through 24 plus 35	Continuous sampling, one TLD exchanged monthly	Gamma Dose	Monthly
		Continuous sampling, one TLD exchanged annually	Gamma Dose	Annually
Waterborne surface drinking	28, 34, 36, 37,	Monthly Composite[c]	Gross Beta	Monthly
			Gamma Isotopic	Monthly
			H-3	Composite, by location, quarterly
			Sr-89, -90	Quarterly (analyses performed on one monthly sample per station per quarter)
Sediment from shoreline	25, 26, 27, 32	Semiannually--spring and fall as weather permits	Gamma Isotopic	Semiannually
			Strontium-89, 90	Semiannually
Ingestion Milk[d]	29, 30, 31, 33	Monthly when animals are not on pasture	I-131, Gamma Isotopic	Monthly
		Semimonthly when animals are on pasture	I-131, Gamma isotopic	Semimonthly
			Sr-89, -90	Quarterly (analyses performed on one monthly sample per station per quarter)

See footnotes at end of table.

TABLE 1
(Page 2 of 2)

PNPP RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

Sample Media	Locations	Sampling Frequency	Type	Analysis Frequency
Fish	25, 32	Semiannually--spring and fall as weather permits	Gamma Isotopic (edible portion)	Semiannually
Silage	29, 30, 31, 33	Annually	Gamma Isotopic	Annually
Food Products	38, 39, 40	Annually	Gamma Isotopic	Annually

(a) Particulate sample filters will be analyzed for gross beta 24 hours or more after sampling to allow for radon and thoron daughter decay. If gross beta activity in air is greater than ten times the mean of the control samples for any medium, gamma isotopic analysis will be performed on the individual samples.

(b) Gamma isotopic analysis means the identification and quantification of gamma-emitting radionuclides that may be attributable to the effluents from the facility.

(c) Composite samples will be collected with equipment that is capable of collecting an aliquot at time intervals that are very short (e.g., hourly) relative to the compositing period (e.g., monthly).

(d) I-131 to be performed at least for 6 months of the last full pasture season prior to operation.

Table 2
(Page 1 of 6)

Sample Locations and Media for the Perry
Radiological Environmental Monitoring Program for 1984

Location No.	Description	Distance (Miles)	Direction	Media(1)	Date Sampling Began
1	Redbird (Haines Road, North of West Chapel Road) On pole 3303609; first pole south of first driveway on left	3.4	ENE	TLD AP, AI	May 1981 Oct. 1982
2	Site boundary; tree line Ash tree 1000 feet NNW of second transmission tower from road	0.7	E	TLD	May 1981
3	Meteorological tower On fence surrounding the equipment shelter	1.0	SE	TLD AP, AI	May 1981 Oct. 1982
4	Site Boundary On pole #W79/SPG5-30; inside auxiliary road gate off Parmly Rd.	0.7	S	TLD AP, AI	May 1981 Oct. 1982
5	Site Boundary, Quincy Substation On pole #L1283/9300; east side of substation	0.6	SW	TLD AP, AI	May 1981 Oct. 1982
6	Concord Service Center (Control) Auburn Road south of Rt. 90; on inside rear fence next to gate	11.0	SSW	TLD AP, AI	May 1981 Oct. 1982

See footnotes at end of table.

Sample Locations and Media for the Perry
Radiological Environmental Monitoring Program for 1984

Location No.	Description	Distance (Miles)	Direction	Media(1)	Date Sampling Began
7	Site Boundary; Lockwood Road Bus Turnaround On tree on right, 100 feet past the turnaround	0.6	NE	TLD	May 1981
8	Site Boundary; Tree Line 1000 feet N of location #2 on tree near rusted manure spreader	0.8	ENE	TLD	May 1981
9	Site Boundary; Transmission Line Tower Third tower from Antioch Road toward the plant	0.7	ESE	TLD	May 1981
10	Site Boundary; Southsoutheast Corner Security Fence On pole at turn in the fence	0.8	SSE	TLD	May 1981
11	Site Boundary; Transmission Line Tower On tower at SW corner of Center and Parmly Roads	0.6	SSW	TLD	May 1981
12	Site Boundary; Transmission Line Tower Access road from N side of Parmly just W of location # 5, left at first turn after 90 degree left; TLD on tower to right	0.6	WSW	TLD	May 1981

See footnotes at end of table.

Table 2
(Page 3 of 6)

Sample Locations and Media for the Perry
Radiological Environmental Monitoring Program for 1984

Location No.	Description	Distance (Miles)	Direction	Media[1]	Date Sampling Began
13	Madison-on-the-Lake At end of Whitewood Drive, N of Chapel Road, NW side of turnaround on pole #835803	4.7	ENE	TLD	May 1981
14	Hubbard Road (South of North Ridge Road) On pole #28974 on W side of road, S side of McMackin Creek	4.9	E	TLD	May 1981
15	Madison Substation (Eagle Street) First pole next to substation near railroad tracks	5.1	ESE	TLD	May 1981
16	Dayton Road (North of Interstate 90) On pole #572203 on left after dirt driveway which is just after the sharp left on Dayton after crossing I-90	5.0	SE	TLD	May 1981
17	Chadwick Road (Cul de Sac South of Interstate 90) On pole #276222/112Z011; last pole on left	5.2	SSE	TLD	May 1981
18	Blair Road On pole on left just after road makes 90 degree left curve from south to east heading toward Grand River Bridge.	5.0	S	TLD	May 1981

See footnotes at end of table.

Table 2
(Page 4 of 6)

Sample Locations and Media for the Perry
Radiological Environmental Monitoring Program for 1984

Location No.	Description	Distance (Miles)	Direction	Media(1)	Date Sampling Began
19	Lane Road and South Ridge Road On pole #PC5648, 100 feet north of intersection	5.3	SSW	TLD	May 1981
20	Nursery Road at Route 2 Overpass On pole #828976, across from entrance to Rt. 2	5.3	SW	TLD	May 1981
21	Hardy Road at Painesville Township Park On pole #378345, east of park entrance	5.1	WSW	TLD	May 1981
22	Painesville On S side of Main Street across from Evergreen Cemetery entrance, on tree 50 feet west of pole #DBPG296	6.9	SW	TLD	May 1981
23	Fairport Harbor (High Street and New Street) On pole on street side of substation	7.9	WSW	TLD	May 1981
24	St. Clair Avenue Substation (Control) In Mentor; on rear fence corner near railroad tracks	15.1	SW	TLD	May 1981
25	PNPP Discharge	0.6	NNW	SED, FSH	May 1981

See footnotes at end of table.

Sample Locations and Media for the Perry
Radiological Environmental Monitoring Program for 1984

Location No.	Description	Distance (Miles)	Direction	Media(1)	Date Sampling Began
26	Offshore at Redbird, vicinty of Ohio Water Service Company Intake	4.2	ENE	SED	May 1981
27	Offshore, vicinty of Fairport Harbor Water Supply System Intake	7.9	WSW	SED	May 1981
28	Ashtabula (Control), CEI Generating Station Intake	22.0	ENE	WTR	Sept. 1982
29	Milk Farm, J. Waites, Antioch Road	1.4	ESE	MLK	Feb. 1983
30	Milk Farm, E. Manley, North Ridge Road	2.3	SSW	MLK	Mar. 1983
31	Milk Farm, Hofer, Antioch Road	1.4	ESE	MLK	Feb. 1984
32	Mentor-on-the-Lake (Control)	15.8	WSW	SED, FSH	May 1981
33	Brookglen Farm (Control), Callow Road	10.2	S	MLK	Oct. 1982
34	PNPP Intake	0.7	NW	WTR	Sept. 1982
35	Site Boundary, Center of Sector, follow tree line around fields south and west of Location #2	0.6	E	AP, AI, TLD	Nov. 1982

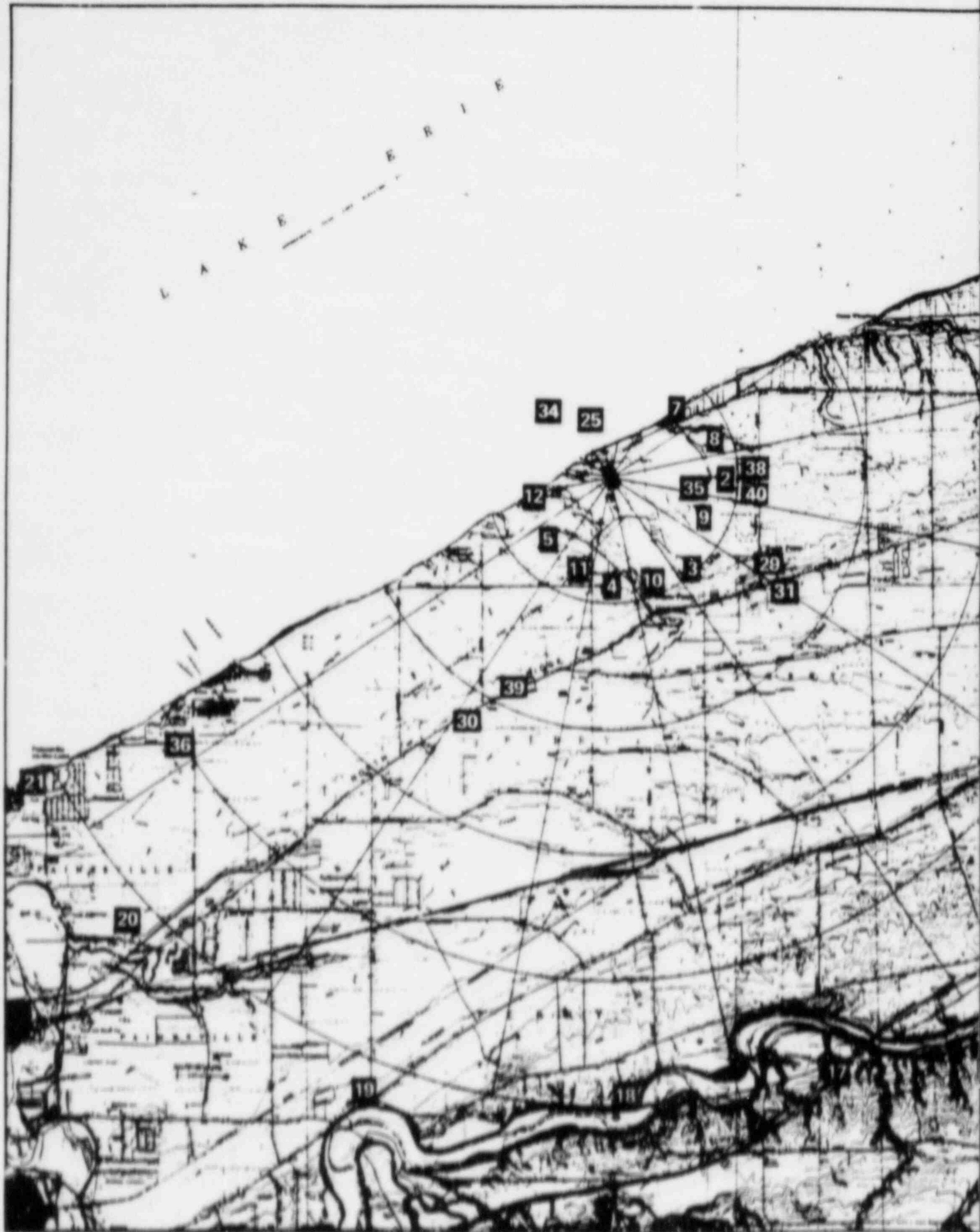
See footnotes at end of table.

Table 2
(Page 6 of 6)

Sample Locations and Media for the Perry
Radiological Environmental Monitoring Program for 1984

Location No.	Description	Distance (Miles)	Direction	Media(1)	Date Sampling Began
36	Painesville Water Supply Intake	3.9	WSW	WTR	Sept. 1982
37	Ohio Water Service Company, Lake Erie East, Madison; at end of Green Road in Redbird	4.1	ENE	WTR	Sept. 1982
38	Farm at site boundary, off Antioch Road	1.1	E	FP	Sept. 1982
39	Goldings, N. Ridge Road	1.8	SSW	FP	Sept. 1983
40	Antioch Road	1.1	E	FP	Sept. 1983

(1) AP = Air particulate
AI = Air iodine
TLD = Ambient gamma dose rate
SED = Sediment
WTR = Water
FSH = Fish
MLK = Milk
FP = Food Products


LAKE ERIE
34
25
7
8
38
2
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36
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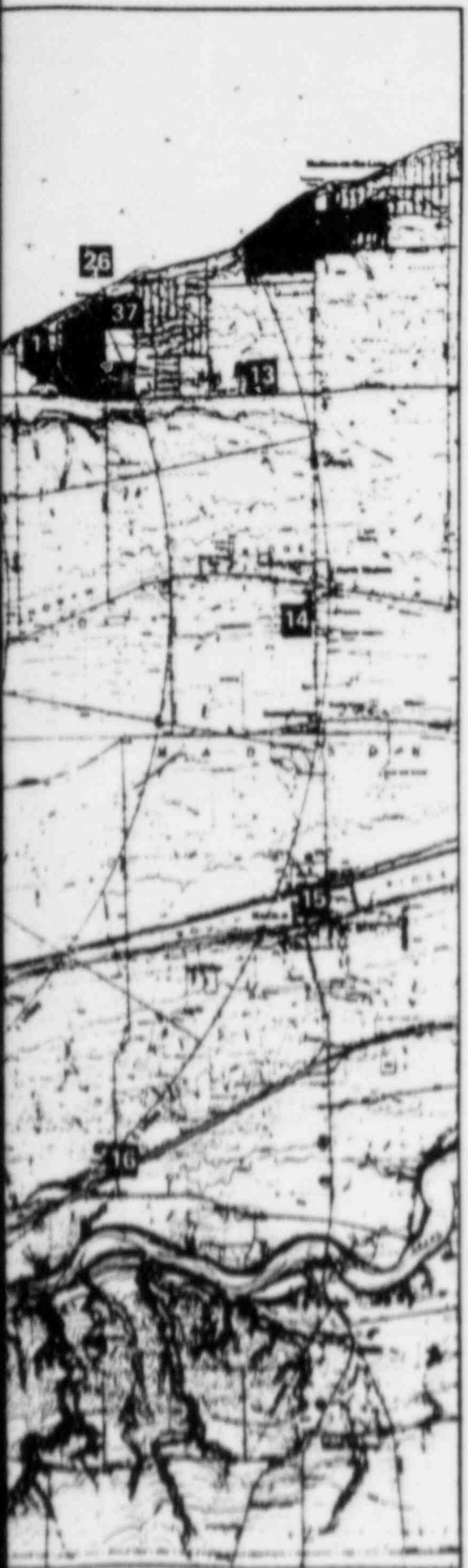

LEGEND

Station No.	Media	Direction
1	Air – TLD	ENE
2	TLD	E
3	Air – TLD	SE
4	Air – TLD	S
5	Air – TLD	SW
7	TLD	NE
8	TLD	ENE
9	TLD	ESE
10	TLD	SSE
11	TLD	SSW
12	TLD	WSW
13	TLD	ENE
14	TLD	E
15	TLD	ESE
16	TLD	SE
17	TLD	SSE
18	TLD	S
19	TLD	SSW
20	TLD	SW
21	TLD	WSW
25	Sediment – Fish	NNW
26	Sediment	ENE
29	Milk	ESE
30	Milk	SSW
31	Milk	ESE
34	Water	NW
35	Air – TLD	E
36	Water	WSW
37	Water	ENE
38	Food Products	E
39	Food Products	SSW
40	Food Products	E

