BNL 51697

1982 ENVIRONMENTAL MONITORING REPORT

L.E. Day and J.R. Naidu, Editors

April 1983

SAFETY AND ENVIRONMENTAL PROTECTION DIVISION

BROOKHAVEN NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC.

Under Contract No. DE-AC02-76CH00016

UNITED STATES DEPARTMENT OF ENERGY

BNL 51697
UC-11
(Environmental Control Technology
and Earth Science — TIC-4500)

1982 ENVIRONMENTAL MONITORING REPORT

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SAFETY AND ENVIRONMENTAL PROTECTION DIVISION

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Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

NTIS price codes:
Printed Copy: A04; Microfiche Copy: A01

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BROOKHAVEN NATIONAL LABORATORY
ENVIRONMENTAL MONITORING REPORT

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1.0 INTRODUCTION

1.1 Background:

The primary purpose of a routine environmental monitoring program, according to Department of Energy (DOE) DOE Order 5484.1 (1), is to determine whether:

1) facility operations, waste treatment, and control systems have functioned as designed and planned from the standpoint of containment of radioactivity, and

2) the applicable environmental radiation and radioactivity standards and effluent control requirements have been met.

Brookhaven National Laboratory's (BNL) environmental monitoring program is designed and developed to accomplish these two primary objectives. While this annual report generally follows the recommendations given in DOE/EP-0023, "A Guide for Environmental Radiological Surveillance at U.S. DOE Installations" (2), considerable latitude has been exercised in tailoring the suggested scope and methodology to meet the BNL site-specific environmental monitoring needs. The Laboratory's environmental surveillance program also includes the sampling and analysis of nonradiological pollutants, such as heavy metals and organics. These latter aspects reflect the widespread local concern about environmental quality, particularly with regard to the preservation of the purity of the aquifer underlying Long Island (3).

1.2 Site Characteristics:

Brookhaven National Laboratory is a multidisciplinary scientific research center. It is situated close to the geographical center of Suffolk County on Long Island, about 97 km east of New York City. Its location with regard to surrounding communities is shown in Figure 1. About 1.29 million people live in Suffolk County (4) and about 0.37 million people in Brookhaven Township, within which the Laboratory is situated. The principal nearby population centers are located in shoreline communities. Table 1 gives the resident population distribution within 80 km of the BNL site. Though much of the land area within a 16 km radius is either forested or under cultivation, there has been some development of suburban housing in proximity to the Laboratory during the last decade.

The Laboratory site is shown in Figure 2. It consists of some 2130 hectares (ha), most of which is wooded, except for a developed area of about 655 ha. The site terrain is gently rolling, with elevations varying between 36.6 and 13.3 m above sea level. The land lies on the western rim of the shallow Peconic River watershed, with a principal tributary of the river rising in marshy areas in the northern and eastern sections of the site.

In terms of meteorology, the Laboratory can be characterized as a well-ventilated site. In common with most of the eastern seaboard, its prevailing ground level winds are from the southwest during the summer, from the northwest

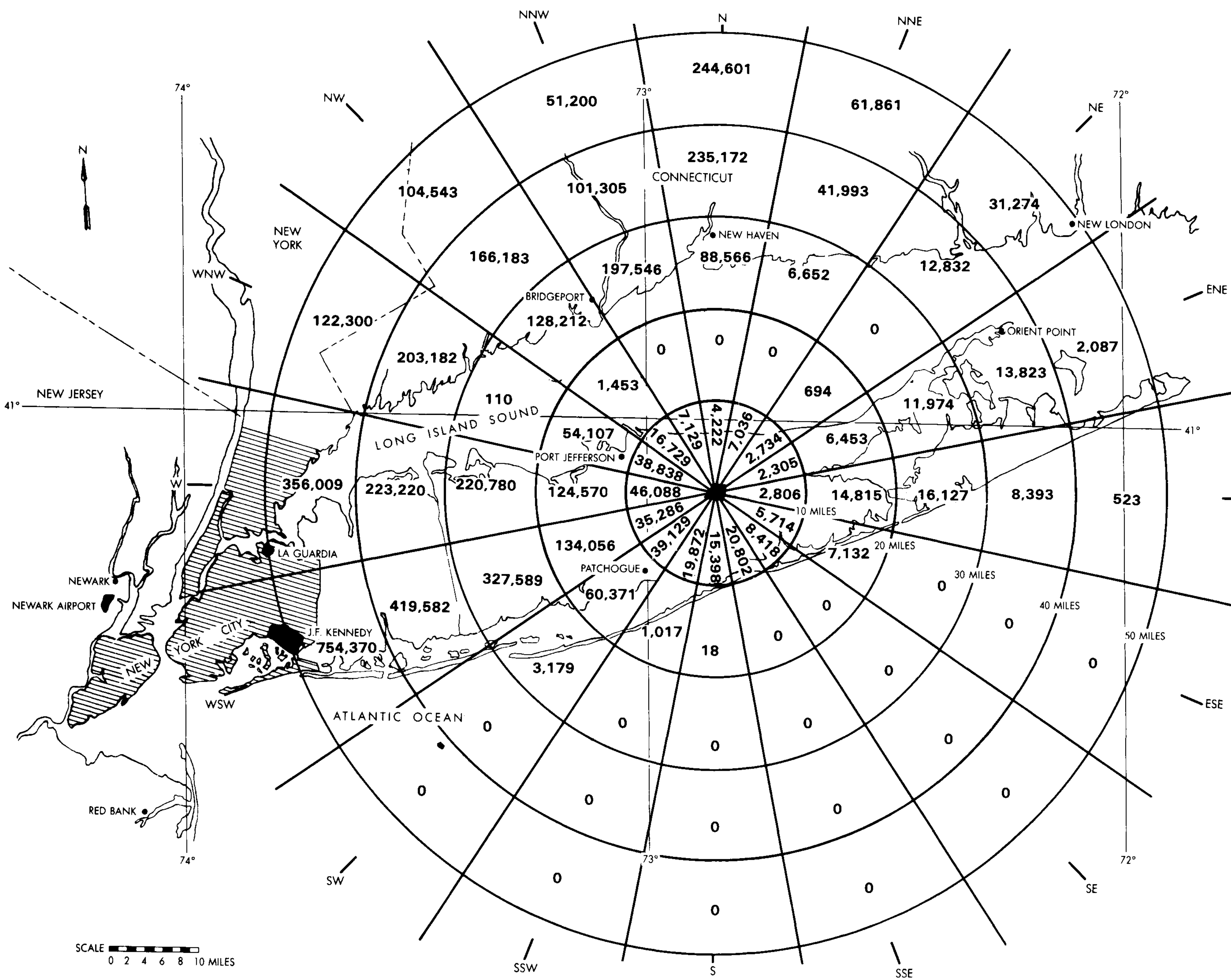


Figure 1. Resident population 1982 within a 50 mile radius of BNL.