PNPP ENVIRONMENTAL
RADIOLOGICAL MONITORING PROGRAM
SAMPLING LOCATIONS WITHIN 5 MILES OF SITE

PERRY NUCLEAR POWER PLANT 1 & 2

THE CLEVELAND ELECTRIC
ILLUMINATING COMPANY

Figure 1

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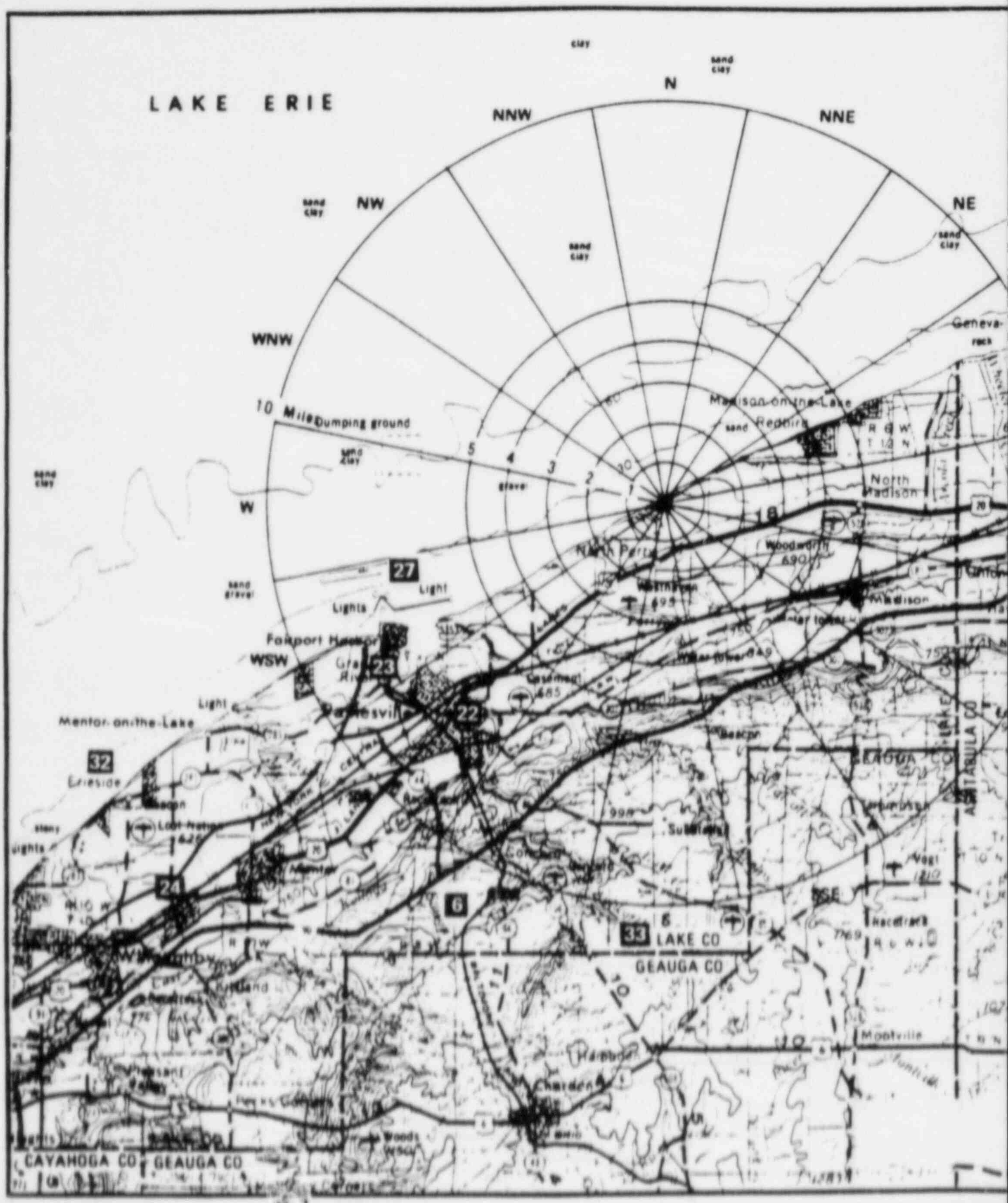
LAKE ERIE
N
NNW
NNE
NW
NE
WNW
W
WSW
10 Mile
Dumping ground
Madison-on-the-Lake
North Madison
Madison
Fairport Harbor
Mentor-on-the-Lake
Erieside
LAKE CO
GEAUGA CO
CAYAHOGA CO
GEAUGA CO
ASHTABULA CO
Chardon
Montville

Also Available On
Aperture Card

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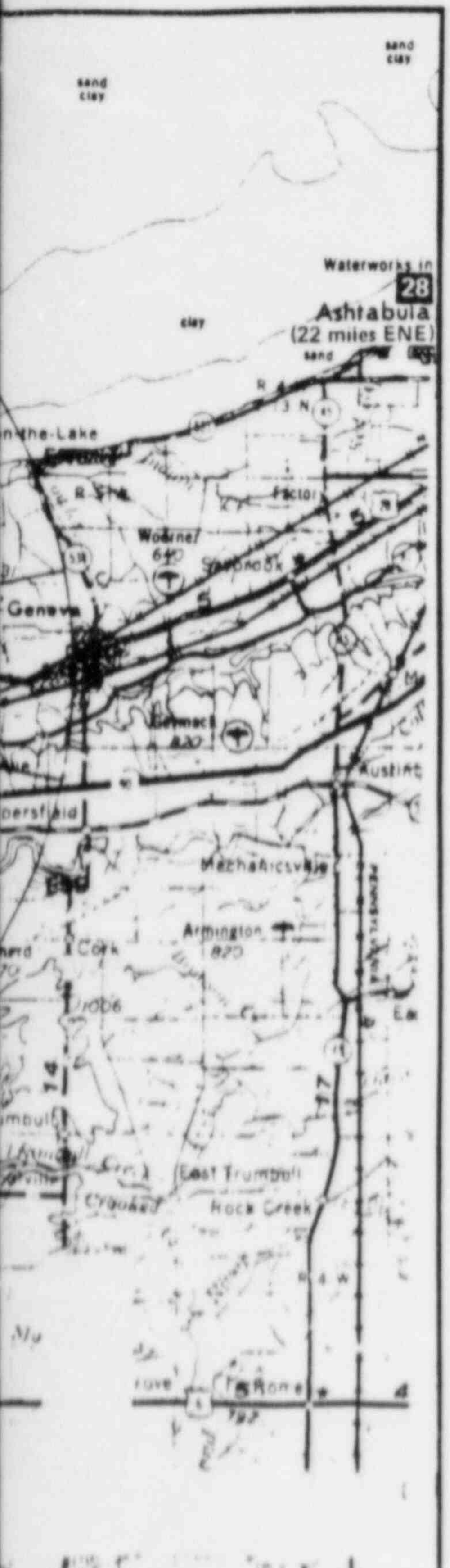
CARD



0 1 2 3 4 5 10 Miles

LEGEND

Station No.	Media	Direction
6	Air – TLD – (Control)	SSW
22	TLD	SW
23	TLD	WSW
24	TLD (Control)	SW
27	Sediment	WSW
28	Water (Control)	ENE
32	Fish – Sediment (Control)	WSW
33	Milk (Control)	S

PNPP ENVIRONMENTAL
RADIOLOGICAL MONITORING PROGRAM
SAMPLING LOCATIONS > 5 MILES FROM SITE

PERRY NUCLEAR POWER PLANT 1 & 2

THE CLEVELAND ELECTRIC
ILLUMINATING COMPANY

Figure 2

8508070259-02

Table 3

Preoperational Summary Report
Chronological History

PNPP REMP 1981 - 1984
(Sheet 1 of 3)

Year	Media	Analysis[1]	Number of Stations[2]
1981	Direct Radiation	TLD- M, A	24
	Fish	Gamma Isotopic-SA	2
	Sediment	Gamma Isotopic-SA	4
1982	Direct Radiation	TLD- M, A	25
	Fish	Gamma Isotopic-SA	2
	Sediment	Gamma Isotopic-SA	4
	Airborne Particulates	Gross Beta-W Gamma Isotopic-Q	6
	Airborne I-131	Iodine-131-W	6
	Water	Gamma Isotopic-M Gross Beta-M Tritium-Q	4
	Milk	Gamma Isotopic-M, SM Iodine-131 -M, SM	1
	Feed/Silage	Gamma Isotopic-A	1
	Vegetation	Gamma Isotopic-A	1

Table 3

Preoperational Summary Report
Chronological History

PNPP REMP 1981 - 1984
(Sheet 2 of 3)

Year	Media	Analysis(1)	Number of Stations(2)
1983	Direct Radiation	TLD-M, A	25
	Fish	Gamma Isotopic-SA	2
	Sediment	Gamma Isotopic-SA Strontium-89, 90 -A	4
	Airborne Particulates	Gross Beta-W Gamma Isotopic-Q	6
	Airborne I-131	Iodine-131 -W	6
	Water	Gamma Isotopic-M Gross Beta-M Tritium-Q Strontium-89, 90 -Q	4
	Milk	Gamma Isotopic-M, SM Iodine-131 -M, SM Strontium-89, 90 -Q	3
	Feed/Silage	Gamma Isotopic-A	3
	Vegetation	Gamma Isotopic-A	3

Table 3

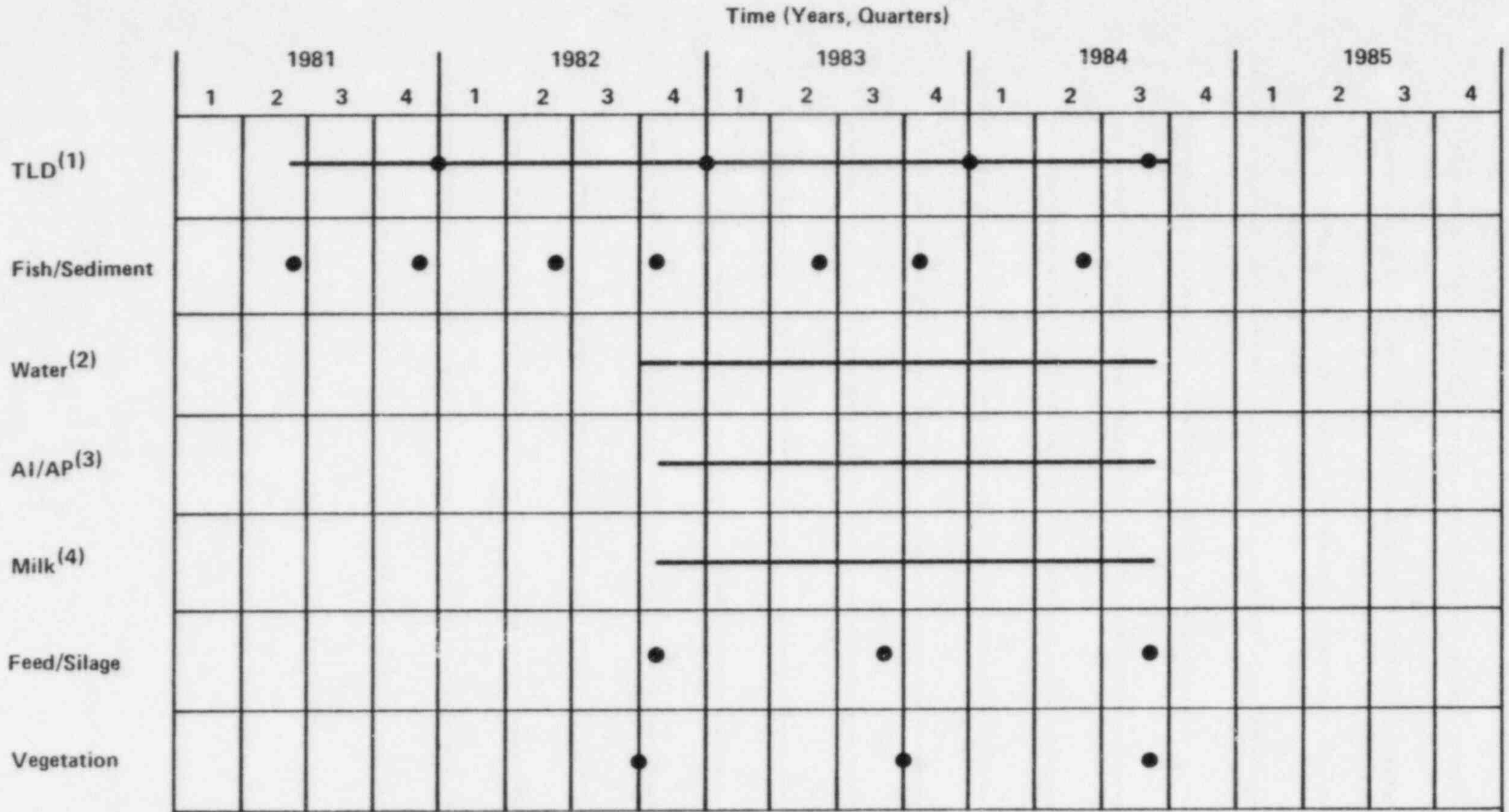
Preoperational Summary Report
Chronological History

PNPP REMP 1981 - 1984
(Sheet 3 of 3)

Year	Media	Analysis(1)	Number of Stations(2)
1984	Direct Radiation	TLD-M, A	25
	Fish	Gamma Isotopic-SA	2
	Sediment	Gamma Isotopic-SA Strontium-89, 90 -A	4
	Airborne Particulates	Gross Beta-W Gamma Isotopic-Q	6
	Airborne I-131	Iodine-131 -W	6
	Water	Gamma Isotopic-M Gross Beta-M Tritium-Q Strontium-89, 90 -Q	4
	Milk	Gamma Isotopic-M, SM Iodine-131 -M, SM Strontium-89, 90 -Q	4
	Feed/Silage	Gamma Isotopic-A	4
	Vegetation	Gamma Isotopic-A	2

(1) W = Weekly
Q = Quarterly
M = Monthly
SA = Semi-Annually
A = Annually
SM = Semi-Monthly

(2) Sum of indicator and control locations



(1) TLD collections are monthly and annually. Dots represent the annual TLD collection.
(2) Water sampling is conducted monthly.
(3) Air Iodine (AI) and Air Particulate (AP) sampling is conducted weekly.
(4) Milk sampling is conducted monthly from November through March and semi-monthly otherwise.

FIGURE 3. SAMPLING MEDIA MILESTONES FOR THE PNPP REMP– 1981 THROUGH 1984.

3.0 SAMPLING METHODS AND PROCEDURES

To derive meaningful and useful data from the radiological environmental monitoring program, sampling methods and procedures are required which will provide samples representative of potential pathways of the area. During the preoperational phase of the program, samples are collected and analyzed not only to obtain background radiological levels, but to acquire experience with the sampling methodology and procedural format dictated by site specific requirements (reference 1). The following methods and procedures were applicable to the monitoring program as of October 1984. Any changes in the methods or procedural formats during the course of the program are reflected in the individual Annual Reports (see references).

A. Direct Radiation

Thermoluminescent dosimeters (TLDs) were used to determine the direct (ambient) radiation levels at twenty-five (25) monitoring points as described in Tables 1 and 2. Sampling locations were chosen according to the criteria given in the USNRC Branch Technical Position on Radiological Monitoring (Revision 1, November 1979) (reference 2). A description of the TLDs used in this program is given in Appendix E. TLDs were located in two rings around the station. An inner ring was located near the site boundary and an outer ring was located at an approximate distance of 4 to 5 miles from the station. Figures 1 and 2 show the locations of the TLD stations.

The area around the station was divided into 16 radial sectors of 22 1/2 degrees each. TLDs were placed in all sectors except those which radiated from the site directly out over the lake without intersecting any unrestricted areas. Additional TLDs were located at three nearby communities and two control locations.

For routine TLD measurements, two dosimeters of $CaSO_4$:Dy in teflon cards were deployed at each selected location. Prior to deployment, individual dosimeters were calibrated by exposure to a known radiation field from a calibrated Cs-137 source. One set of dosimeters was exchanged on a monthly

basis and the second set was exchanged on an annual basis. Additional sets of dosimeters were shipped with each exchange cycle to serve as in-transit controls. For routine exchanges TLDs were shipped by ground transportation one evening, picked up and exchanged the following day, and returned by ground transportation on the second evening. This was done to maintain the minimum possible in-transit dose. Upon receipt at the laboratory, the TLDs were read and the dose rates were calculated using the previously determined calibration factors.

B. Fish

Fish sampling was conducted semiannually at two locations. The immediate vicinity of the discharge was selected as an indicator location (#25), and an offshore location at Mentor-on-the-Lake (#32) was chosen as a control location.

Using a passive collection technique, an experimental gill net (mesh ranging from approximately 1.0 to 2.5 inches to maximize catches in useful size ranges) was set at each sampling location by biologists under contract to NUS Corporation. Nets were set in the evening and removed the following morning. Entrapped surviving fish not required for sampling were released. A Scientific Collecting Permit was obtained from the Ohio Department of Natural Resources to permit this sampling.

Available edible species were filleted at the time of collection. The edible portions were packed in dry ice and shipped to the laboratory for analysis by gamma spectrometry.

C. Sediment

Sediment samples were collected semiannually at four locations. Two locations were nominally the same as the locations chosen for fish sampling. At Mentor-on-the-Lake (#32) and Perry discharge (#25) the sediment was collected approximately 1 mile offshore. Some movement was necessary to find a suitable substrate for sampling. Sediment samples were also collected offshore in the

vicinities of Fairport Harbor (#27) and Redbird (#26). Samples were collected with a petite ponar grab sampler in about 30 feet of water. A sample was composited at each location in a plastic container. Approximately 1 kilogram was frozen and shipped to the laboratory for analysis by gamma spectrometry, and strontium-89 and -90.

D. Airborne Particulates/Iodine-131

Research Appliance Company continuous low volume air sampler units (Model #209088-2) were used to collect air particulates and airborne iodine-131. Airborne particulates were collected by drawing air through a 47-millimeter diameter glass fiber filter. Air iodine-131 was collected by drawing air through a 57 millimeter diameter TEDA impregnated charcoal cartridge (F & J Specialty Products, Inc.). The sampling units are housed in ventilated metal cabinets bolted to utility poles.

The air sampling network consists of six (6) stations; one is located in Redbird (#1) approximately 3.4 miles ENE of the Perry plant and four are located at the site boundary (#3,4,5 and 35). The control location is located at the Concord Service Center (#6), approximately 11 miles SSW of the plant. These locations are identified in Figures 1 and 2 and described in Tables 1 and 2.

The samplers were run continuously and the filter and charcoal cartridge exchanged weekly. The elapsed time of sampling was recorded on an elapsed-time meter. Total air volume was calculated and recorded by the site technician from the initial and final volumes as registered on the dry gas meter.

E. Water

The water sampling network consists of four (4) stations as identified in Figures 1 and 2 and described in Tables 1 and 2. Stations 28 and 34 utilize Horizon Interval Samplers, which collect a small volume of water at short intervals, nominally 15 minutes. Stations 36 and 37 utilize an interval

timer (Dayton #2E357) to control a solenoid valve (Dayton #6X230) on a pressurized sampling line. This arrangement draws small aliquots at periodic intervals. The small volumes are automatically composited into a five-gallon container. Samples from the four (4) stations are collected monthly by the site technician.

F. Milk/Silage

Milk samples were collected monthly during the months of November, December, January, February, and March, and semi-monthly during the remaining months. The control location, Brookglen Farm (station 33), is located approximately 10.2 miles south of the Perry plant. The other 3 milk sampling locations are Station 29 (1.4 miles ESE), Station 30 (2.3 miles SSW) and Station 31 (1.4 miles ESE). As a preservative, formalin was added to each sample at the time of collection. A feed/silage sample was taken annually from each of the milk sampling locations.

G. Vegetation

Vegetation (various fruits and vegetables) was collected annually. Samples were collected from station 38 in 1982, stations 38, 39, and 40 in 1983, and stations 38 and 39 in 1984.

4.0 SUMMARY AND DISCUSSION OF ANALYTICAL RESULTS

Data from the radiological analyses of environmental media collected during the report period are averaged and tabulated below. The procedures and specifications followed in the laboratory for these analyses were as required in Section 5.0 of the NUS Environmental Services Division Quality Assurance Manual, 9019xx-2, and were detailed in the NUS Radiological Laboratory Work Instructions.

Radiological analysis of environmental media characteristically approach and frequently fall below the detection limits of state-of-the-art measurement methods (reference 1). (See Appendix B). The data tables presented in this report include averages based only on concentrations above the limit of detection. The frequency of the averages (i.e., quarterly, monthly, annually) is based on the sampling frequency and the expected degree of variability of the analytical results.

Included in the discussion are ranges of average values for various reporting periods and an overall range of individual values for the total program. Individual data points used to calculate the averages contained in this report are found in Appendix D and the respective annual reports. Values of the range limits are followed (in parentheses) by an indication of the station and reporting period in which that value occurred.

A. Direct Radiation

Average monthly environmental radiation dose rates determined by thermoluminescent dosimeters (TLDs) are given in Table 4. Average monthly dose rates are plotted in Figure 4. A comparison of the average-annual and average-monthly dose rates, by station, is presented in Table 5. The original PIC (pressurized ionization chamber) readings (3/24/81), which were used as an initial environmental characterization and to detect gross anomalies, are also included in Table 5. Average annual dose rates (in units of mR/year) from the monthly and annual cycles are presented in Table 6.

Table 4

Preoperational Summary Report
Direct Radiation - Thermoluminescent Dosimetry
Monthly Averages[1] - May 1981 Through September 1984
(Sheet 1 of 2)

Year	Month	Dose Rate (mR/day ± 2s)
1981	May	0.18 ± 0.06
	June	0.23 ± 0.09
	July	0.16 ± 0.04
	August	0.17 ± 0.06
	September	0.19 ± 0.05
	October	0.24 ± 0.04
	November	0.21 ± 0.09
	December	0.18 ± 0.08
	Annual $\overline{X}$	0.19 ± 0.08
1982	January	0.17 ± 0.07
	February	0.15 ± 0.05
	March	0.16 ± 0.04
	April	0.19 ± 0.09
	May	0.18 ± 0.09
	June	0.21 ± 0.07
	July	0.17 ± 0.08
	August	0.21 ± 0.09
	September	0.18 ± 0.13
	October	0.21 ± 0.05
	November	0.26 ± 0.07
	December	0.22 ± 0.06
	Annual $\overline{X}$	0.19 ± 0.10
1983	January	0.22 ± 0.06
	February	0.21 ± 0.05
	March	0.22 ± 0.04
	April	0.22 ± 0.06
	May	0.22 ± 0.05
	June	0.21 ± 0.06
	July	0.24 ± 0.06
	August	0.24 ± 0.06
	September	0.24 ± 0.06
	October	0.21 ± 0.05
	November	0.21 ± 0.07
	December	0.22 ± 0.04
	Annual $\overline{X}$	0.22 ± 0.06

Table 4

Preoperational Summary Report
Direct Radiation - Thermoluminescent Dosimetry
Monthly Averages[(1)] - May 1981 Through September 1984
(Sheet 2 of 2)

Year	Month	Dose Rate (mR/day ± 2s)
1984	January	0.18 ± 0.04
	February	0.19 ± 0.05
	March	0.15 ± 0.09
	April	0.21 ± 0.09
	May	0.21 ± 0.06
	June	0.22 ± 0.09
	July	0.22 ± 0.09
	August	0.24 ± 0.07
	September	0.24 ± 0.06
	Annual $\overline{X}$	0.21 ± 0.09

(1) Simple average ± 2s. Annual average (and its 2s) is calculated from the individual station results.

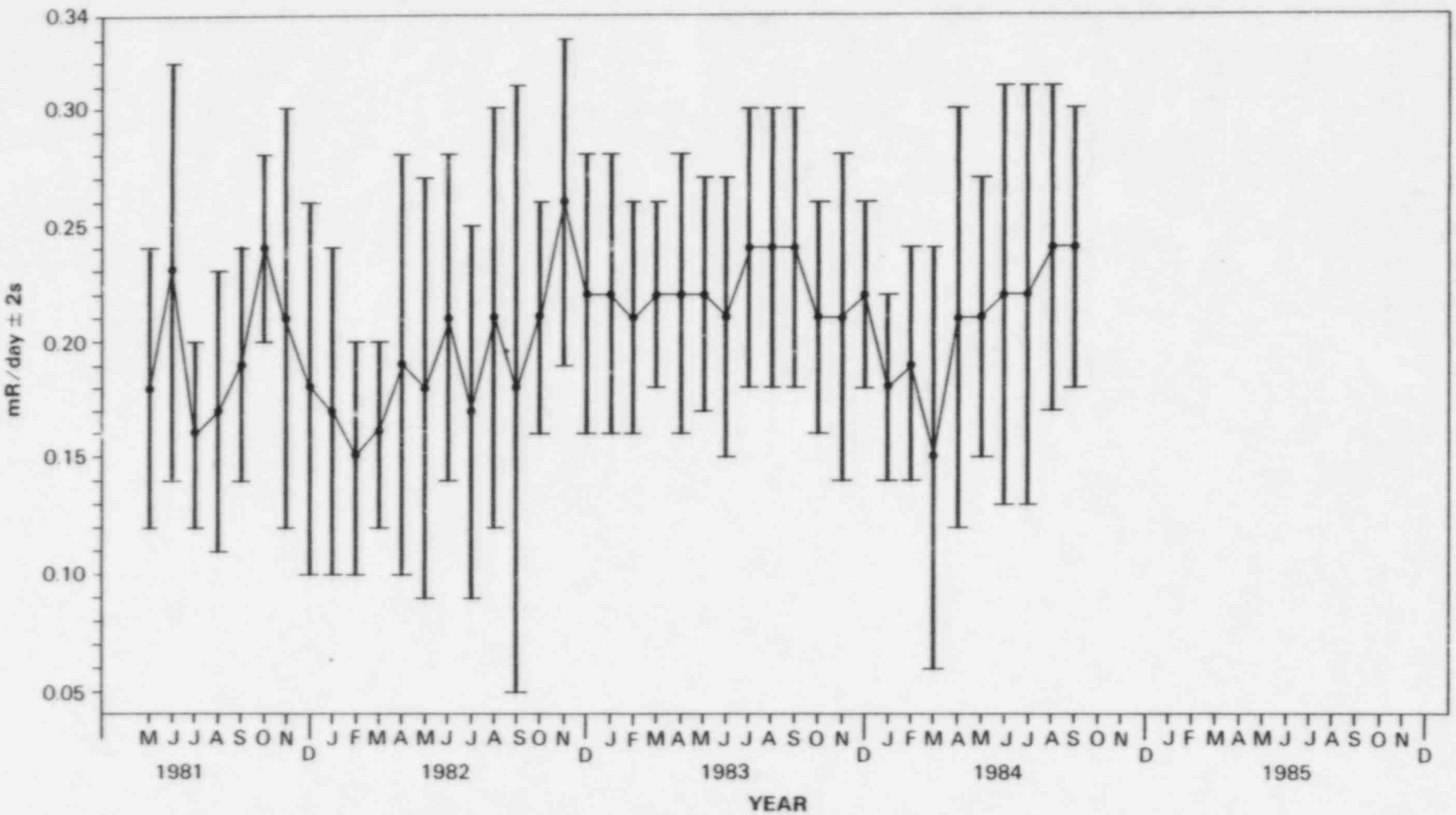


Figure 4. Average Monthly Ambient Radiation Levels in the Vicinity of the Perry NPP, May 1981 through September 1984

Table 5

Preoperational Summary Report
Comparison of Average-Annual and Average-Monthly
Direct Radiation Measurements, 1981 Through 1984

Results in Units of mR/day ± 2s

Station	PIC Readings[1] (March 24, 1981)	Annual Cycle TLD[2] (1981-1984)	Monthly Cycle TLD[3] (May 1981-September 1984)
1	0.20 ± 0.02	0.19 ± 0.03	0.20 ± 0.07
2	0.18 ± 0.01	0.18 ± 0.04	0.19 ± 0.08
3	0.19 ± 0.03	0.18 ± 0.06	0.20 ± 0.07
4	0.21 ± 0.02	0.20 ± 0.04	0.21 ± 0.07
5	0.20 ± 0.02	0.17 ± 0.04	0.20 ± 0.08
6	0.20 ± 0.02	0.18 ± 0.03	0.19 ± 0.08
7	0.19 ± 0.02	0.18 ± 0.05	0.21 ± 0.09
8	0.19 ± 0.02	0.18 ± 0.06	0.18 ± 0.06
9	0.19 ± 0.04	0.17 ± 0.06	0.18 ± 0.07
10	0.19 ± 0.02	0.18 ± 0.03	0.19 ± 0.06
11	0.21 ± 0.03	0.18 ± 0.08	0.19 ± 0.08
12	0.19 ± 0.02	0.19 ± 0.02	0.19 ± 0.09
13	0.21 ± 0.01	0.17 ± 0.08	0.20 ± 0.07
14	0.20 ± 0.02	0.21 ± 0.05	0.19 ± 0.06
15	0.21 ± 0.02	0.20 ± 0.08	0.20 ± 0.06
16	0.25 ± 0.03	0.23 ± 0.06	0.25 ± 0.08
17	0.23 ± 0.01	0.21 ± 0.08	0.23 ± 0.09
18	0.28 ± 0.02	0.29 ± 0.08	0.28 ± 0.09
19	0.21 ± 0.02	0.20 ± 0.07	0.20 ± 0.07
20	0.21 ± 0.02	0.21 ± 0.06	0.20 ± 0.08
21	0.22 ± 0.01	0.21 ± 0.06	0.22 ± 0.08
22	0.20 ± 0.02	0.22 ± 0.03	0.21 ± 0.08
23	0.23 ± 0.02	0.22 ± 0.04	0.22 ± 0.07
24	0.20 ± 0.02	0.21 ± 0.04	0.20 ± 0.10
35	(5)	0.18 ± 0.03	0.19 ± 0.04
Average[4]	0.21 ± 0.04	0.20 ± 0.07	0.21 ± 0.09

(1) PIC readings were taken once at the beginning of the program as a preliminary characterization and to detect gross anomalies. Errors of PIC readings are two standard deviations of the average of 10 field readings.
(2) Errors of annual cycle TLDs are two standard deviations of the annual cycle TLD station results.
(3) Errors of monthly cycle TLDs are two standard deviations of the monthly cycle TLD station results.
(4) Error of the PIC Readings average is two standard deviations of the column data. Errors of the Annual Cycle and Monthly Cycle TLD averages are calculated from the individual Annual and Monthly station results.
(5) Sampling at station 35 was begun in November of 1982.

Monthly averages (from Table 4) ranged from 0.15 ± 0.09 mR/day (Mar. 1984) to 0.26 ± 0.07 mR/day (Nov. 1982). Individual monthly dose rates ranged from 0.07 ± 0.03 mR/day (station 12, Mar. 1984) to 0.37 ± 0.12 mR/day (station 18, June 1981). Preoperational station averages from the monthly and annual TLD cycles are given in Table 5. Station 18 (5.0 miles S) had consistently higher monthly dose rates throughout the program, as the annual-cycle and monthly-cycle averages indicate. Significant variations occur between geographical areas as a result of geological composition. Temporal variations result from changes in cosmic ray intensity, local human activities, and factors such as ground cover and soil moisture.

Oakley (reference 3) calculates an ionizing radiation dose equivalent of 82.2 mR/year for Ohio including a terrestrial component of 45.6 mR/year and an ionizing cosmic ray component of 36.6 mR/year (excludes neutron component). Since Oakley's values represent averages covering wide geographical areas, the measured ambient radiation averages in Table 6 for the immediate locale of Perry is consistent with Oakley's observations.

B. Fish

Average annual gamma spectrometry results for fish are found in Table 7. Naturally occurring K-40 constituted the major detectable nuclide activity in the flesh portions of the fish. Annual averages for K-40 ranged from 2800 ± 1600 pCi/kg, wet (1984) to 4000 ± 4400 pCi/kg, wet (1981). Individual K-40 results ranged from 1600 ± 300 pCi/kg, wet (station 32, May 1981) to 9900 ± 900 pCi/kg, wet (station 25, May 1981). Cs-137 was detected in all years, except 1984 (as of May, 1984). Annual Cs-137 averages ranged from 22 ± 13 pCi/kg, wet (1982) to 30 ± 39 pCi/kg, wet (1981). Individual Cs-137 results ranged from 6.1 ± 3.0 pCi/kg, wet (station 25, Oct. 1983) to 56 ± 39 pCi/kg, wet (station 25, May 1981).

Since it is present in global fallout, the occasional detection of Cs-137 in environmental media is not unusual. Because of its relatively long half-life, the abundant gamma of Cs-137's equilibrium daughter (Ba-137), and the

Table 6

Preoperational Summary Report
Direct Radiation-Thermoluminescent Dosimetry
Average Annual Dose Rates - 1981 through 1984

Year[1]	Dose Rate (mR/year)
1981-M	69.4
1981-A	62.1
1982-M	69.4
1982-A	76.7
1983-M	80.3
1983-A	69.4
1984-M	76.7
1984-A	80.3
Preoperational Average-M	76.7
Preoperational Average-A	73.0
Oakley, 1972[2]	82.2

(1) M = Average dose rate calculated from individual monthly results. A = Average dose rate calculated from individual annual results.

(2) Oakley's value is for Ohio and includes a terrestrial component of 45.6 mR/year and an ionizing cosmic ray component of 36.6 mR/year (excludes neutron component).

Table 7

Preoperational Summary Report
Gamma Spectrometry of Fish Samples

Annual Averages(1) - 1981 Through 1984

Results in Units of pCi/kg (wet) ± 2s

Year	K-40	Cs-137	Others
1981	4000 ± 4400	30 ± 39	(2)
1982	3400 ± 1500	22 ± 13	(2)
1983	3900 ± 2600	28 ± 25	(2)
1984	2800 ± 1600	(2)	(2)

(1) Positive activities only, simple average ± 2s.
(2) Only LLD's reported or not detected.

chemical properties of cesium, this isotope is the one most frequently observed resulting from long-term fallout. (Note: to determine the activity of Cs-137 (a pure beta emitter) through gamma spectrometry, the gamma emitting equilibrium daughter of Cs-137 (Ba-137) is measured.)

C. Sediment

The processes by which radionuclides and stable elements are concentrated in bottom sediments are complex, involving physicochemical interaction in the environment between the various organic and inorganic materials from the watershed. These interactions can proceed by a myriad of steps in which the elements are adsorbed on or displaced from the surfaces of colloidal particles enriched with chelating organic materials. Biological action of bacteria and other benthic organisms also contribute to the concentration of certain elements and in the acceleration of the sedimentation process.