TABLE 1

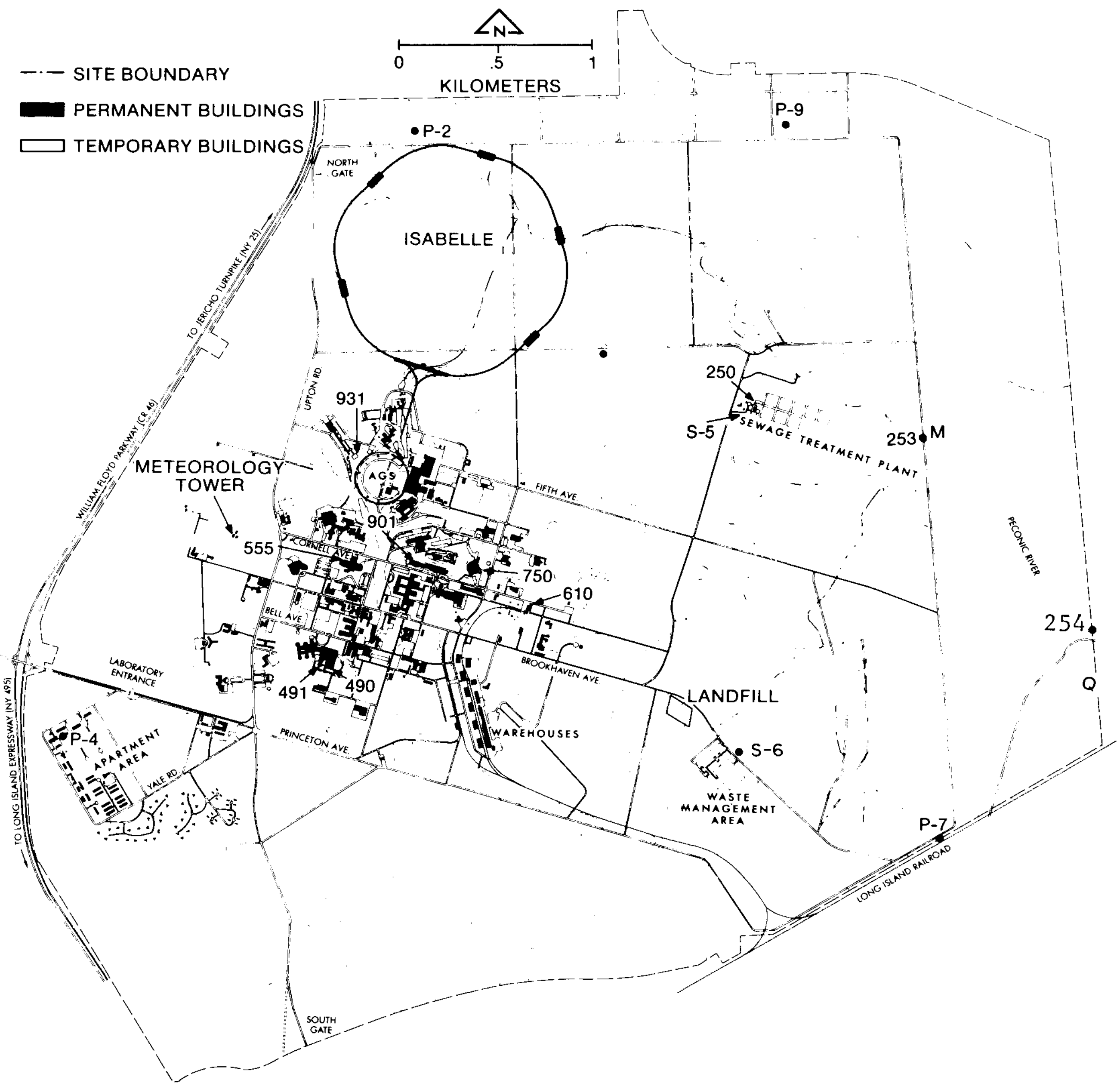
1982 BNL Environmental Monitoring

Resident Popluation (1982)[a] Distribution Within 80 Km Radius of BNL

Sector	0-16 Km (10 mi)	16-32 Km (20 mi)	32-48 Km (30 mi)	48-64 Km (40 mi)	64-80 Km (50 mi)	Total	Remarks
SSW	19,872	1,017	0	0	0	20,889	Beyond 32 Km - Atlantic Ocean
SW	39,129	60,371	3,179	0	0	102,679	Beyond 48 Km - Atlantic Ocean
WSW	35,286	134,056	327,589	419,582	754,370	1,670,883	Beyond 80 Km - Part of New York City
W	46,088	124,570	220,780	223,220	356,009	970,667	Beyond 80 Km - New York City
WNW	38,838	54,107	110	203,182	122,300	418,537	Beyond 32 Km and 48 Km - Long Island Sound; beyond 48 Km - Connecticut and New York
NW	16,729	1,453	128,212	116,183	104,543	367,120	Same as WNW
NNW	7,129	0	197,546	101,305	51,200	357,180	Between 16 Km and 32 Km - Long Island Sound; beyond 20 Km - Connecticut
N	4,222	0	88,566	235,172	244,601	572,561	Same as NNW
NNE	7,036	0	6,652	41,993	61,861	117,542	Same as NNW
NE	2,734	694	0	12,832	31,274	47,534	Between 32 Km and 48 Km - Long Island Sound; beyond 48 Km - Connecticut
ENE	2,305	6,453	11,974	13,823	2,087	36,642	North Fork of Long Island
E	2,806	14,815	16,127	8,393	523	42,664	South Fork of Long Island and Atlantic Ocean
ESE	5,714	7,132	0	0	0	12,846	Long Island and beyond 32 Km - Atlantic Ocean
SE	8,418	0	0	0	0	8,418	Beyond 18 Km - Atlantic Ocean
SSE	20,802	0	0	0	0	20,802	Same as SE
S	15,398	18	0	0	0	15,416	Beyond 32 Km - Atlantic Ocean
Total	272,506	404,686	1,000,735	1,375,685	1,728,768	4,782,380	

[a] Population data estimated from information supplied by the Long Island Regional Planning Board and Long Island Lighting Company. (4)

BROOKHAVEN NATIONAL LABORATORY SITE



ENVIRONMENTAL MONITORING STATIONS	
AIR	
P-2	NORTHWEST PERIMETER
P-4	SOUTHWEST PERIMETER
P-7	SOUTHEAST PERIMETER
P-9	NORTHEAST PERIMETER
S-5	SEWAGE TREATMENT AREA
S-6	WASTE MANAGEMENT AREA
S-13	SW CORNER, ECOLOGY FIELD
WATER	
250	SEWAGE TREATMENT PLANT
M	PECONIC RIVER, 0.5 MI. DOWNSTREAM FROM TREATMENT PLANT
Q	SITE BOUNDARY

DESIGNATION	EFFLUENT RELEASE POINT
250	SAND FILTER BEDS
253	PECONIC R. STREAM BED
254	SITE BOUNDARY
490	MRC STACK
491	MRR STACK
555	CHEMISTRY STACK
750	HFBR STACK
901	VAN DE GRAAFF STACK
931	BLIF STACK
445	WASTE MANAGEMENT AREA
610	STEAM PLANT

Figure 2. Location of emission points and monitoring stations.

during the winter, and about equally from these two directions during the spring and fall (5).

Studies of Long Island hydrology and geology (6-8) in the vicinity of the Laboratory indicate that the uppermost Pleistocene deposits, which are between 31-61 m thick, are generally sandy and highly permeable. Water penetrates them readily and there is little direct run-off into surface streams, except during periods of intense precipitation. The annual total for 1982 was 123 cm, equivalent to the average annual precipitation of 122 cm. About half of this precipitation is lost to the atmosphere through evapotranspiration and the other half percolates to recharge groundwater. The groundwater in the vicinity of the Laboratory moves predominantly in a horizontal direction to the Great South Bay (6). This is influenced toward a more easterly direction in the Peconic River watershed portions of the site. The estimated rate of movement at the groundwater surface is about 16.2 cm d^{-1} (6).

1.3 Existing Facilities:

A wide variety of scientific programs are conducted at Brookhaven, including research and development in the following areas:

1) the fundamental structure and properties of matter,

2) the interactions of radiation, particles and atoms with other atoms and molecules,

3) the physical, chemical and biological effects of radiation, and of other energy-related environmental pollutants,

4) the production of special radionuclides and their medical applications,

5) energy and nuclear related technology,

6) the assessment of energy sources, transmission and uses, including their environmental and health effects.

Among the major scientific facilities operated at the Laboratory to carry out the above programs are:

1) the High Flux Beam Reactor (HFBR) which is fueled with enriched uranium, moderated and cooled by heavy water, and which formally operated at a routine power level of 40 MW(th, th = thermal). Modifications to the primary water cooling system were made to allow the power level to be raised to 60 MW(th), and operation at this level commenced in September 1982,

2) the Medical Research Reactor (MRR), an integral part of the Medical Research Center (MRC), is fueled with enriched uranium, moderated and cooled by natural water, and is operated intermittently at power levels up to 3 MW(th),

3) the Alternating Gradient Synchrotron (AGS), a proton accelerator which operates at energies up to 33 GeV, is used for high energy research,

4) the 200 MeV Proton Linac, which serves as an injector for the AGS, also supplies a continuous beam of protons for radionuclide production by spallation reactions in the Brookhaven Linac Isotopes Production Facility (BLIF) and in the Chemistry Linac Irradiation Facility (CLIF),

5) the Tandem Van de Graaff, Vertical Accelerator and Chemistry Van de Graaff, which are used in medium energy physics investigations, as well as for special nuclide production,

6) the National Synchrotron Light Source which utilizes a linear accelerator and booster synchrotron as an injection system for two electron storage rings operating at energies of 700 MeV vacuum ultraviolet (VUV) and 2.5 GeV (x-ray) is used for VUV spectroscopy and for x-ray diffraction studies.

7) The Colliding Beam Accelerator (CBA), currently under construction, will utilize two opposed proton beams of 400 GeV to make available effective energies up to 800 GeV to facilitate advanced studies in high energy physics. It is anticipated that it will be operational sometime in the late 1980's.

Additional programs involving irradiations and/or the use of radionuclides for scientific investigations are carried on at other Laboratory facilities including those at the Medical Research Center, the Biology Department, the Chemistry Department, and the Department of Energy and Environment (DEE). At the Hot Laboratory, special purpose radionuclides are developed and processed for on- and off-site use under the joint auspices of the DEE and the Medical Department. This facility also contains a radioactive waste treatment center, which includes an evaporator for volume reduction of liquid wastes.

Most of the airborne radioactive effluents at Brookhaven originate from the HFBR, BLIF and the research Van de Graaff, with lesser contributions from the Chemistry and Medical Research Centers. The first two also produce significant fractions of the Laboratory's liquid radioactive wastes, with additional smaller contributions originating from the Medical Research Center, the Hot Laboratory complex, as well as from decontamination and laundry operations. Current environmental monitoring programs are being enhanced so as to permit the evaluation and impact of non-radiological pollutants being released to the environment.

2.0 SUMMARY

The environmental levels of radioactivity and other pollutants found in the vicinity of BNL during 1982 are summarized in this report. As an aid in the interpretation of the data, the amounts of radioactivity and other pollutants released in airborne and liquid effluents from Laboratory facilities to the environment are also indicated. The environmental data includes external radiation levels; radioactive air particulates; tritium concentrations; the amounts and concentrations of radioactivity in and the water quality of the stream into which liquid effluents are released; the concentrations of radioactivity in biota from the stream; the concentrations of radioactivity in and the water quality of ground waters underlying the Laboratory; and concentrations of radioactivity in milk samples obtained in the vicinity of the Laboratory.

External Radiation:

At the perimeter environmental monitoring stations P-2 and P-4, the annual dose-equivalent rates due to skyshine (scattered neutron radiation) were about 1.23 mrem a^{-1} and 3.51 mrem a^{-1}, respectively. These values are too small to be measured and therefore have not been included in the final dose-equivalent rate for BNL.

Air and Rainfall - Radioactivity:

Other than tritium, there was no indication of BNL radioactive effluents in environmental air and precipitation samples. The largest concentration of tritium in air at the site boundary, 3.5×10^2 pCi m^{-3} was 0.2% of the Radiation Concentration Guide (RCG). The largest average concentration of tritium in precipitation was at or below the Minimum Detection Limit (MDL) which was 200 pCi l^{-1} (2×10^{-7} µCi ml^{-1}). The MDL represents about 1% of the standard for drinking water.