Table 8 presents the average annual concentrations of the various gamma emitting isotopes detected in the sediments sampled from the PNPP environment. K-40 was detected in all samples with annual averages ranging from 12,000 ± 10,000 pCi/kg, dry (1982) to 17,000 ± 10,000 pCi/kg, dry (1981). Individual K-40 results ranged from 7300 ± 700 pCi/kg, dry (Station 26, Oct. 1982) to 24,000 ± 4000 pCi/kg, dry (station 26, May, 1981).

The man-made radioisotope, Cs-137, was detected in samples from all years except 1984 (as of May, 1984). Annual Cs-137 averages ranged from 200 ± 150 pCi/kg, dry (1983) to 370 ± 420 pCi/kg, dry (1982). Individual Cs-137 values ranged from 24 ± 12 pCi/kg, dry (Station 27, May 1981) to 670 + 150 pCi/kg, dry (station 32, May 1982). Since it is present in global fallout, the occasional detection of Cs-137 in environmental media is not unusual.

Co-60 was detected in 4 samples from 1981, with an annual average of 140 ± 90 pCi/kg, dry. Individual Co-60 values ranged from 87 ± 30 pCi/kg, dry to 190 ± 30 pCi/kg, dry. On October 16, 1980, the Peoples Republic of China conducted an above-ground nuclear weapons test (reference 4). Department of Energy (D.O.E.) monitoring data indicate that high altitude debris from

Table 8

Preoperational Summary Report
Gamma Spectrometry of Sediment Samples

Annual Averages[1] - 1981 Through 1984

Results in Units of pCi/kg (dry) ± 2s

				Uranium-238 Daughters			Thorium-232 Daughters					
Year	K-40	Cs-137	Co-60	Bi-214	Pb-214	Ra-226	Bi-212	Pb-212	Tl-208	Ac-228	Ra-224	Others
1981	17,000 ± 10,000	220 ± 330	140 ± 90	1100 ± 600	1100 ± 800	1100 ± 730	780 ± 580	830 ± 680	280 ± 290	850 ± 570	2400 ± 1800	Ce-144 @ 950 ± 130(4)
1982	12,000 ± 10,000	370 ± 420	(2)	570 ± 230	910 ± 760	1300 ± 670	790 ± 490	680 ± 900	480 ± 190	770 ± 840	2700 ± 2300	(2)
1983	13,000 ± 6,000	200 ± 150	(2)	800 ± 480	900 ± 510	850 ± 480	940 ± 170	590 ± 430	710 ± 380	740 ± 510	(2)	(2)
1984	12,000 ± 4,000	(3)	(2)	970 ± 810	940 ± 640	940 ± 690	(2)	650 ± 480	680 ± 390	860 ± 600	(2)	(2)

(1) Positive activities only, simple average ± 2s.
(2) Not Detected.
(3) Only LLDs reported.
(4) Positive activity detected in only (1) one sample. In these cases the error reported is the 2s counting error for the individual analysis.

the test passed over the east coast of the United States about 19 days after the announced detonation date. The presence of Co-60 in PNPP sediment samples in 1981 may be attributed to this weapons test. One would expect to detect increased levels of activity in air initially and then, after deposition and settling, to appear in sediments.

An assortment of daughters from the naturally occurring uranium and thorium decay chains were also detected. Average annual values for these radioisotopes ranged from 280 ± 290 pCi/kg, dry (Tl-208, 1981) to 2700 ± 2300 pCi/kg, dry (Ra-224, 1982). Individual values for the uranium and thorium daughters ranged from 150 ± 20 pCi/kg, dry (Tl-208, station 27, May 1981) to 3400 ± 1000 pCi/kg, dry (Ra-224, Station 26, Nov. 1981).

Beginning in 1983, Sr-89 and Sr-90 analyses were performed on sediment samples. No detectable activity has been observed.

D. Airborne Particulates/Airborne I-131

Average monthly gross beta results for airborne particulates are listed in Table 9 and plotted in Figure 5. Airborne I-131 results are not tabulated since there was no detectable activity during the pre-operational program.

In considering the results of gross activity measurements, it is important to keep in mind the inherent limitations of gross beta counting for mixtures of unknown composition. The counting efficiency for an unknown mixture of activities varies considerably with the energy of decay and the amount of absorbing material in the sample. Because of this, the results of gross activity measurements are difficult to interpret. Gross activity measurements are used primarily as a screening device to determine whether further analyses should be performed.

Average monthly gross beta activity in airborne particulates ranged from 12 ± 7 E-03 pCi/m^3 (May 1983) to 25 ± 10 E-03 pCi/m^3 (Jan. 1984). Individual weekly gross beta results ranged from 4.7 ± 4.6 E-03 pCi/m^3 (station 1, April 1984) to 42 ± 8 E-03 pCi/m^3 (station 5, Oct. 1981).

Table 9

Preoperational Summary Report
Gross Beta in Air Particulate Filters

Monthly Averages[1] - October 1982 Through August 1984

Year	Month	Activity (E-03 pCi/m^3 ± 2s)
1982	October	21 ± 17
	November	21 ± 7
	December	19 ± 11
	Annual $\bar{X}$	20 ± 12
1983	January	17 ± 6
	February	20 ± 17
	March	13 ± 9
	April	13 ± 7
	May	12 ± 7
	June	22 ± 22
	July	19 ± 15
	August	22 ± 15
	September	20 ± 7
	October	19 ± 16
	November	19 ± 8
	December	24 ± 9
	Annual $\bar{X}$	19 ± 14
1984	January	25 ± 10
	February	18 ± 5
	March	17 ± 11
	April	12 ± 9
	May	13 ± 5
	June	16 ± 11
	July	18 ± 9
	August	23 ± 5
	Annual $\bar{X}$	17 ± 12

(1) Simple average ± 2s. Annual average (and its 2s) is calculated from the individual station results.

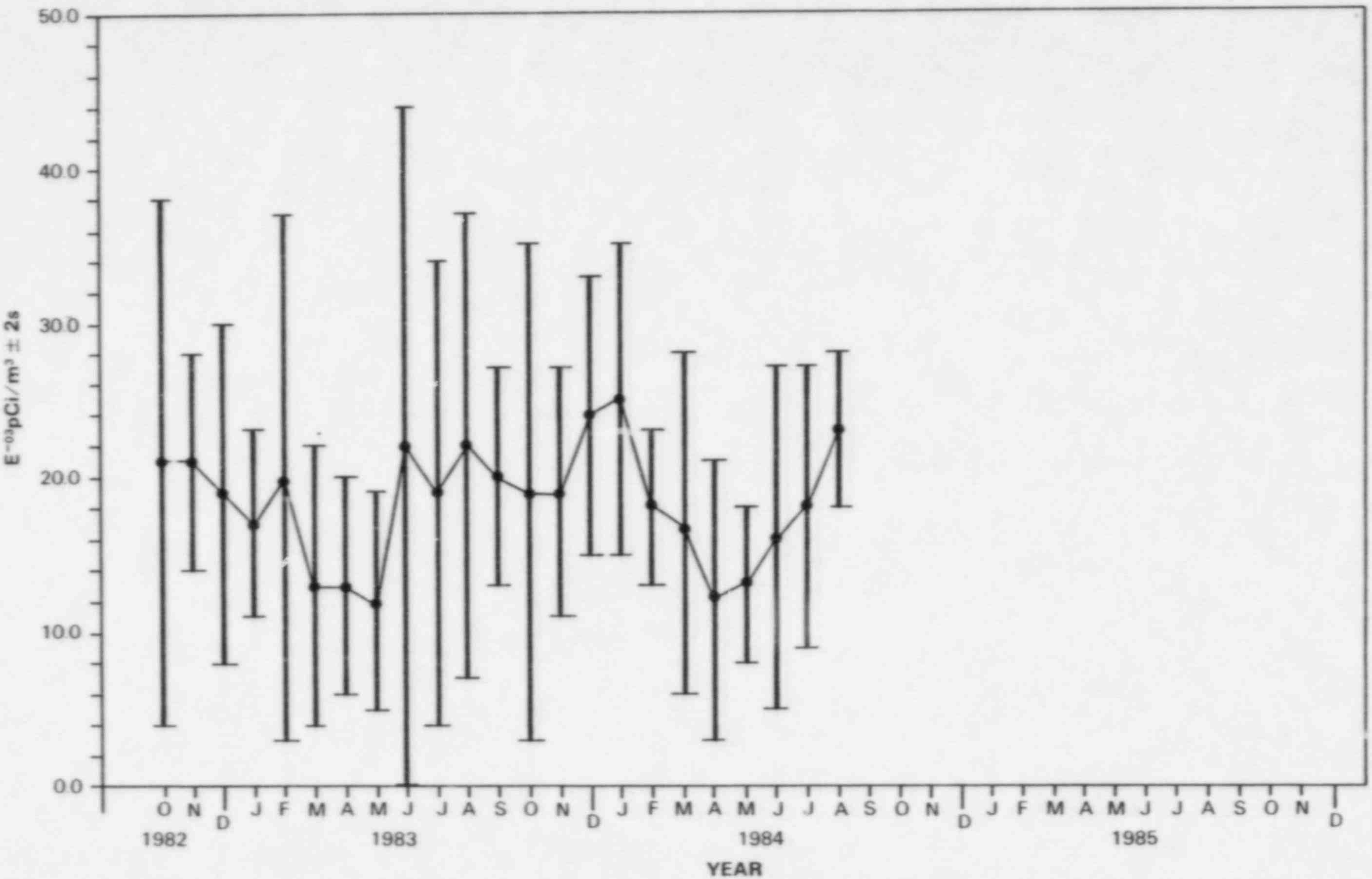


Figure 5. Average Monthly Gross Beta Activity in Air Particulates in the Vicinity of the Perry NPP, October 1982 through August 1984

Average quarterly gamma spectrometry data is presented in Table 10. Cosmogenic Be-7 was the only nuclide detected in the composite samples. Quarterly averages for Be-7 ranged from 49 ± 16 E-03 pCi/m^3 (Q4, 1983) to 68 ± 16 E-03 pCi/m^3 (Q1, 1984). Individual Be-7 results ranged from 39 ± 19 E-03 pCi/m^3 (station 35, Q1, 1983) to 94 ± 28 E-03 pCi/m^3 (station 5, Q3, 1983).

E. Water

Gamma spectrometry results are not tabulated since there was no detectable activity during the pre-operational period.

Monthly gross beta averages are found in Table 11 and plotted in Figure 6. Average monthly activities ranged from 2.0 ± 1.3 pCi/l (January, 1984) to 6.4 ± 4.8 pCi/l (June, 1983). Individual monthly gross beta activities ranged from 1.4 ± 1.4 pCi/l (station 34, Jan. 1984) to 9.0 ± 1.3 pCi/l (station 37, June, 1983).

Quarterly tritium averages are found in Table 12. All LLD values were found for quarter 4 of 1982 and quarters 1 and 4 of 1983. Average quarterly activities ranged from 220 ± 70 pCi/l (Q3, 1984) to 780 ± 200 pCi/l (Q2, 1983). Individual tritium activities ranged from 190 ± 190 pCi/l (stations 34 and 37, Q3, 1984) to 780 ± 200 pCi/l (station 37, Q2, 1983).

Beginning in 1983, quarterly Sr-89 and Sr-90 analyses were performed on water samples. In 1983, positive Sr-90 activity (0.62 ± 0.61 pCi/l) was detected in one August sample from station 28. In 1984, positive Sr-90 activity (1.4 ± 0.5 pCi/l) was detected in one February sample from station 36. There was no detectable Sr-89 activity.

F. Milk/Silage

Average annual gamma spectrometry of milk results are found in Table 13. There was no detectable I-131 in milk during the program.

Table 10

Preoperational Summary Report
Gamma Spectrometry of Composited Air Particulate Filters

Quarterly Averages(1) - Fourth Quarter 1982
Through Second Quarter 1984

Results in Units of E-03 $pCi/m^3 \pm 2s$

Year	Quarter	Be-7	Others
1982	4	51 ± 24	(2)
1983	1	49 ± 15	(2)
	2	53 ± 17	(2)
	3	62 ± 33	(2)
	4	49 ± 16	(2)
	Annual $\overline{X}$	54 ± 25	
1984	1	68 ± 16	(2)
	2	55 ± 13	(2)
	Annual $\overline{X}$	61 ± 20	

(1) Positive activities only, simple average ± 2s. Annual average (and its 2s) is calculated from the individual station results.
(2) Only LLDs reported or not detected.

Table 11

Preoperational Summary Report
Gross Beta in Water

Monthly Averages[1] - September 1982
Through July 1984

Year	Month	Activity (pCi/l ± 2s)
1982	September	4.6 ± 1.3
	October	3.7 ± 2.5
	November	4.2 ± 1.7
	December	4.2 ± 1.2
	Annual $\overline{X}$	4.2 ± 1.7
1983	January	4.6 ± 1.6
	February	2.9 ± 1.4
	March	3.0 ± 0.4
	April	3.5 ± 0.9
	May	5.4 ± 2.7
	June	6.4 ± 4.8[2]
	July	5.5 ± 1.5
	August	5.1 ± 2.7
	September	3.2 ± 2.1
	October	3.5 ± 2.8
	November	4.2 ± 3.0
	December	4.3 ± 4.9
	Annual $\overline{X}$	4.2 ± 3.3
1984	January	2.0 ± 1.3
	February	2.5 ± 1.9
	March	5.4 ± 2.8
	April	2.5 ± 0.6
	May	4.5 ± 5.3
	June	3.5 ± 2.3
	July	3.4 ± 1.2
	Annual $\overline{X}$	3.4 ± 3.3

(1) Positive activities only, simple average ± 2s. Annual average (and its 2s) is calculated from the individual station results.
(2) Positive activity detected in only (1) one sample. In these cases the error reported is the 2s counting error for the individual analysis.

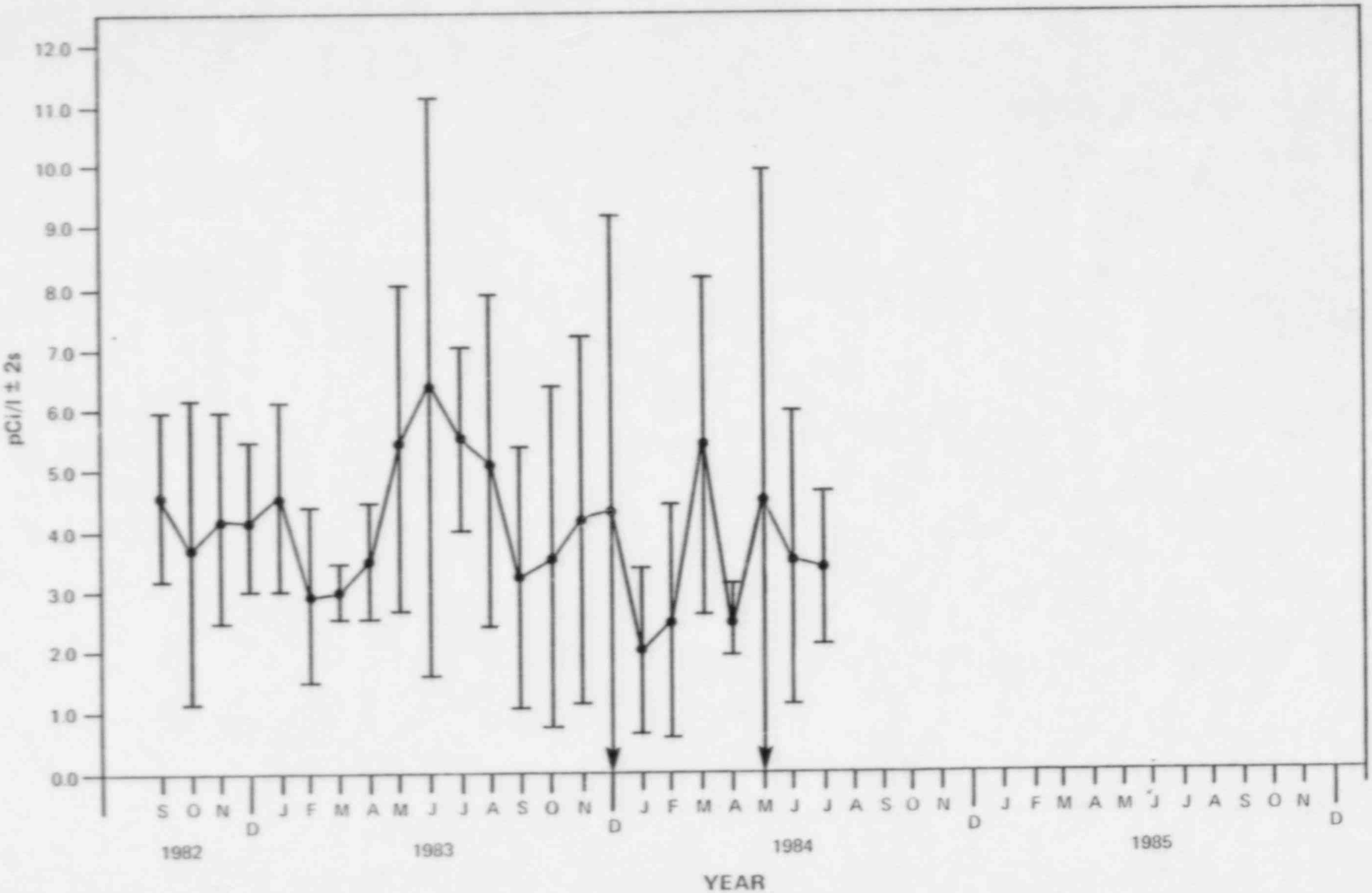


Figure 6. Average Monthly Gross Beta Activity in Water in the Vicinity of the Perry NPP, September 1982 through July 1984

Table 12

Preoperational Summary Report
Tritium in Water, Quarterly Composite by Location

Quarterly Averages[1] - Third Quarter 1982
Through Third Quarter 1984

Year	Quarter	Activity (pCi/l ± 2s)
1982	3[2]	310 ± 160[4]
	4[3]	(5)
	Annual $\overline{X}$	310 ± 160[4]
1983	1	(5)
	2	780 ± 200[4]
	3	300 ± 120
	4	(5)
	Annual $\overline{X}$	420 ± 490
1984	1	300 ± 200[4]
	2	490 ± 190[4]
	3[6]	220 ± 70
	Annual $\overline{X}$	280 ± 220

(1) Positive activities only, simple average ± 2s. Annual average (and its 2s) is calculated from the individual station results.
(2) Only September 1982 data was used to calculate Third Quarter average.
(3) Tritium water samples were not collected during October, 1982.
(4) Positive activity detected in only (1) one sample. In these cases the error reported is the 2s counting error for the individual analysis.
(5) Only LLDs reported.
(6) Only July 1984 data was used to calculate the Third Quarter average.