Air - Nonradioactive:

At the central Steam Plant, the most recent measurement of the stack emission of air particulates indicated that the average rate was 0.078 lb/10^6 Btu. A calculation based on meterological parameters indicates that at the site boundary, their concentration was 0.24 µg m^{-3}, 0.3% of the yearly average ambient Air Quality Standard. At the site boundary, the calculated concentrations of SO_2 and NO_x, resulting from the steam plant operations, were 0.0006 ppm, and 0.0004 ppm, respectively, which were about 2 and 0.8% of their respective ambient air quality standards.

Liquid Effluent - Sewage Treatment Plant:

Of the sewage effluent released onto the sand filter beds of the Laboratory sewage treatment plant, 82% flowed directly into the Peconic River. The balance was assumed to have percolated into the ground water underlying the beds. The gross beta concentration of the output from them was 18.3 pCi l^{-1} (1.83×10^{-8} µCi ml^{-1}), or 0.6% of the Radiation Concentration Guide (RCG). The tritium concentration was 8.6 nCi l^{-1} (8.6×10^{-6} µCi ml^{-1}), or 0.3% of the RCG. The same concentration was assumed for the infiltration into groundwater.

Liquid Effluents - National Pollutant Discharge Elimination System Permit:

Except for 35 daily pH levels which were "out of limit" and two instances of suspended solids percent removal, all reportable non-radiological parameters of the Laboratory sewage effluent were within the limits set forth in the Laboratory's permit, issued by the Environmental Protection Agency (EPA) under the National Pollution Discharge Elimination System. The average water quality of the sewage treatment plant effluent at the point of discharge was at or within water quality standards for the receiving body of water.

Peconic River - On Site:

Downstream, a significant amount of the combined flow from the sand filter beds and from upstream of the Peconic River also percolated into the groundwater (Table 11). This occurred between the sewage treatment plant outfall and the Laboratory perimeter, mostly during the latter half of the year. At the former site boundary (Station M), the gross beta concentration was 13.5 pCi l^{-1} (1.35×10^{-8} μCi ml^{-1}), or 0.4% of the RCG, and the tritium concentration was 6.3 nCi l^{-1} (6.3×10^{-6} μCi ml^{-1}), or 0.2% of the RCG. At the site boundary, the gross beta concentration was 4.7 pCi l^{-1} (0.47×10^{-8} μCi ml^{-1}), or 0.2% of the RCG, and the tritium concentration was 4.4 nCi l^{-1} (4.4×10^{-6} μCi ml^{-1}), or 0.1% of the RCG.

Peconic River - Off-Site:

Bimonthly sampling of the Peconic River water downstream of the sewage treatment plant outfall has indicated a decrease of concentrations of radioactivity. At a location 4.8 km downstream, the average gross beta concentration as established by bimonthly grab sampling was 2.0 pCi l^{-1} (2.0×10^{-9} μCi ml^{-1}), or 0.1% of the RCG and the tritium concentration was 0.3 nCi l^{-1} (0.3×10^{-6} μCi ml^{-1}), or 0.01% of the RCG. About 24 km downstream, at the river's mouth, the average concentration of gross beta activity was 4.7 pCi l^{-1} (4.7×10^{-9} μCi ml^{-1}); that of tritium being 0.2 nCi l^{-1} (0.2×10^{-6} μCi ml^{-1}). Based on total flow and activity per unit volume, the total gross beta activity in the river at that location exceeded that at the Laboratory's site boundary. This difference is attributed to the fact that the total flow at the river's mouth is increased due to the tributary additions which, in turn, have added fallout radionuclides that were present in the drainage area of the tributaries.

Peconic River - Aquatic Biological Studies:

Seasonal collections of fish from the Peconic River were conducted at the site boundary. The data on fish obtained from the river at the site boundary suggested the presence of small amounts of radioactivity attributable to the Laboratory's past releases. The maximum concentration of ^{137}Cs in fish was about 823 pCi kg^{-1}. This concentration would result in a dose commitment that was about 1% of the RCG, based on an assumed ingestion of 50 g of fish per day.

Groundwater - Supply and Process Wells and Recharge Basins:

About 18 million liters of water per day obtained from on-site supply wells were used for "once through" cooling and returned to groundwater in on-site recharge basins. The concentration of gross beta activity at point of recharge was, on the average, 2.7 times greater than that of the supply wells, and was about 9% of the EPA Drinking Water Standard. The tritium concentrations were near or at the MDL, which is about 1% of the EPA Drinking Water Standard.

Groundwater - Surveillance Wells:

Groundwater surveillance was conducted in a network of some 100 sampling wells installed adjacent to and downstream from identified areas where there is a potential for the percolation and migration of radioactivity and other contaminants in groundwater. With the aquifer underlying Long Island being classified as a "sole source" it was necessary to apply EPA Drinking Water Standards to all activities concerning groundwater use or recharge.

a. On-Site Wells:

Immediately adjacent to the sand filter beds and to the Peconic River on-site and at the site boundary, gross beta, tritium and ^{90}Sr concentrations have been decreasing, when compared to those observed during previous years. This reflects the decrease in the concentrations due to decay and dilution. They were not more than a few percent of the EPA Drinking Water Standards. The largest average gross alpha concentration, 1.52 pCi l^{-1} (1.52×10^{-9} µCi ml^{-1}) was 10% of the EPA Drinking Water Standard for unidentified mixtures containing alpha activity other than ^{226}Ra. It was not directly relatable to any known Laboratory effluent releases. The largest average gross beta concentration was 19.7 pCi l^{-1} (19.7×10^{-9} µCi ml^{-1}); the largest average tritium concentration was 136 nCi l^{-1} (136×10^{-6} µCi ml^{-1}).

On-site, adjacent to the Solid Waste Management area, the landfill, the former open dump, and the decontamination facility storm sewer sump, above ambient background concentrations of gross beta activity, ^{90}Sr, and tritium were found in a number of nearby groundwater surveillance wells. Much of the gross beta activity appeared to be related to ^{90}Sr.

At the Waste Management area, the largest ^{90}Sr concentration, 32.2 pCi l^{-1} (32.2×10^{-9} µCi ml^{-1}), or 4 times the EPA Drinking Water Standard, was found in a well 175 m southeast of the area. This level reflects the effects of a known inadvertent injection into groundwater which occurrred in 1960.

At the landfill, an average gross alpha concentration of 3.3 pCi l^{-1} (3.3×10^{-9} µCi ml^{-1}), or 0.2 times the EPA Drinking Water Standard, an average gross beta concentration of 55.4 pCi l^{-1} (10^{-9} µCi ml^{-1}), or 1.1 times the compliance level based on the EPA Drinking Water Standard, and an average tritium concentration of 14.5 nCi l^{-1} (14.5×10^{-6} µCi ml^{-1}) or 0.7 times the EPA Drinking Water Standard, were the largest found. They were found in wells located 80 and 100 m south of the perimeter of the working area.

At the decontamination facility storm sewer sump, a ^{90}Sr concentration of 51 pCi l^{-1} (51×10^{-9} µCi ml^{-1}), 6 times the EPA Drinking Water Standard, was found in a surveillance well within a few meters of the sewer outfall into the sump.

Iron and zinc were found in excess of their respective standards (0.6 and 0.3 ppm for surface waters) in numerous sampling wells on-site. However, this appears to be related to corrosion from the well casings and not to Laboratory effluents, except for a few wells adjacent to the Landfill. There, the largest concentration of iron was 93 ppm and of zinc, 3.3 ppm.

In all cases, the on-site levels of radioactivity or of other agents which were found in above ambient background in ground water appeared to be confined to within a hundred meters of their origin. They would require decades of travel before reaching the site boundary. Concentrations of radioactivity, and water quality parameters, in ground water from perimeter surveillance wells (other than those adjacent to the Peconic River) were at or near background and only a few percent of the EPA Drinking Water Standards.

b. Off-Site Wells:

Concentrations of gross alpha and gross beta radioactivity were found to be slightly higher in a sampling well about 0.35 km east of the site boundary than in wells at the boundary itself. The gross alpha concentration, 1.32 pCi l^{-1} (1.32 x 10^{-9} μCi ml^{-1}), was 9% of the EPA Drinking Water Standard. However, this was not directly relatable to any known Laboratory effluent. The gross beta concentration, 3.9 pCi l^{-1} (3.9 x 10^{-9} μCi ml^{-1}), was 7.8% of the EPA Drinking Water Standard. ^{90}Sr levels were comparable to those in the wells at the site boundary.

Except for pH levels slightly lower than the Water Quality Standard, but within the local natural variation, most other indices of water quality in these surveillance wells were within the standards.

Total Population Dose Resulting from Laboratory Sources

The collective average dose-equivalent rate (total population dose) attributable to Laboratory sources, for the population up to a distance of 80 km, was calculated to be 2.72 rem a^{-1} (person-rem a^{-1}) as compared to a natural background dose-equivalent rate to the same population of about 315,125 rem a^{-1} (person-rem a^{-1}).

3.0 MONITORING DATA COLLECTION, ANALYSIS AND EVALUATION

3.1 External Radiation Monitoring:

Dose-equivalent rates at the site boundary, including natural background (as influenced by fallout) and the increments attributable to Laboratory activity, were determined through the use of CaF_2:Dy thermoluminescent dosimeters (TLD) (9) exposed for monthly periods at each of the four perimeter monitoring stations P-2, P-4, P-7, and P-9, the locations of which are shown in Figure 2.

The observed dose-equivalent rates from external gamma radiation, as measured by TLDs, are given in Table 2. There was no measurable addition to the natural background attributable to Laboratory activities. The dose-equivalent rate from naturally occurring external background radiation at the site perime

TABLE 2

1982 BNL Environmental Monitoring

Site-Perimeter External Dose-Equivalent Rates from Background and BNL Operations

	Location[a]				
Period	Northwest Perimeter (P-2)	Southwest Perimeter (P-4)	Southeast Perimeter (P-7)	Northeast Perimeter (P-9)	Average Background[b]
	mrem				
Minimum (Monthly)	4.9	5.2	5.0	5.2	5.1
Maximum (Monthly)	6.4	6.3	6.2	6.9	6.3
Average (Monthly)	5.5	5.6	5.4	5.8	5.5
Total (Annual)	65.9	67.2	64.7	69.6[c]	65.9

(a) Locations of monitoring stations indicated in Figure 2.

(b) Average of P-2, P-4, and P-7. These monitoring stations are assumed to be unaffected by BNL on-site radiations or effluents.
Station P-9 was excluded from the average because the station lies on a bed of coal cinders. These cinders contain radium and thorium at concentrations larger than the foundation material used at other perimeter stations thus resulting in a background which is slightly different than the other perimeter stations.

(c) Based on average for 11 months. Readings for August were lost due to vandalism.