Naturally occurring K-40 was detected in all milk samples. Annual averages ranged from 1300 ± 100 pCi/l (1982) to 1500 ± 500 pCi/l (1983). Individual K-40 results ranged from 860 ± 150 pCi/l (station 33, July 1983) to 2000 ± 200 pCi/l (station 29, Oct. 1983).

Cs-137 was detected in fourteen milk samples during the program, eight in 1983 and six in 1984. Annual averages ranged from 2.4 ± 1.7 pCi/l (1983) to 3.0 ± 2.3 pCi/l (1984). Individual Cs-137 results ranged from 1.4 ± 1.3 pCi/l (station 29, Sept. 1983) to 4.4 ± 1.6 pCi/l (station 29, May 1984).

Beginning in 1983, quarterly Sr-89 and Sr-90 analyses were performed on milk samples (Table 14). Positive Sr-90 activity was detected in six samples, two in 1983 and four in 1984. Annual averages ranged from 0.84 ± 0.70 pCi/l (1984) to 2.7 ± 2.4 pCi/l (1983). Individual Sr-90 results ranged from 0.47 ± 0.43 pCi/l (station 33, Feb. 1984) to 3.5 ± 1.5 pCi/l (station 30, Nov. 1983).

Average annual gamma spectrometry of feed/silage results are presented in Table 15. Naturally occurring K-40 was detected in all samples. Annual averages ranged from 4900 ± 700 pCi/kg, wet (1982) to 8100 ± 10,000 pCi/kg, wet (1984). Individual K-40 results ranged from 2600 ± 300 pCi/kg, wet (station 31, Aug. 1984) to 18,000 ± 2000 pCi/kg, wet (station 31, Aug. 1984).

Cosmogenic Be-7 was also detected in many of the feed/silage samples. Annual averages ranged from 360 ± 330 pCi/kg, wet (1983) to 5000 ± 2600 pCi/kg, wet (1982). Individual Be-7 results ranged from 240 ± 120 pCi/kg, wet (station 29, Aug. 1983) to 5000 ± 2600 pCi/kg, wet (station 33, Oct. 1982).

G. Vegetation

Average annual results for gamma spectrometry of vegetation are presented in Table 16. Naturally occurring K-40 was the only nuclide detected. Annual averages ranged from 1900 ± 1500 pCi/kg, wet (1982) to 2100 ± 2000 pCi/kg, wet (1984). Individual K-40 results ranged from 630 ± 200 pCi/kg, wet (station 40, Sept. 1983) to 4100 ± 500 pCi/kg, wet (station 38, July 1984).

Table 13

Preoperational Summary Report
Gamma Spectrometry of Milk Samples

Annual Averages[1] - 1982 Through 1984

Results in Units of pCi/l ± 2s

Year	K-40	Cs-137
1982	1300 ± 100	(2)
1983	1500 ± 500	2.4 ± 1.7
1984	1500 ± 400	3.0 ± 2.3

(1) Positive activities only, simple average ± 2s.
(2) Only LLDs reported.

Table 14

Preoperational Summary Report
Strontium-90 in Milk

Annual Averages[1] - 1983 Through 1984

Year	Activity (pCi/l ± 2s)
1983	2.7 ± 2.4
1984	0.84 ± 0.70

(1) Positive activities only, simple average ± 2s.

Table 15

Preoperational Summary Report
Gamma Spectrometry of Feed/Silage

Annual Averages[1] - 1982 Through 1984

Results in Units of pCi/kg (wet) ± 2s		
Year	K-40	Be-7
1982	4900 ± 700[2]	5000 ± 2600[2]
1983	7000 ± 6000	360 ± 330
1984	8100 ± 10,000	1200 ± 900

(1) Positive activities only, simple average ± 2s.
(2) Positive activity detected in only (1) one sample. In these cases the error reported is the 2s counting error for the individual analysis.

Table 16

Preoperational Summary Report
Gamma Spectrometry of Vegetation Samples

Annual Averages(1) - 1982 Through 1984

Results in Units of pCi/kg (wet) ± 2s	
Year	K-40
1982	1900 ± 1500
1983	2100 ± 1800
1984	2100 ± 2000

(1) Positive activities only, simple average ± 2s.

Table 17

Summary of Data for the Perry NPP Radiological Environmental Monitoring Program - 1981 Through 1984
(Sheet 1 of 5)

Name of Facility: Perry NPP Units 1 and 2, Docket Nos. 50-440 and 50-441
Location of Facility: 35 Miles Northeast of Cleveland, Ohio (Lake County)

Reporting Period: March 23, 1981 Through October 2, 1984

Medium or Pathway Sampled (Units of Measurement)	Type and total Number of Analyses Performed	Lower Limit of Detection[1]	All Indicator Locations Mean (f)[2] (Range)	Location with Highest Preoperational Mean: Name, Distance, and Direction	Location with Highest Preoperational Mean: Mean (f)[2] (Range)	Control Locations Mean (f)[2] (Range)
TLDs (mR/day)	Gamma Dose-991		0.21 (913/913) (0.07 - 0.37)	Station 18 5.0 miles S	0.28 (41/41) (0.19 - 0.37)	0.20 (78/78) (0.11 - 0.36)
Fish (pCi/kg, wet)	Gamma - 66					
	K-40		3900 (32/32) (1800 - 9900)	Only one indicator location sampled for this medium		3300 (31/34) (1600 - 4700)
	Cs-137	150	36 (9/32) (20 - 56)			21 (11/34) (6.1 - 46)
	Co-58	130	LLD			LLD
	Co-60	130	LLD			LLD
	Cs-134	130	LLD			LLD
	Fe-59	260	LLD			LLD
	Mn-54	130	LLD			LLD
	Zn-65	260	LLD			LLD
Sediment (pCi/kg, dry)	Gamma Spec-28					
	K-40		14,000 (21/21) (7300 - 24000)	Station 26 4.2 miles ENE	15,000 (7/7) (7300 - 24,000)	13,000 (7/7) (8800 - 16,000)
	Cs-137	180	280 (13/21) (24 - 470)	Station 26 4.2 mile ENE	340 (6/7) (150 - 470)	230 (5/7) (38 - 670)
	Co-60		150 (3/21) (120 - 190)	Station 26 4.2 miles ENE	170 (2/7) (150 - 190)	87 (1/7) (87 - 87)
	Bi-214		940 (17/21) (430 - 1500)	Station 26 4.2 miles ENE	1200 (6/7) (630 - 1500)	700 (6/7) (510 - 980)

Table 17

Summary of Data for the Perry NPP Radiological Environmental Monitoring Program - 1981 Through 1984
(Sheet 2 of 5)

Name of Facility: Perry NPP Units 1 and 2, Docket Nos. 50-440 and 50-441
Location of Facility: 35 Miles Northeast of Cleveland, Ohio (Lake County)

Reporting Period: March 23, 1981 Through October 2, 1984

Medium or Pathway Sampled (Units of Measurement)	Type and total Number of Analyses Performed	Lower Limit of Detection[1]	All Indicator Locations Mean (f)[2] (Range)	Location with Highest Preoperational Mean: Name, Distance, and Direction	Location with Highest Preoperational Mean: Mean (f)[2] (Range)	Control Locations Mean (f)[2] (Range)
Sediment (pCi/kg, dry) (Continued)	Pb-214		1000 (21/21) (460 - 1600)	Station 26 4.2 miles ENE	1300 (7/7) (590 - 1600)	810 (7/7) (570 - 970)
	Ra-226		1100 (19/21) (490-1800)	Station 26 4.2 miles ENE	1300 (6/7) (1100 - 1600)	810 (6/7) (630 - 980)
	Bi-212		890 (6/21) (610 - 1200)	Station 25 0.6 miles NNW	960 (1/7) (960 - 960)	610 (2/7) (550 - 660)
	Pb-212		740 (20/21) (270 - 1600)	Station 26 4.2 mile ENE	900 (7/7) (320 - 1300)	580 (7/7) (280 - 900)
	Tl-208		620 (13/21) (150 - 940)	Station 26 4.2 miles ENE	830 (4/7) (590 - 940)	530 (5/7) (250 - 880)
	Ac-228		810 (19/21) (280 - 1400)	Station 26 4.2 miles ENE	980 (7/7) (430 - 1200)	740 (5/7) (580 - 1000)
	Ra-224		2900 (3/21) (1800 - 3500)	Station 25 0.6 miles NNW	3500 (1/7) (3500 - 3500)	1900 (2/7) (1900 - 1900)
	Ce-144		950 (1/21) (950 - 950)	Station 26 4.2 miles ENE	950 (1/7) (950 - 950)	(3)
	Cs-134	150	LLD			LLD
	Strontium-8					
	Sr-89		LLD			LLD
	Sr-90		LLD			LLD

Table 17

Summary of Data for the Perry NPP Radiological Environmental Monitoring Program - 1981 Through 1984
(Sheet 3 of 5)

Name of Facility: Perry NPP Units 1 and 2, Docket Nos. 50-440 and 50-441
Location of Facility: 35 Miles Northeast of Cleveland, Ohio (Lake County)

Reporting Period: March 23, 1981 Through October 2, 1984

Medium or Pathway Sampled (Units of Measurement)	Type and total Number of Analyses Performed	Lower Limit of Detection(1)	All Indicator Locations Mean (f)(2) (Range)	Location with Highest Preoperational Mean: Name, Distance, and Direction	Location with Highest Preoperational Mean: Mean (f)(2) (Range)	Control Locations Mean (f)(2) (Range)
Airborne Particulates (E-03 pCi/m^3)	Gross Beta-582	10	18 (463/484) (4.7 - 42)	Station 5 0.6 miles SW	19 (92/97) (8.1 - 42)	18 (96/98) (5.7 - 37)
	Gamma Spec-42					
	Be-7		56 (29/35) (39 - 94)	Station 5 0.6 miles SW	62 (6/7) (46 - 94)	54 (6/7) (40 - 72)
	Ce-144		LLD			LLD
	Cs-134	50	LLD			LLD
	Cs-137	60	LLD			LLD
	Nb-95		LLD			LLD
	Zr-95		LLD			LLD
Air Iodine (pCi/m^3)	I-131 - 583	0.07	LLD			LLD
Water (pCi/l)	Gross Beta-92	4	4.0 (65/69) (1.4 - 9)	Station 37 4.1 miles ENE	4.5 (21/23) (1.5 - 9)	3.9 (23/23) (1.6 - 6.2)
	Gamma Spec-					
	Ba-140	60	LLD			LLD
	Co-58	15	LLD			LLD
	Co-60	15	LLD			LLD
	Cs-134	15	LLD			LLD
	Cs-137	18	LLD			LLD
	Fe-59	30	LLD			LLD
	La-140	15	LLD			LLD
	Mn-54	15	LLD			LLD
	Nb-95	15	LLD			LLD
	Zn-65	30	LLD			LLD
	Nr-95	30	LLD			LLD

Table 17

Summary of Data for the Perry NPP Radiological Environmental Monitoring Program - 1981 Through 1984
(Sheet 4 of 5)

Name of Facility: Perry NPP Units 1 and 2, Docket Nos. 50-440 and 50-441
Location of Facility: 35 Miles Northeast of Cleveland, Ohio (Lake County)

Reporting Period: March 23, 1981 Through October 2, 1984

Medium or Pa.... Sampled (Units of Measurement)	Type and total Number of Analyses Performed	Lower Limit of Detection[1]	All Indicator Locations Mean (f)[2] (Range)	Location with Highest Preoperational Mean: Name, Distance, and Direction	Location with Highest Preoperational Mean: Mean (f)[2] (Range)	Control Locations Mean (f)[2] (Range)
Water (pCi/l) (Continued)	Tritium-36	2000	350 (9/27) (190 - 780)	Station 37 4.1 miles ENE	410 (4/9) (190 - 780)	240 (2/9) (240 - 240)
	Strontium-8					
	Sr-89		LLD			LLD
	Sr-90		1.4 (1/4) (1.4 - 1.4)	Station 36 3.9 miles WSW	1.4 (1/4) (1.4 - 1.4)	0.62 (1/4) (0.62 - 0.62)
Milk (pCi/l)	Gamma Spec-105					
	K-40		1600 (70/70) (1100 - 2000)	Station 31 1.4 miles ESE	1700 (11/11) (1500 - 1900)	1300 (35/35) (860 - 1500)
	Cs-137	18	2.7 (13/70) (1.4 - 4.4)	Station 31 1.4 miles ESE	3.6 (1/11) (3.6 - 3.6)	2.0 (1/35) (2.0 - 2.0)
	Ba-140	60	LLD			LLD
	Cs-134	15	LLD			LLD
	La-140	15	LLD			LLD
	Iodine-131 - 105	1	LLD			LLD
	Strontium-11					
	Sr-89		LLD			LLD
	Sr-90		1.6 (4/8) (0.72 - 3.5)	Station 30 2.3 miles SSW	2.4 (2/3) (1.3 - 3.5)	1.1 (2/3) (0.47 - 1.8)

Table 17

Summary of Data for the Perry NPP Radiological Environmental Monitoring Program - 1981 Through 1984
(Sheet 5 of 5)

Name of Facility: Perry NPP Units 1 and 2, Docket Nos. 50-440 and 50-441
Location of Facility: 35 Miles Northeast of Cleveland, Ohio (Lake County)

Reporting Period: March 23, 1981 Through October 2, 1984

Medium or Pathway Sampled (Units of Measurement)	Type and total Number of Analyses Performed	Lower Limit of Detection[1]	All Indicator Locations Mean (f)[2] (Range)	Location with Highest Preoperational Mean: Name, Distance, and Direction	Location with Highest Preoperational Mean: Mean (f)[2] (Range)	Control Locations Mean (f)[2] (Range)
Feed/Silage (pCi/kg, wet)	Gamma Spec-14					
	Be-7		890 (5/10) (240 - 1800)	Station 29 1.4 miles ESE	1000 (2/4) (240 - 1800)	2900 (2/4) (890 - 5000)
	K-40		8200 (10/10) (2600 - 18,000)	Station 31 1.4 miles ESE	10,000 (2/2) (2600 - 18,000)	5700 (4/4) (2800 - 11,000)
	Cs-134	60	LLD			LLD
	Cs-137	80	LLD			LLD
	I-131	60	LLD			LLD
Vegetation (pCi/l)	Gamma Spec-21					
	K-40		2000 (21/21) (630 - 4100)	Station 38 1.1 mile E	2300 (11/11) (980 - 4100)	Only indicator locations sampled for this medium
	Cs-134	60	LLD			
	Cs-137	80	LLD			
	I-131	60	LLD			

(1) LLD is lower limit of detection as defined and required in USNRC Branch Technical Position on An Acceptable Radiological Environmental Monitoring Program, Revision 1, November 1979.

(2)(f) is the ratio of positive results to the number of samples analyzed for the parameter of interest.

(3) Not Detected.

5.0 LAND USE SURVEY

The annual land use survey was performed in the environs of the Perry NPP on July 9th and July 10th 1984[5]. The purpose of this survey was to identify the potential indicator milk sampling locations as well as the nearest vegetable garden and residence in each of the sixteen standard sampling sectors around the plant. The outer bound of the survey for identifying the "nearest" or potential indicator locations was 5 miles. In addition, candidate "control" milk sampling locations were verified. Table 18 identifies the nearest garden and residence in each sector for which one could be identified within the 5 mile radius. Table 19 identifies all the potential indicator milk sampling locations within 5 miles of the plant. Control milk sampling locations are given in Table 20.

Table 18

Nearest Gardens and Residences by Sector Identified During the 1984 Perry NPP Annual Land Use Survey

Direction	Nearest Residence (Distance/Address)	Nearest Garden (Distance/Address)
NE	0.6 miles 4384 Lockwood	0.6 miles 4384 Lockwood
ENE	1.0 miles 4602 Lockwood	1.1 miles 4611 Lockwood
E	1.2 miles 2684 Antioch	1.2 miles 2684 Antioch
ESE	1.2 miles 2774 Antioch	1.2 miles 2774 Antioch
SE	1.2 miles 4495 North Ridge	1.0 mile 4495 North Ridge
SSE	0.8 miles 3119 Parmly	0.8 miles 3119 Parmly
S	0.9 miles 3121 Center	0.8 miles 3157 Center
SSW	0.9 miles 3850 Clark	1.5 miles 3787 North Ridge
SW	1.2 miles 3440 Clark	1.3 miles 3078 Perry Park
WSW	1.2 miles 3462 Parmly	1.2 miles 2970 & 2971 Perry Park

Note: Closest residences and gardens are not identified for sectors over water. These sectors are as follows: W, WNW, NW, NNW, N, and NNE.

Table 19

Milk Animals Identified During the 1984 Perry NPP Annual Land Use Survey[1]

Location	Number/Type of Animals	Comments
1 mile SSE 3291 Parmly	3 Goats (and 2 kids)	
2 miles E 2541 Townline	12 Goats	
2.6 miles SSE 3907 Call	1 Dairy cow	No longer has goat; 2 beef animals
1.1 mile S 3830 Center	3 Goats	
1.4 miles SE 4776 North Ridge	2 Goats	
1.4 miles ESE 2908 Antioch	2 Goats	Waites, sampling location[2]
2.6 miles SSE 4761 Davis	1 Dairy cow	Possible future sample location
1.4 miles ESE 2897 Antioch	10 Goats	Hofer, sampling location[2]
2.3 miles SSW 3203 North Ridge	30 Goats	Manley, sampling location[2]

(1) All locations are within 5 miles of the plant.

(2) Participant in the Perry NPP Radiological Environmental Monitoring Program.

Table 20

Control[1] Milk Sampling Locations Identified During The 1984 Perry NPP Annual Land-Use Survey

Location	Description
12 miles SSE 8187 Callow Road	Brookglen Farm[2] Major dairy herd
11 miles SSE 13863 Painesville - Warren Road	Rettger Major dairy herd

(1) Control locations are greater than 10 miles from the plant.

(2) Participant in the Perry NPP Radiological Environmental Monitoring Program.

6.0 CONCLUSIONS

The preoperational radiological environmental monitoring program for the Perry Nuclear Power Plant has fulfilled the objectives as stated in Section 1.0. Procedures, equipment, and techniques have been evaluated and modifications, when necessary, have been implemented. Important pathways to be monitored after the plant is in operation have been identified. Background levels of radiation and concentrations of radioactive materials in environmental media in the area surrounding the plant have been measured. Finally, baseline data for statistical comparison with future operational analytical results have been established. A statistical summary of the preoperational results appears in Table 17.

There were no unusual levels of radiation or concentrations of radioactive materials during the PNPP preoperational program. The man-made radioisotope, Cs-137, was detected during all years of the program and in a variety of media. This isotope is the one most frequently observed resulting from long-term global fallout. Cesium-137 was detected at its expected range of activities. Cobalt-60 was detected in 4 sediment samples from 1981. Since it is also present in global fallout, the occasional detection of Co-60 is not unusual, however, this particular instance can probably be attributed to the October 1980 Chinese weapons test (reference 4). In general, the PNPP data are comparable to data obtained at other sites during the preoperational phase.

7.0 REFERENCES

1. National Council on Radiation Protection and Measurements, Environmental Radiation Measurement, NCRP Report No. 50, Washington, D.C. December 27, 1976

2. U. S. Nuclear Regulatory Commission, An Acceptable Radiological Environmental Monitoring Program, Radiological Assessment Branch Technical Position, November 1979, Revision 1.

3. Oakley, D.C., Natural Radiation Exposure in the United States, ORP/SID 72-1 Office of Radiation Programs, U. S. Environmental Protection Agency, Washington, D.C., June 1972.

4. Department of Energy, Environmental Monitoring in the Vicinity of the Savannah River Plant, Annual Report for 1980, DPSPU 81-30-1.

5. NUS Corporation, "Perry Nuclear Power Plant Land-Use Survey for 1984. NUS-4628, November 1984.

6. NUS Corporation, "Preoperational Radiological Environmental Monitoring Program at the Perry Nuclear Power Plant", Partial Annual Report, NUS-4649, 1984.

7. NUS Corporation, "Preoperational Radiological Environmental Monitoring Program at the Perry Nuclear Power Plant", Annual Report, NUS-4514, 1983.

8. NUS Corporation, "Preoperational Radiological Environmental Monitoring Program at the Perry Nuclear Power Plant", Annual Report, NUS-4338, 1982.

9. NUS Corporation, "Preoperational Radiological Environmental Monitoring Program at the Perry Nuclear Power Plant", Annual Report, NUS-4082A, 1981.

7.0 REFERENCES

1. National Council on Radiation Protection and Measurements, Environmental Radiation Measurement, NCRP Report No. 50, Washington, D.C. December 27, 1976

2. U. S. Nuclear Regulatory Commission, An Acceptable Radiological Environmental Monitoring Program, Radiological Assessment Branch Technical Position, November 1979, Revision 1.

3. Oakley, D.C., Natural Radiation Exposure in the United States, ORP/SID 72-1 Office of Radiation Programs, U. S. Environmental Protection Agency, Washington, D.C., June 1972.

4. Department of Energy, Environmental Monitoring in the Vicinity of the Savannah River Plant, Annual Report for 1980, DPSPU 81-30-1.

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6. NUS Corporation, "Preoperational Radiological Environmental Monitoring Program at the Perry Nuclear Power Plant", Partial Annual Report, NUS-4649, 1984.

7. NUS Corporation, "Preoperational Radiological Environmental Monitoring Program at the Perry Nuclear Power Plant", Annual Report, NUS-4514, 1983.

8. NUS Corporation, "Preoperational Radiological Environmental Monitoring Program at the Perry Nuclear Power Plant", Annual Report, NUS-4338, 1982.

9. NUS Corporation, "Preoperational Radiological Environmental Monitoring Program at the Perry Nuclear Power Plant", Annual Report, NUS-4082A, 1981.

Appendix A

APPENDIX A

LABORATORY QUALITY ASSURANCE

1. Introduction

The quality assurance program of the Radiological Laboratory of NUS is briefly described in this appendix.

Information on each incoming sample is entered in a permanent log book. A sample number is assigned to each sample at the time of receipt. This sample number uniquely identifies each sample.

Laboratory counting instruments are calibrated, using radionuclide standards obtained from the National Bureau of Standards, the EPA, and reliable commercial suppliers, such as Amersham-Searle. Calibration of counting instruments is maintained by regular counting of radioactive reference sources. Background counting rates are measured regularly on all counting instruments. Additional performance checks for the gamma-ray scintillation spectrometer include regular checks and adjustment, when necessary, of energy calibration.

Blank samples are processed, with each group of samples analyzed for specific radionuclides, using radiochemical separation procedures. Blank, spiked (known quantities of radioactivity added), and replicate samples are processed periodically to determine analytical precision and accuracy.

2. Laboratory Analyses for Quality Assurance

The quality assurance procedures employed in the conduct of radiological monitoring programs by the Environmental Services Division Radiological Laboratory are as required in the Division Quality Assurance Manual and detailed in the NUS Radiological Laboratory Work Instruction. These procedures include the requirement for (1) laboratory analysis of samples distributed by appropriate government or other standards-maintaining agencies in a laboratory intercomparison program, (2) analysis of some of the client's environmental samples

split with other independent laboratories, and (3) analysis in duplicate of a specific fraction of the client's environmental samples.

The NUS Radiological Laboratory participated in the U.S. Environmental Protection Agency Radioactivity Intercomparison Studies (Cross-check) Program.

Appendix B

APPENDIX B

REPORTING OF ANALYTICAL RESULTS

In the tables presenting analytical measurements, the calculated value is reported with the two sigma counting error (2s) derived from a statistical analysis of both the sample and background count rates. The precision of the results is influenced by the size of the sample, the background count rate, and the method used to round off the value obtained to reflect the degree of significance of the results. For analytical results obtained from gamma spectral analysis, the precision is also influenced by the composition and concentrations of the radionuclides in the sample, the size of the sample, and the assumptions used in selecting the radionuclides to be quantitatively determined. The two sigma error for the net counting rate is:

$$2s = 2\left(\frac{R_s}{t_s} + \frac{R_b}{t_b}\right)^{1/2}$$

Where:

R_s = sample counting rate
R_b = background counting rate
t_s = sample counting time
t_b = background counting time

If the measurements on the samples are not statistically significant (i.e., the two sigma count error is equal to or greater than the net measured value), then the radioactivity concentrations in the samples are considered not detected.

Results reported as less than ("LT") are below the lower limit of detection (LLD). The LLD is defined as the smallest concentration of radioactive material in a sample that will yield a net count (above system background) that will be detected with 95 percent probability with only 5 percent probability of falsely concluding that blank observation represents a "real" signal.

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

$$LLD = \frac{4.66s_b}{E \times V \times 2.22 \times Y \times \exp(-\lambda \Delta t)}$$

where:

LLD is the lower limit of detection as defined above (as pCi 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 disintegration)

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

2.22 is the number of disintegrations per minute per picocurie

Y is the fractional radiochemical yield (when applicable)

λ is the radioactive-decay constant for the particular radionuclide

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

The following are definitions or descriptions of statistical terms used in the reporting and analysis of environmental monitoring results.

Precision relates to the reproducibility of measurements within a set, that is, to the scatter or dispersion of a set about its central value.

Measures of the Central Value of a Set. Mean (or Average or Arithmetic Mean) is the sum $\sum_{i=1}^{n} X_i$ of the values of individual results divided by the number of results in the set. The mean is given by:

$$\bar{X} = (X_1 + X_2 + \ldots X_n) / n = \sum_{i=1}^{n} X_i/n$$

Measures of Precision with a Set. Standard Deviation is the square root of the quantity (sum of squares of deviations of individual results from the mean, divided by one less than the number of results in the set). The standard deviation, s, is given by:

$$s = \sqrt{\sum_{i=1}^{n} (X_i - \bar{X})^2 / (n-1)}$$

Standard deviation has the same units as the measurement. It becomes a more reliable expression of precision as n becomes larger. When the measurements are independent and normally distributed, the most useful statistics are the mean for the central value and the standard deviation for the dispersion.

Note: In the USEPA Intercomparison Program, the standard deviation given by EPA is for the expected laboratory result from three analyses. The standard deviation given by NUS is the standard deviation from the mean of three reported values.

Relative Standard Deviation is the standard deviation expressed as a fraction of the mean, $s/\bar{X}$. It is sometimes multiplied by 100 and expressed as a percentage.

Range is the difference in magnitude between the largest and the smallest results in a set. Instead of a single value, the actual limits are sometimes expressed (minimum value/maximum value).

Appendix C

APPENDIX C

DEVIATIONS FROM THE PROGRAM

The following deviations in the PNPP preoperational monitoring program have been documented in the individual Annual Reports (see references). There were no problems that resulted in serious losses of data. Following is a brief summary of the deviations encountered during the preoperational period.

Medium	Year	Deviation	Cause of Deviation
Direct Radiation	1981	Missing TLDs: May, station 7 June, station 24 August, stations 6, 14, and 22 October, station 6 December, station 22	Vandalism
	1982	Missing TLDs: January, station 22 February, station 22 October, station 17 November, station 15 December, station 6 Annual cycle, stations 6, 15, and 17	Vandalism
	1983	Missing TLDs: June, station 15 September, station 8 November, station 21 December, station 2 Annual cycle, station 21	Vandalism
	1984	None	

Medium	Year	Deviation	Cause of Deviation
Fish	1981	Sensitivities of Fe-59, Co-58 and Zn-65 exceeded Branch Technical Position guidelines for several May and November samples.	Laboratory equipment failures and delays in counting.
	1982	None	
	1983	Gamma Spectrometry analysis was not performed on one May Yellow Perch sample from station 25.	Sample was destroyed in analysis.
	1984	None	
Sediment	1981-1984	None	
Air Particulates/ Air Iodine	1982	None	
	1983	March: Air Particulate and Air Iodine samples were not collected from station 5 for the week 3/1 to 3/8.	Air Sampler malfunction.
	1984	July: Air Particulate sample not collected from station 3 for the week 7/3 to 7/11. Sensitivity for I-131 exceeded Branch Technical Position guidelines.	Air sampler malfunction.
Water	1983	August, September, October: Sensitivities for Ba-140 and La-140 exceeded Branch Technical Position guidelines for all stations.	Delays in counting.

Medium	Year	Deviation	Cause of Deviation
Water (cont.)	1984	February: Sr-89 and Sr-90 analyses were not performed on sample from station 34.	Positive Sr-89 activity was detected in the original sample and a confirmatory analysis was scheduled. However, an insufficient amount of sample remained for re-analysis. No data was reported since the results could not be confirmed.
Milk	1982	None	
	1983	August through November: Sensitivities for Ba-140 and/or La-140 exceeded Branch Technical Position guidelines for 90% of the samples.	Delays in counting.
	1983	August: Sr-89 and Sr-90 analyses were not performed on sample from station 30. November: Sr-89 and Sr-90 analyses were not performed on samples from stations 29 and 33.	Insufficient sample for re-analysis. Original results could not be confirmed.
	1984	None	
Feed/Silage	1982-1984	None	
Vegetation	1982-1984	None	

Appendix D

Note: This appendix lists detectable measurements only. Lower limits of detection are not included. Any gaps appearing in these tables can be attributed to being either LLD values or missing data, which can be found in the annual reports (references 6 through 9) or Appendix C, respectively.