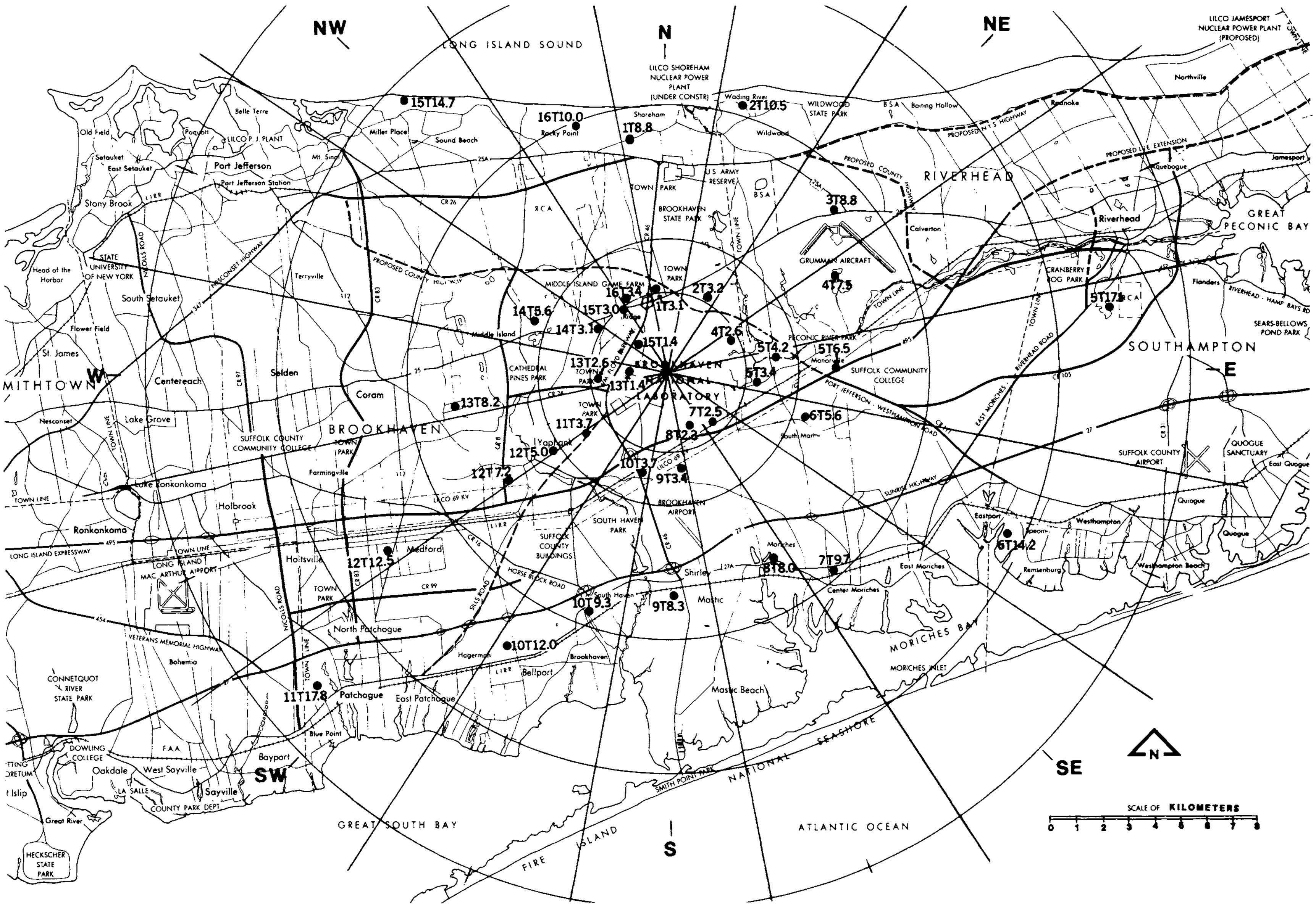


Figure 3. Location of off-site thermoluminescent dosimeters Brookhaven National Laboratory.

TABLE 3

1982 BNL Environmental Monitoring
Off-Site External Dose-Equivalent Rates

New TLD[(1)] #	Old TLD #	Compass Heading (degrees)	Distance from HFBR Stack (km)[(2)]	Annual[(3)] Total mrem
1T3.1	1A	350	3.1	68.1
1T8.8	16B	350	8.8	57.1
2T3.2	2A	31	3.2	56.8
2T10.5	2B	14	10.5	63.5
3T8.8	3A	46	8.8	59.3
4T2.6	4A	62	2.6	57.3
4T7.5	4B	59	7.5	58.8
5T17.1	4C	81	17.1	57.7
5T6.5	5B	88	6.5	56.7
5T4.2	4A	79	4.2	52.5
6T5.6	6A	107	5.6	53.2
6T14.2	6B	115	14.2	50.6
7T9.7	7A	140	9.7	57.7
7T2.5	7A	139	2.5	70.7
8T2.3	8A	155	2.3	57.7
8T8.0	8A	151	8.0	72.1
9T3.4	9A	173	3.4	56.6
9T8.3	9B	178	8.3	58.8
10T3.7	10A	196	3.7	71.8
10T9.3	10A	199	9.3	49.0
10T12.0	10B	211	12.0	63.6
11T3.7	11A	233	3.7	59.3
11T17.8	11A	229	17.8	50.6
12T5.0	12A	238	5.0	56.2
12T7.2	12B	241	7.2	61.4
12T12.5	12B	238	12.5	61.8
13T1.4	13A	273	1.4	67.0
13T2.6	13	263	2.6	58.8
13T8.2	13B	262	8.2	56.0
14T3.1	14	302	3.1	79.6
14T5.6	14A	290	5.6	72.8
15T3.0	16A	325	3.0	57.2
15T1.4	15A	306	1.4	67.3
15T14.7	15B	316	14.7	64.0
16T3.4	16A	331	3.4	72.9
16T10.0	16B	339	10.0	62.9
Gun Barrel Shield - Building (535A)[(4)]				17.0

(1) See Figure 3 for TLD location.

(2) See Figure 2 for Stack (#750) location.

(3) Estimate based upon time weighted averages. The standard deviation of the measurement is approximately ± 10%.

(4) Represents background value for TLD and is based on four measurements.

TABLE 4

1982 BNL Environmental Monitoring
Gaseous Effluent Release Locations and Data on Effluent Pollutant (Radionuclides, Particulate, SO_2 and NO_x) Concentrations

Building[a]	Facility and Release Point	Release Height[b] (m)	Principal Pollutant	On-Line Monitoring	Fixed Sampling Devices	Amount Released During 1982
490	Medical Research Center Roof Stack	13.7	Tritium	None	Dessicant for tritium vapor	1.5×10^{0} Ci (vapor)
491	Medical Research Reactor - Stack	45.7	Argon-41	Moving tape for radio-particulates	Charcoal for radioiodines	3.3×10^{2} Ci[c]
555	Chemistry - Roof Stack	16.8	Tritium	None	Dessicant for tritium vapor	1.8×10^{0} Ci
750	High Flux Beam Reactor } Stack	97.5	Tritium	None	Dessicant for tritium vapor	3.3×10^{2} Ci
801	Hot Laboratory } Stack		Xenon-127	None		4.0×10^{0} Ci
			Gross Beta particulate	Beta scintillator for radioactive gases	Particulate filter for gross beta; charcoal cartridge for radioiodines	2.0×10^{-3} Ci
901	Van de Graaff Accelerator	18.3	Tritium (gas + vapor)	Kanne Chamber for tritium (gas + vapor)	Dessicant for tritium vapor	1.5×10^{1} Ci (gas)[f] 1.3×10^{1} Ci (vapor)[f]
931	Linac Isotope Facility	18.3	Tritium vapor	G-M Detector for radiogases	Dessicant for tritium vapor	1.4×10^{-1} Ci
			Oxygen-15			3.3×10^{4} Ci[d]
610	Central Steam Plant - Stack	19.8	Particulates	None	None	2.1×10^{4} Kg[e]
			SO_2	None	None	2.2×10^{5} Kg[e]
			NO_x	None	None	1.0×10^{5} Kg[e]

(a) Locations given in Figure 2.

(b) Above ground level.

(c) Calculated from reported operating time and "one-time" measured emmision rate at 3 MW power level.

(d) Calculated from reported operating and estimated production rate at 180 μamp full beam current.

(e) Estimated - based on amount of fuel consumed (See Table 6).

(f) Calculated on basis of total hours of tritium acceleration, rate of tritium input to the ion source, and scrubber efficiency.

ter averaged 65.9 mrem a^{-1}. Fluctuations noted over the years (10) are within local variations of natural background levels and are regulated to a significant extent by climatic variations (11).