Table D-1

Direct Radiation - Thermoluminescent Dosimetry
Results for Monthly Exchange Cycles
PNPP REMP 1981-84

(Results in mR/day)
(Sheet 1 of 4)

Year	Location	January	February	March	April	May	June	July	August	September	October	November	December
1981	1					0.22	0.25	0.15	0.16	0.18	0.24	0.22	0.17
	2					0.18	0.18	0.14	0.14	0.19	0.21	0.12	0.18
	3					0.23	0.21	0.16	0.15	0.21	0.26	0.23	0.16
	4					0.23	0.22	0.18	0.17	0.21	0.26	0.22	0.16
	5					0.21	0.20	0.15	0.18	0.17	0.22	0.19	0.17
	6					0.22	0.27	0.17		0.19		0.15	0.20
	7						0.25	0.16	0.17	0.18	0.22	0.17	0.29
	8					0.17	0.18	0.15	0.17	0.18	0.21	0.19	0.19
	9					0.19	0.23	0.15	0.15	0.17	0.22	0.15	0.13
	10					0.19	0.20	0.14	0.15	0.18	0.22	0.15	0.18
	11					0.18	0.19	0.13	0.15	0.16	0.23	0.16	0.19
	12					0.16	0.17	0.14	0.16	0.17	0.25	0.19	0.15
	13					0.21	0.20	0.14	0.15	0.17	0.22	0.24	0.14
	14					0.21	0.23	0.16		0.17	0.24	0.23	0.16
	15					0.19	0.23	0.17	0.16	0.18	0.22	0.26	0.16
	16					0.17	0.29	0.19	0.22	0.21	0.28	0.25	0.21
	17					0.16	0.26	0.17	0.19	0.22	0.27	0.28	0.15
	18					0.19	0.37	0.22	0.25	0.27	0.28	0.25	0.27
	19					0.18	0.27	0.17	0.19	0.20	0.21	0.29	0.19
	20					0.15	0.20	0.16	0.15	0.18	0.22	0.17	0.16
	21					0.15	0.23	0.18	0.17	0.20	0.25	0.20	0.16
	22					0.12	0.27	0.15		0.17	0.23	0.19	
	23					0.14	0.26	0.19	0.15	0.22	0.25	0.22	0.18
	24					0.16		0.17	0.11	0.18	0.22	0.20	0.14

Table D-1

Direct Radiation - Thermoluminesent Dosimetry
Results for Monthly Exchange Cycles
PNPP REMP 1981-84

(Results in mR/day)
(Sheet 2 of 4)

Year	Location	January	February	March	April	May	June	July	August	September	October	November	December
1982	1	0.19	0.14	0.15	0.15	0.20	0.22	0.17	0.21	0.13	0.20	0.26	0.20
	2	0.17	0.13	0.13	0.20	0.20	0.20	0.18	0.19	0.11	0.19	0.26	0.19
	3	0.26	0.13	0.17	0.16	0.13	0.20	0.16	0.21	0.12	0.20	0.26	0.22
	4	0.16	0.17	0.16	0.23	0.22	0.21	0.18	0.22	0.11	0.20	0.25	0.23
	5	0.13	0.14	0.18	0.14	0.18	0.19	0.21	0.25	0.12	0.20	0.26	0.20
	6	0.13	0.13	0.21	0.14	0.16	0.17	0.18	0.20	0.11	0.17	0.25	
	7	0.13	0.15	0.15	0.19	0.16	0.21	0.14	0.22	0.12	0.22	0.25	0.22
	8	0.15	0.16	0.14	0.11	0.18	0.17	0.17	0.22	0.11	0.18	0.23	0.19
	9	0.14	0.17	0.13	0.16	0.18	0.18	0.10	0.22	0.18	0.23	0.20	0.20
	10	0.16	0.12	0.14	0.18	0.21	0.22	0.17	0.20	0.13	0.21	0.23	0.20
	11	0.16	0.15	0.17	0.18	0.18	0.18	0.11	0.23	0.34	0.20	0.26	0.21
	12	0.15	0.18	0.13	0.18	0.13	0.18	0.17	0.22	0.32	0.22	0.25	0.20
	13	0.16	0.15	0.14	0.19	0.13	0.20	0.21	0.20	0.26	0.20	0.25	0.21
	14	0.15	0.15	0.15	0.17	0.16	0.20	0.11	0.21	0.18	0.19	0.23	0.22
	15	0.15	0.13	0.14	0.21	0.19	0.22	0.18	0.23	0.21	0.21		0.21
	16	0.22	0.21	0.17	0.26	0.24	0.27	0.22	0.28	0.21	0.26	0.28	0.28
	17	0.17	0.15	0.17	0.28	0.18	0.26	0.12	0.26	0.20		0.30	0.26
	18	0.21	0.21	0.20	0.28	0.27	0.29	0.23	0.36	0.23	0.28	0.32	0.31
	19	0.16	0.13	0.15	0.18	0.18	0.20	0.18	0.17	0.17	0.22	0.28	0.22
	20	0.20	0.13	0.14	0.21	0.29	0.20	0.12	0.17	0.18	0.20	0.24	0.26
	21	0.22	0.16	0.16	0.13	0.17	0.23	0.24	0.17	0.19	0.22	0.26	0.26
	22			0.16	0.17	0.11	0.24	0.20	0.16	0.18	0.22	0.25	0.24
	23	0.18	0.17	0.15	0.24	0.18	0.24	0.22	0.17	0.20	0.21	0.27	0.25
	24	0.23	0.18	0.15	0.15	0.11	0.16	0.12	0.16	0.16	0.25	0.36	0.22
	35											0.23	0.19

Table D-1

Direct Radiation - Thermoluminesent Dosimetry
Results for Monthly Exchange Cycles
PNPP REMP 1981-84

(Results in mR/day)
(Sheet 3 of 4)

Year	Location	January	February	March	April	May	June	July	August	September	October	November	December
1983	1	0.22	0.20	0.22	0.25	0.23	0.20	0.23	0.28	0.24	0.20	0.19	0.24
	2	0.23	0.20	0.22	0.20	0.21	0.24	0.20	0.24	0.23	0.20	0.20	0.23
	3	0.22	0.21	0.21	0.21	0.21	0.23	0.27	0.25	0.28	0.21	0.20	0.21
	4	0.22	0.21	0.23	0.23	0.22	0.21	0.23	0.23	0.27	0.21	0.18	0.24
	5	0.21	0.21	0.22	0.19	0.20	0.19	0.24	0.24	0.23	0.21	0.18	0.22
	6	0.21	0.21	0.22	0.18	0.23	0.22	0.27	0.27	0.28	0.20	0.19	0.19
	7	0.22	0.19	0.20	0.22	0.24	0.17	0.18	0.24		0.17	0.17	0.20
	8	0.20	0.18	0.20	0.15	0.23	0.18	0.20	0.22	0.21	0.21	0.19	0.19
	9	0.20	0.19	0.23	0.17	0.25	0.18	0.20	0.23	0.21	0.19	0.19	0.22
	10	0.20	0.21	0.23	0.18	0.17	0.20	0.22	0.25	0.22	0.18	0.20	0.20
	11	0.23	0.19	0.20	0.20	0.20	0.18	0.22	0.20	0.22	0.19	0.18	0.21
	12	0.20	0.19	0.21	0.24	0.18	0.19	0.23	0.21	0.30	0.22	0.20	0.21
	13	0.22	0.21	0.20	0.19	0.21	0.17	0.23	0.21	0.23	0.19	0.21	0.22
	14	0.20	0.19	0.18	0.21	0.22		0.24	0.21	0.22	0.22	0.22	0.25
	15	0.21	0.22	0.23	0.21	0.23	0.28	0.28	0.29	0.27	0.25	0.31	0.24
	16	0.26	0.26	0.27	0.22	0.26	0.25	0.24	0.27	0.25	0.22	0.25	0.29
	17	0.24	0.22	0.23	0.23	0.22	0.28	0.31	0.32	0.33	0.31	0.30	0.22
	18	0.32	0.28	0.28	0.29	0.30	0.20	0.24	0.22	0.26	0.23	0.22	0.22
	19	0.20	0.21	0.20	0.19	0.21	0.22	0.24	0.22	0.24	0.21	0.24	0.23
	20	0.25	0.23	0.20	0.22	0.21	0.21	0.25	0.27	0.22	0.22		0.23
	21	0.24	0.22	0.20	0.23	0.23	0.26	0.25	0.21	0.25	0.23	0.22	0.23
	22	0.24	0.21	0.23	0.25	0.23	0.23	0.24	0.24	0.24	0.23	0.24	0.23
	23	0.25	0.22	0.22	0.27	0.25	0.20	0.28	0.22	0.23	0.21	0.21	0.20
	24	0.24	0.18	0.21	0.24	0.23	0.20	0.20	0.21	0.20	0.21	0.20	0.19
	35	0.19	0.17	0.19	0.21	0.20	0.24	0.24	0.23	0.20	0.20	0.23	

Table D-1

Direct Radiation - Thermoluminesent Dosimetry
Results for Monthly Exchange Cycles
PNPP REMP 1981-84

(Results in mR/day)
(Sheet 4 of 4)

Year	Location	January	February	March	April	May	June	July	August	September	October	November	December
1984	1	0.17	0.17	0.10	0.24	0.19	0.23	0.16	0.24	0.22			
	2	0.18	0.18	0.12	0.19	0.20	0.23	0.21	0.21	0.21			
	3	0.20	0.20	0.19	0.22	0.20	0.15	0.21	0.26	0.24			
	4	0.17	0.20	0.10	0.18	0.21	0.18	0.22	0.29	0.24			
	5	0.17	0.18	0.12	0.17	0.19	0.20	0.21	0.25	0.22			
	6	0.18	0.20	0.13	0.19	0.20	0.28	0.26	0.22	0.22			
	7	0.16	0.17	0.09	0.16	0.16	0.14	0.19	0.21	0.21			
	8	0.17	0.16	0.10	0.12	0.19	0.17	0.21	0.24	0.23			
	9	0.16	0.19	0.17	0.21	0.21	0.21	0.18	0.23	0.21			
	10	0.17	0.19	0.09	0.17	0.17	0.21	0.23	0.20	0.21			
	11	0.17	0.17	0.07	0.32	0.18	0.21	0.21	0.24	0.19			
	12	0.18	0.21	0.17	0.21	0.21	0.16	0.18	0.18	0.24			
	13	0.17	0.16	0.15	0.20	0.21	0.20	0.17	0.24	0.23			
	14	0.18	0.17	0.15	0.22	0.23	0.20	0.24	0.25	0.24			
	15	0.23	0.21	0.14	0.26	0.23	0.35	0.25	0.27	0.32			
	16	0.20	0.24	0.17	0.22	0.26	0.24	0.29	0.28	0.26			
	17	0.25	0.25	0.27	0.32	0.28	0.28	0.28	0.37	0.32			
	18	0.18	0.20	0.17	0.20	0.19	0.23	0.22	0.23	0.23			
	19	0.19	0.20	0.19	0.20	0.17	0.26	0.14	0.24	0.22			
	20	0.19	0.20	0.20	0.23	0.24	0.26	0.34	0.27	0.27			
	21	0.18	0.18	0.18	0.22	0.26	0.20	0.22	0.25	0.24			
	22	0.21	0.22	0.19	0.25	0.21	0.21	0.21	0.24	0.22			
	23	0.17	0.21	0.16	0.21	0.19	0.20	0.24	0.25	0.23			
	24	0.16	0.19	0.16	0.22	0.18	0.16	0.16	0.23	0.22			
	35	0.16	0.14	0.18	0.19	0.23	0.22	0.21	0.24				

Table D-2

Direct Radiation - Thermoluminescent Dosimetry
Results for Annual Exchange Cycles
PNPP REMP 1981-84

(Results in mR/day)

Location	1981	1982	1983	1984
1	0.18	0.21	0.19	0.19
2	0.17	0.19	0.15	0.19
3	0.15	0.21	0.17	0.20
4	0.18	0.22	0.18	0.20
5	0.14	0.19	0.16	0.18
6	0.19		0.16	0.18
7	0.15	0.18	0.17	0.21
8	0.15	0.21	0.17	0.20
9	0.15	0.18	0.15	0.21
10	0.17	0.19	0.16	0.18
11	0.14	0.20	0.16	0.23
12	0.18	0.18	0.18	0.20
13	0.12	0.20	0.16	0.20
14	0.25	0.20	0.19	0.21
15	0.16		0.21	0.24
16	0.20	0.24	0.21	0.27
17	0.17		0.22	0.25
18	0.23	0.30	0.30	0.32
19	0.15	0.21	0.21	0.23
20	0.16	0.22	0.23	0.21
21	0.18	0.23		0.23
22	0.20	0.23	0.22	0.22
23	0.19	0.22	0.22	0.24
24	0.18	0.22	0.21	0.23
35			0.17	0.19

Table D-3

Gamma Spectrometry of Fish Samples
PNPP REMP 1981-84

(Results in pCi/kg (wet))
(Sheet 1 of 2)

Year	Location	Fish Species	Cs-137	K-40
1981	25	Freshwater Drum		4900
	25	Spottail Shiner		2100
	25	Walleye	51	3400
	25	Yellow Perch	56	9900
	32	Brown Trout	30	4600
	32	Carp	11	3000
	32	Freshwater Drum		2900
	32	Spottail Shiner		1600
	32	White Sucker	14	4200
	32	Yellow Perch	19	3000
	32	Yellow Perch		4300
1982	25	Freshwater Drum		3000
	25	Freshwater Drum		3500
	25	Perch		2500
	25	Rainbow Smelt		2800
	25	Stone Cat		4000
	25	Walleye		5900
	25	White Bass		4700
	25	White Sucker		3700
	25	White Sucker		3600
	25	White Sucker		3000
	25	Yellow Perch	28	3200
	32	Freshwater Drum	17	2800
	32	Freshwater Drum	28	3300
	32	Golden Redhorse		2900
	32	Rainbow Smelt		2800
	32	Walleye		
	32	Walleye		3000
	32	White Bass		2900
	32	White Bass		3400
	32	White Sucker		3400
	32	White Sucker		3200
	32	Yellow Perch		3800
	32	Yellow Perch	16	3100

Table D-3

Gamma Spectrometry of Fish Samples
PNPP REMP 1981-84

(Results in pCi/kg (wet))
(Sheet 2 of 2)

Year	Location	Fish Species	Cs-137	K-40
1983	25	Carp		4600
	25	Freshwater Drum	38	3400
	25	Freshwater Drum		3100
	25	Rock Bass		3900
	25	Smallmouth Bass	36	4300
	25	Walleye		2200
	25	White Bass	25	8500
	25	White Bass	24	3600
	25	White Sucker	6.1	3700
	25	White Sucker		4400
	25	Yellow Perch		
	25	Yellow Perch	20	4300
	32	Carp		3300
	32	Freshwater Drum	23	2800
	32	Freshwater Drum	46	3500
	32	Walleye		3100
	32	Walleye	18	3700
	32	White Bass		4100
	32	White Bass	43	5100
	32	White Sucker		4700
	32	White Sucker		3600
	32	Yellow Perch		3900
	32	Yellow Perch		2000
1984	25	Freshwater Drum		2500
	25	Walleye		2700
	25	White Bass		2300
	25	White Sucker		3900
	25	Yellow Perch		1800
	32	Freshwater Drum		1900
	32	Walleye		3200
	32	White Bass		
	32	Yellow Perch		3800

Table D-4

Gamma Spectrometry of Sediment Samples
PNPP REMP 1981-84

(Results in pCi/kg (dry))

Year	Location	Bi-214	Pb-214	Ra-226	Pb-212	Tl-208	Ac-228	K-40	Cs-137	Co-60	Bi-212	Ra-224	Ce-144
1981	25	1200	1300	1100	980	440	1100	17000	190				
	26	1300	1500	1300	1200		1100	24000	450	190			950
	27		460	490	310	150	410	9700	24				
	32	800	810	720	470	250	680	12000	38		550		
	25	1300	1300	1400	910		1100	24000	390				
	26	1500	1600	1600	1300		1100	17000	390	150	1200	3400	
	27	800	820	980	720		600	15000	150	120	710	1800	
	32	830	950	970	760		680	16000	160	87	660	1900	
1982	25		1500		1600		1400	14000				3500	
	26		1300		800		1100	16000	400				
	27		1200	1800	800			21000	390				
	32		870	900	900		770	14000	670			1900	
	25	690	750	1300	490		630	8800	140		960		
	26	630	590	1300	320	590	430	7300	470		610		
	27	430	490	1100	270	420	280	7500					
	32	520	570		280	440		8800	120				
1983	25	1000	1100	1100	580	740		12000					
	26	1000	1300	1100	890	920	850	15000	150		880		
	27	560	700	630		590	620	13000					
	32	980	970	980	680	880	1000	15000	160				
	25	660	680	670	470	620	620	9600	310				
	26	1100	1100	1100	790	940	1100	18000	190		1000		
	27	540	590	570	310	430	380	10000					
	32	560	720	640	380	570	580	11000					
1984	25	1200	890	1000	510	810	710	14000					
	26	1400	1400	1400	1000	880	1200	9800					
	27	750	710	730	490	500	660	13000					
	32	510	750	630	580	520		12000					

Table D-5

Gross Beta in Air Particulate Filters
PNPP REMP 1981-84

(Results in E-03 pCi/m3)
(Sheet 1 of 2)

	1982						1983						1984					
Month	1	3	4	5	6	35	1	3	4	5	6	35	1	3	4	5	6	35
January							20	16	18	16	14	16	24	23	25	24	29	26
							19	10	16	16	21	16	28	23	27	27	25	23
							19	20	17	16	17	16	31	29	31	31	34	32
							19	15	15	23	23	19	23	20	14	17	17	19
February							15	13	11	12	15	12	18	20	14	19	18	19
							31	29	35	35	34	34	17	17	15	16	21	16
							28	23	24	16	18	21	14	21	16	18	19	18
							12	13	15	14	13	16	23	19	13	16	17	19
March							17	21	15		20	20	14	14	12	8.1	12	13
							18	18	13	14	8.7	15	27	27	28	29	23	20
							7.2	11	8.2			5.7	16	20	18	14	13	13
							8.1	13	12	11	12	8.7	17	19	15	16	12	17
April							15	14	10	12	15	17	14	15	13	13	13	16
								9.1					13	15	15	15	15	11
							12	8.1	15	12	9.3	9.2	4.7	7.6	8.1	8.1	5.7	7
							9.6	16	18	22	13	12	6.5	11	8.3	10	9.5	6.3
							13	14	16	14	17	12	19	21	18	18	19	18
May							15	13	17	12	13	11	16	16	13	12	15	13
									7.2	8.4	11	11	9.6	12	8.6	13	9.9	13
							11	9.7	11	18	19	12	16	13	12	17	18	16
								8	8.6		7.7		13	11	13	12	16	15
June											8.4		20	21	15	18	14	17
							27	22	20	26	26	30	23	23	23	27	25	26
							34	41	29	40	34	24	12	15	15	15	12	14
							14	6.6	10	9.8	9.9	13	9.2	14	13	20	13	12
													9	10	9.7	11	8.6	6.3

Table D-5

Gross Beta in Air Particulate Filters
PNPP REMP 1981-84

(Results in E-03 pCi/m3)
(Sheet 2 of 2)

	1982						1983						1984					
Month	1	3	4	5	6	35	1	3	4	5	6	35	1	3	4	5	6	35
July							11	14	11	12	12	10	22		16	22	17	18
							16	12	14		15	11	25	20	22	26	22	20
							35	28	23	32	25	22	16	19	14	20	17	17
							12		14	12	11		12	16	11	14	13	8.6
							27	29	25	24	20	26						
August							24	21	17	16	19	21	25	28	21	22	20	24
							11			9.8	11	10	21	24	20	20	24	23
							25	23	22	26	25	24						
							31	34	31	33	29	29						
September							19	22	18	20	25	22						
							18	17	14	22	19	20						
							19	23	23	16	25	23						
							15	21	15	17	25	19						
October	22	18	14	19	15		32	33	30	32	27	30						
	36	32	35	12	37		13	9.6	13	13	16	12						
	15	21	15	12	15		25	27	21	23	29	26						
	16		14	16	15		9.9	11	11	13	13	11						
	20	22	22	20	28	15	16	18	16	13	14	15						
November	22	21	16	19	17	18	21	21	17	21	21	17						
	21	19	20	18	15	17	17	16	17	18	16	17						
	23	28	27	26	25	24	15	17	16	15	18	15						
	26	23	20	20	23	17	26	24	26	28	22	21						
December	11	9	17	19	9	11	19	20	17	15	16	17						
	20	23	24	26	32	27	24	26	24	23	23	26						
	22	18	15	22	22	19	23	22	20	29	22	24						
	18	17	27	11	15	22	24	31	25	29	24	29						
	20	23	19	23	21	16	25	27	25	31	29	24						

Table D-6

Gamma Spectrometry of Composited Air Particulate Filters
PNPP REMP 1981-84

(Results in E-03 pCi/m3)

		Be-7		
Quarter	Location	1982	1983	1984
1	1		57	57
	3		57	61
	4		44	63
	5		46	76
	6		52	72
	35		39	76
2	1			62
	3		59	60
	4		47	44
	5			51
	6			52
	35			58
3	1		61	
	3		53	
	4		49	
	5		94	
	6		64	
	35		52	
4	1	51		
	3		58	
	4	40	44	
	5	51	52	
	6	44	40	
	35	71		

Table D-7

Gross Beta in Water
PNPP REMP 1981-84

(Results in pCi/l)

Year	Location	January	February	March	April	May	June	July	August	September	October	November	December
1982	28									5.2	3.3	3.0	4.0
	34									5.0	2.9	4.4	4.0
	36									3.8	3.1	4.9	3.8
	37									4.4	5.6	4.6	5.1
1983	28	4.5	3.9	2.8	3.3	3.9	6.2	5.5	6.0	3.7	1.6	6.2	3.0
	34	4.5	2.7	2.8	3.0	5.0	7.0		6.4	3.0	4.3	4.0	3.7
	36	3.6	2.8	3.1	4.1	5.5	3.2		3.4	1.8	4.7	2.7	2.5
	37	5.6	2.3	3.2	3.5	7.2	9.0		4.7	4.3	3.2	3.7	7.9
1984	28	1.9	3.7	5.5	2.6	3.6	4.2	3.1					
	34	1.4	2.9	4.0	2.7	3.3	3.5	4.2					
	36	2.7	2.0	4.9	2.0	8.4	4.5	2.8					
	37		1.5	7.3	2.5	2.6	1.9	3.4					

Table D-8

Tritium in Water
Quarterly Composite by Location
PNPP REMP 1981-84

(Results in pCi/l)

Year	Quarter	Location	Value
1982	3	37	310
1983	2	37	780
	3	28	240
		36	310
		37	360
1984	1	36	300
	2	36	490
	3	28	240
		34	190
		36	260
		37	190

Table D-9

Gamma Spectrometry of Milk Samples
PNPP REMP 1981-84

(Results in pCi/l)

Year	Location	January	February	March	April	May	June	July	August	September	October	November	December
Element: K-40													
1982	33(1)										1300	1300	1400
	33											1300	
1983	29		1300	1500	1500	1400	1700	1600	1200	1800	2000	1700	1400
	30			1600	1800	1200	1500	1100	1600	1900	1700	1700	1400
	33	1300	1200	1300	1100	1200	1300	860	1300	1300	1500	1500	1300
	29				1600	1800	1900	1700	1700	1800	1700		
	30				1600	1400	1300	1700	1500	1300	1600		
	33				1300	1400	1100	1400	1100	1000	1400		
1984	29	1400	1600	1600	1700	1800	1700	1700	1800				
	30	1400	1400	1300	1500	1500	1400	1600	1700				
	31		1600	1500	1700	1700	1900	1800	1800				
	33	1500	1300	1400	1300	1300	1300	1200	1300				
	29				1800	1700	1800	1700					
	30				1400	1500	1500	1600					
	31				1600	1700	1500	1700					
	33				1300	1300	1400	1300					
Element: Cs-137													
1983	29(2)						3.4		3.5	1.4	1.6		
	29									1.8			
	30						2.3			2.0	3.1		
1984	29				2.1	4.4							
	30				1.7	4.0							
	31					3.6							
	33					2.0							

(1) Station 33 is listed twice since there was semi-monthly sampling in November, 1982.
(2) Station 29 is listed twice since there was semi-monthly sampling in September, 1982. Cs-137 was detected in both September samples from station 29.

Table D-10

Strontium-90 in Milk
PNPP REMP 1981-84

(Results in pCi/l)

Year	Month	Station	Sr-90
1983	August	33	1.8
1983	November	30	3.5
1984	February	29	0.85
		30	1.30
		31	0.72
		33	0.47

Table D-11

Gamma Spectrometry of Feed/Silage
PNPP REMP 1981-84

(Results in pCi/kg (wet))

Year	Location	Be-7	K-40
1982	33	5000	4900
1983	29(1)	240	6500
	29(2)		6500
	30(1)	470	12000
	30(2)		6000
	33(1)		3900
1984	29(1)	1800	11000
	29(2)		5600
	30(1)	1100	9200
	30(2)		4900
	31(1)	860	18000
	31(2)		2600
	33(1)	890	11000
	33(2)		2800

(1) Pasture grass/hay
(2) Grain

Table D-12

Gamma Spectrometry of Vegetation Samples
PNPP REMP 1981-84

(Results in Units of pCi/kg (wet))

Year	Station	Vegetation Type	K-40
1982	38	Peaches	1800
	38	Acorn Squash	2800
	38	Pears	1200
	38	Cauliflower	2700
	38	Apples	980
	38	Cabbage	2100
1983	38	Squash	3700
	38	Cabbage	2000
	39	Apples	1700
	39	Peaches	1800
	40	Tomatoes	2400
	40	Cucumbers	2200
	40	Peppers	630
1984	38	Zucchini	1800
	38	Peppers	2500
	38	Beets	4100
	39	Tomatoes	1800
	39	Apples	1200
	39	Corn	2800
	39	Cucumbers	1200
	39	Peaches	1400

Appendix E

APPENDIX E

NUS ANALYTICAL PROCEDURES

Environmental samples for radiological monitoring programs are collected and analyzed in accordance with procedures described in detail in individual work instructions. The work instructions used in the Radiological Laboratory have been drawn from published analytical methods, including those of the Environmental Measurements Laboratory, DOE (formerly Health and Safety Laboratory of the U. S. Energy Research and Development Administration) and the laboratories of the U. S. Environmental Protection Agency. The current versions of these published manuals, copies of methods published in the Regulatory Guides of the U. S. Nuclear Regulatory Commission, and other compendia of government or industry approved analytical methods are at hand at NUS and were relied upon as the basis for laboratory protocol.

Adaptions and summaries for use by the laboratory personnel of the detailed procedures from the above mentioned sources were prepared by the senior laboratory staff on the basis of their professional knowledge and appraisal of methods and of recent improvements in technique and instrumentation. These work instructions were then reviewed by knowledgeable personnel and approved by the Manager, Radiological Laboratory, in radioanalytical program work. Summaries of the typical laboratory operations are presented below.

Sample Preparation

Samples are processed prior to analysis to satisfy a number of conditions. Sieving and grinding operations are performed to obtain homogeneous samples and permit removal of representative aliquots. Volume reduction is used to match standard counting geometries or to meet required sensitivities.

Other processes may be used to obtain specific fractions of samples for analysis (e.g., filleting to obtain edible fractions of fish). Chemical and physical processing will also be used to remove interferences when a specific

nuclide is being measured. Preparations of various sample types for the Fermi-2 program are presented below.

Air Particulates

For determination of gross alpha and gross beta, air filters are mounted for counting in stainless steel planchets and counted in low-background gas-proportional counting system. All air filter samples are counted at least 72 hours after collection in order to allow natural radon and thoron radioactivities to decay.

For determination of gamma emitters, an individual air filter sample or several air filter samples composited by stacking are placed in a plastic dish. The dish is covered, placed on a high resolution germanium detector, and the gamma-ray spectrum obtained. The observed spectral data are processed to obtain radionuclide concentrations.

Water

For the measurement of beta on total water samples, 200 milliliters of water of low solids content (i.e., well, drinking, river, etc.) is evaporated to a low volume in a Teflon beaker; the sample is then transferred to a stainless steel planchet, evaporated to dryness, and weighed to establish the self-absorption correction.

For the analysis of gamma emitters, up to 3 liters of the total water sample are accurately dispensed into a Marinelli beaker of appropriate size. The beaker containing the sample is placed on a high resolution germanium detector, and counted using a multi-channel pulse height analyzer. Background data is obtained with a Marinelli beaker containing distilled water.

To determine tritium in water, a portion of the sample is distilled to remove impurities and an accurately measured volume of the distillate is added to a liquid scintillation counting vial containing a liquid scintillation cocktail. The sample is counted in a liquid scintillation counter.

Milk

A preservative, such as formalin, normally is added to the sample in the field, as soon as possible after collection and mixed thoroughly with the milk. Carrier solutions for specified elements may also be added at time of collection.

For gamma spectrometric analysis, three liters of the milk sample are accurately dispensed into the Marinelli beaker. The beaker containing the sample is placed on a high resolution germanium detector and counted using a multichannel pulse height analyzer. The observed spectral data is processed to obtain the specific radionuclide concentrations.

Biological Tissues

A sufficient amount of raw tissue sample (to yield about 20 grams of ash) is placed in a heat-resistant dish of suitable size, weighed, and dried for about 24 hours at about 200'C. The dried sample is ashed in a muffle furnace. If Cs-137 analysis is to be performed on the ash, the maximum ashing temperature is 540'C. The ash weight is obtained and the sample is screened and stored in a plastic container for future analysis.

For gross beta analysis, approximately one hundred milligrams of the ashed sample is transferred to a stainless steel planchet, accurately weighed, and distributed evenly on the planchet with a minimum amount of distilled water. The sample is dried under a heat lamp and counted in a low-background gas-proportional counting system.

For gamma spectrometry of a biological material, the ashed, dried, or raw sample is transferred to a suitably sized plastic container and weighed. The sample container is sealed, placed on high resolution germanium detector, and counted using a multi-channel pulse height analyzer.

Vegetation

A sufficient amount of raw vegetation sample (to yield approximately 30 grams of ash) is placed in a heat-resistant dish, weighed, and dried overnight in an oven at about 110'C. If the analysis is to be performed on ash, the sample is dried as above or on a hot plate set at low heat and ashed in a muffle furnace. After ashing, the ash is weighed, screened and stored for future analysis.

For determination of gamma emitters, the ashed, dried, or raw sample is transferred to a plastic container, weighed, and the container is sealed. The sample container is placed on a high resolution germanium detector and counted using a multi-channel pulse height analyzer. Samples of leafy foods such as cabbage, lettuce, or chard may be pureed in a blender and the sample counted in a 3-liter Marinelli beaker to avoid loss of iodine by drying or ashing.

Soils and Sediment

Approximately 500 grams of the soil or sediment sample are oven-dried overnight at 110'C-125'C. The dried sample is ground to a fine consistency, screened, and stored in a plastic container for future analysis.

For determination of gamma emitters, 150-200 grams of the prepared soil or sediment sample are transferred to a plastic container and weighed. The container is sealed, placed on a high resolution germanium detector, and counted using a multi-channel pulse height analyzer.

RADIOCHEMICAL SEPARATIONS

In the analysis of specific isotopes, chemical separations are often necessary to remove interferences or improve sensitivity. The separation methods used in this program are summarized below.

Iodine-131 in Milk or Water

To analyze for I-131 in milk or water, iodine carrier (as iodide) is added to the sample and mixed well. Iodine carrier and activity are separated from the milk or water by adsorption on an ion-exchange resin. Iodine is stripped from the resin by oxidation with hypochlorite solution. The separated iodine is purified by solvent extraction of elemental iodine and finally precipitated as copper iodide. The precipitate is filtered and weighed to determine the chemical yield, then mounted for counting in a low-background beta counter or a beta-gamma coincidence counter.

MEASUREMENT INSTRUMENTATION

Proportional Counting

Low background gas proportional counters are used for measurement of alpha and beta decay.

Tennelec LB-5100 Automatic Low Background Alpha/Beta Counting Systems and Beckman Widebeta-II's are "pancake type" gas-flow proportional counters with four inches of lead shielding and anti-coincidence guard counters to reduce the background counting rate. Samples are changed and counted automatically. Teletype readouts are used.

Reference source and background counting rates are measured daily and recorded in a log. After each gas cylinder change the reference sources are measured at the "plateau point", "low test", and "high test" positions to be sure that the detector is operating on a plateau.

Berthold 770's are alpha/beta counting systems with ten gas-flow sample detectors and a common guard detector. Samples are changed manually. The plateau is checked at 50 volt intervals each time a new tank of gas is installed. Backgrounds, blanks, and check sources are counted at the time of use of this instrument and recorded in a separate log.

The alpha and beta radioactivity concentrations are calculated from the observed counting rates corrected for background. Background counting rates are obtained using a blank in the same geometry as the sample. Beta and alpha reference samples are counted on a routine basis.

Liquid Scintillation Counting

Both ambient and refrigerated liquid scintillation counters are used for measuring low energy beta emitters. All use automatic changing of samples contained in low-background vials. A teletype readout is used.

Sealed, unquenched tritium and background sources, provided by the manufacturer, are measured frequently to determine that the response of the instrument has not changed significantly. Results of these measurements are recorded in a log kept in the laboratory.

Standard tritium spiked samples and blank samples are counted with each group of samples to determine the counting efficiency and background counting rate. The results of the measurements are recorded in a log.

Tritium activity is calculated from the observed counting rates using a tritium counting efficiency determined from the HTO standards counted under the same conditions as the samples.

Gamma Spectrometry

Samples for gamma spectrometric analysis are placed in 3-liter or 1-liter Marinelli beakers, 2-1/4 inch diameter plastic dishes or 3-1/4 inch plastic dishes, or other geometries depending on the volume available for analysis. Prepared samples are then counted on one of several gamma spectrometry systems.

Gamma spectrometry is performed with high resolution germanium detectors, either GeLi or HpGe. Pulse height analysis is performed with Canberra Series 85 MCAs and a PDP 11/44 data analysis system. Spectra are analyzed with the Spectran-F software supplied by Canberra. The energy calibration of

this system is checked with an NBS mixed gamma source. Performance checks and operating records are maintained in a log.

Thermoluminescent Dosimetry

The thermoluminescent dosimetry (TLD) system used by NUS for environmental radiation monitoring utilizes Teflon-calcium sulfate:dysprosium activated (Teflon-$CaSO_4$:Dy) dosimeters for high sensitivity. The dosimeters are read in a Teledyne Isotopes Model 8300 reader. The dosimeters are exposed in the field in a special environmental badge which includes various filters to assess the contribution of various gamma-ray energies to the observed exposure. There are four primary and four backup readout areas per TLD card.

The dosimetry system is calibrated by reading dosimeters which have been exposed in an accurately known gamma radiation field. The performance of the TLD reader is checked and adjusted, if necessary, immediately before reading a batch of dosimeters using procedures described in the manufacturer's instruction manual for this system. These checks include the measurement of reader response to a reference light source built into the instrument.

The radiation dose accumulated by the TLDs before placing them in the field is eliminated by annealing the dosimeters shortly before placing them at the site to be measured. Correction for radiation dose accumulated in-transit between the field location and the NUS Laboratory is made by annealing appropriate control dosimeters in order to determine the dose accumulated by the TLDs for each part of the shipping cycle. The control dosimeters are returned to the laboratory for readout at the same time as the exposed field dosimeters.