During 1982, 37 TLDs were placed at off-site locations for monitoring around the facility. Figure 3 shows the locations of the TLDs with respect to the Laboratory (HFBR Stack, #750 as the center; Figure 2). The standard 16 sectors with sector #1 centering on true North has been used to locate the TLDs (12). The dose-equivalent rates observed are given in Table 3 and are comparable with the average background given in Table 2. Variations observed could be attributed to climatic changes (28).

3.2 Airborne Effluents and Ground-Level Air Particulates, Tritium and Radioiodine Monitoring:

3.2.1 Facilities and Effluents:

The principal Laboratory facilities from which radioactive or nonradioactive effluents are released to the atmosphere are listed in Table 4. Their locations on the Laboratory site are shown in Figure 2. The installed on-line effluent monitors, sampling devices, and the types and amounts of effluents released during 1982 are indicated in Table 4.

Considerable dilution with ambient air occurs between the release points to the atmosphere and the site boundary. Additionally, radioactive decay decreases the concentrations of shorter lived radionuclides during the transit time between the point of release and the site boundary. Consequently, the concentrations of airborne radioactivity at the site boundary were reduced to levels where no detectable increase in dose-equivalent rate was apparent during 1982.

Oxygen-15, Argon-41 and Xenon-127 are radioactive gases with relatively short half-lives. Oxygen-15, which has a two minute half-life, is produced by the interaction of protons and water in the BLIF facility and generated at an estimated rate per unit beam current of 0.21 Ci $\mu A^{-1}\ h^{-1}$. When this facility is operated at the full beam current of 180 μA, the ^{15}O equilibrium activity at the point of generation is 1.8 Ci. Argon-41, which has a 110-minute half-life, is produced by the interaction of neutrons and ventilating air in the shield of the Medical Research Reactor and released from its stack at an estimated per unit power level rate of 1 Ci $MW(th)^{-1}h^{-1}$ when the reactor is operated at full power of 3 MW(th). Xenon-127, which has a 36.4-day half-life, is produced at the BLIF facility and is processed at the Hot Laboratory for commercial uses. It is occasionally released from the transfer system at the latter facility. The radioactive gases released, except for ^{127}Xe, are a function of operational time and facility power level (10).

Tritium (^3H) has a 12.3-year half-life, and is a very low energy beta emitter ($T_{\beta(max)}$ = 18.6 KeV). It is of principal environmental significance when in the form of tritiated water vapor (HTO), which is taken up and utilized by living systems as is ordinary water. Of the 361 Ci of tritium released from the Laboratory research facilities during 1982 (Table 4), 15 Ci (4%) were in gas

TABLE 5

1982 BNL Environmental Monitoring
Estimated Radionuclide Content of Incinerated Materials[a]

Radionuclide	Half-Life	Quantity[b] (mCi)
^{3}H	12.2y	280.0
^{65}Zn	243.0d	0.7
^{14}C	5730y	29.0
^{32}P	14.3d	0.8
^{35}S	87.9d	4.4
^{59}Fe	45.6d	0.1
^{125}I	60.2d	1.3
^{117m}Sn	14.0d	0.1
^{51}Cr	27.8d	1.1

y = year

d = day

[a] Incinerated in the Waste Management Incinerator.

[b] Activity less than 100 μCi have not been reported.

eous form, and 346 Ci (96%) were released as HTO. Tritium releases remained at low levels during 1982 as the Laboratory continued to employ as low as reasonably achievable practices.

The Laboratory incinerates certain categories of waste in the Waste Management Incinerator. The individual radionuclides, their half-lives and total quantities in the incinerated waste material are shown in Table 5. ^3H formed the largest in quantity - 0.28 Ci. Other radionuclides ranged from 0.1 mCi to 30 mCi. Limits on the amount incinerated and meterological dispersion are utilized to assure that airborne concentrations at the site boundary were small fractions of the Radiation Concentration Guides (RCG).

Most of the heating requirements for the principal buildings at the Laboratory are supplied by a central steam plant (Figure 2). The estimated amounts of conventional pollutants released from its stack are shown in Table 6. Those for sulfur dioxide (SO_2) and nitrogen oxides (NO_x) were estimated from reported emission factors for comparable plants [13], adjusted for the actual sulfur content of the fuel utilized at the plant. The amount of particulates produced was based on the average concentration determined from stack sampling of the steam boiler units in a series of tests conducted during 1977. At that time the average particulate emission rate was 0.078 lb $MBTU^{-1}$. This was below the emission limit of 0.1 lb $MBTU^{-1}$ for particulates as set forth by the New York State Department of Environmental Conservation (Part 227, Stationary Combustion Installations).

The emissions of SO_2, NO_x and particulates have decreased markedly since 1976 when the Laboratory initiated the utilization of light feed stock (LFS), such as mineral spirits, alcohol, jet fuel and reconstituted fuels. In 1982, the fraction of LFS relative to total fuel consumption, was 40%. These light stock fuels typically have a weighted average sulfur content of 0.5% or less as compared to the typical 1% sulfur content of #6 oil and therefore contribute to the reduction of pollutants discharged to the atmosphere through the stack. In 1982, the mean fuel combustion efficiency over the entire range of boiler loading capacities was determined to be 99.8% for No. 5 Boiler firing ALF [29]. Under actual operating conditions the combustion efficiency is significantly higher than this value as the upper limits of the boiler loading capacity are rarely reached. Samples of LFS used in the preparation of Alternate Liquid Fuels (ALF) are analyzed for cadmium, lead and chlorinated hydrocarbons to ensure that the burning of ALF does not constitute a potential environmental problem [10,14]. In addition, the practice of heat recovery from waste materials serves to promote the beneficial reuse of otherwise discarded natural resources.

3.2.2 Sampling and Analysis:

The Brookhaven environmental air monitoring program is designed to identify and quantify airborne radioactivity attributable to natural sources, to activities remote from the Laboratory (e.g., above ground nuclear weapon tests) and to Laboratory activities. Most of the air concentrations of radioactivity detected during 1982 is attributable to natural sources, to a decreasing extent weapons tests, and to Laboratory activities, virtually none.

TABLE 6

1982 BNL Environmental Monitoring

Estimated Concentrations of SO_2, NO_x and Particulates at the Central Steam Plant Stack (Bldg. #610) and at the Site Boundary

Effluent	Total kg	Calculated Stack Concentration	Average Site Boundary Concentration[a]	EPA Primary Air Quality Standard {15}
SO_2	2.2×10^5 [b]	180 ppm	0.0006 ppm	0.03 ppm
NO_x	9.7×10^5	100 ppm	0.0004 ppm	0.05 ppm
Particulates	2.1×10^4 [c]	$0.06\ g\ m^{-3}$	$0.24\ \mu g\ m^{-3}$	$75\ \mu g\ m^{-3}$

[a] Based on average X/Q of 2.4×10^{-7} sec m^{-3} calculated by BNL Meteorolgy Group (1982).

[b] Based on average 1.0% sulfur content.

[c] Based on measured average value during February 1977 stack sampling conducted on main steam boiler unit (New York Testing Laboratories, Inc., Westbury, N.Y., 11590).

3.2.3 Air Samples:

During 1982, positive displacement air pumps were operated at a flow rate of 15 ℓ min^{-1} at the monitoring station adjacent to the solid waste management area (S-6), and at the site boundary stations P-2, P-4, P-7 and P-9 (see Figure 2 for locations). The air sampling media consisted of a 5 cm diameter air particulate filter (Gelman type) followed by a 12.5 cm^3 bed of triethylene diamine (TEDA) impregnated charcoal for collection of radiohalogens. To assure collection of all radioiodine species at a suitable flow rate, a parallel low volume filter system sampler was operated at a flow rate of 56 ℓ min^{-1}. It consisted of a 7.6 cm diameter air particulate filter (Gelman type G), followed by a 250 cm^3 TEDA impregnated charcoal filter.

The air particulate samples were counted for gross beta activity using an anti-coincidence proportional counter. The data are shown in Table 7. A seasonal trend was observed for gross beta activity in 1982. The gross beta activity was at a maximum at all monitoring stations during the first quarter. This is attributed to the spring exchange between stratosphere and troposphere, which results in an increase in particulate concentrations at this time.

In addition to counting for gross beta activity, analyses for gamma emitting nuclides were performed on a composite of all air particulate samples shortly after the end of each month. These data are also reported in Table 7. No ^{131}I was detected during 1982, which is consistent with the absence of any reported atmospheric nuclear tests during the year, and with operations at the Laboratory.

Sampling for tritium vapor was performed at each of the air sampling stations by drawing a small side stream of air (∿100 cm^3 min^{-1}) through silica gel cartridges. The cartridges were normally changed on a bimonthly basis. The collected vapor was subsequently removed from the gel by heating; then condensed, collected, and assayed by liquid scintillation counting. Tritium vapor concentrations data obtained from the samples at each of the BNL perimeter stations during 1982 is shown in Table 8.

The highest quarterly average concentrations were observed during the first quarter at the southeast station (P-7) and during the third quarter of the year at the northeast station (P-9). The highest annual average concentration, 1.11×10^2 pCi/m^3, was observed at station P-7. This value was 0.06% of the Radiation Concentration Guide (RCG). The yearly average concentrations at stations P-2 and P-4 were at or near the MDL. The annual average concentration for the site boundary was 4.04×10^1 pCi/m^3, 0.02% of the RCG.

The current Laboratory environmental monitoring program does not include routine air sampling for nonradioactive substances. The calculated annual average concentrations at the site boundary of the conventional pollutants released from the central steam plant are listed in Table 6. All were less than 3% of the EPA Primary Air Quality Standard for the reported constituents (14).

About 255 kg of various pesticides, chiefly organo-phosphates, Thiodan, Diazinon, Carbaryl and Parathion, were applied on site during 1982, principally

TABLE 7

1982 BNL Environmental Monitoring
Gross Beta Concentrations in Air Particulate Filters
and Gamma Emitting Nuclides in Charcoal Filters

(pCi/m^3)

Period	Location[a]	Number of Samples	Gross Beta Average	Gross Beta Maximum	Gross Beta Minimum	^{137}Cs[b]
January to March	N.E. Perimeter (P-9)	13	0.09	0.21	0.03	0.003
	S.E. Perimeter (P-7)	11	0.05	0.10	0.01	0.003
	S.W. Perimeter (P-4)	12	0.04	0.07	0.003	0.003
	N.W. Perimeter (P-2)	12	0.05	0.18	0.02	0.003
April to June	N.E. Perimeter	13	0.03	0.06	0.01	0.003
	S.E. Perimeter	12	0.03	0.05	0.01	0.002
	S.W. Perimeter	13	0.02	0.05	0.01	0.003
	N.W. Perimeter	14	0.03	0.05	0.01	0.003
July to September	N.E. Perimeter	7	0.02	0.02	0.01	0.003
	S.E. Perimeter	13	0.02	0.02	0.01	0.003
	S.W. Perimeter	13	0.02	0.20	0.003	0.004
	N.W. Perimeter	13	0.01	0.02	0.002	0.002
October to December	N.E. Perimeter[c]	13	0.01	0.02	0.004	0.003
	S.E. Perimeter	13	0.02	0.03	0.01	0.003
	S.W. Perimeter	13	0.02	0.03	0.01	0.003
	N.W. Perimeter	13	0.01	0.02	0.01	0.003
Annual Summary	N.E. Perimeter[d]	46	0.04	0.21	0.004	0.003
	S.E. Perimeter	49	0.03	0.10	0.01	0.003
	S.W. Perimeter	51	0.03	0.20	0.003	0.003
	N.W. Perimeter	52	0.03	0.18	0.002	0.003

[a] Locations are shown in Figure 2.

[b] Sample - Composite of charcoal filters from all stations.

[c] One month's data less than MDL; not included in the average.

[d] Based on an eleven month sample period.

Applicable Standards - Table 20

TABLE 8

1982 BNL Environmental Monitoring

Tritium Vapor Concentration in Air (pCi/m^3)

Quarterly Period	P-9 Northeast Perimeter[c] N-ENE (348.75-78.75°)	P-7 Southeast Perimeter E-SSE (78.75-168.75°)	P-4 Southwest Perimeter S-WSW (168.75-258.75°)	P-2 Northwest Perimeter[a] W-NNW (258.75-348.75°)	Minimum Detection Limit[b]
First	2.5×10^{0}	3.5×10^{2}	$<5.4 \times 10^{-1}$	$<3.1 \times 10^{-1}$	
Second	2.7×10^{0}	5.2×10^{1}	$<1.9 \times 10^{0}$	$<8.1 \times 10^{-1}$	
Third	1.5×10^{2}[a]	4.0×10^{1}	$<2.4 \times 10^{0}$	4.7×10^{0}	$0.9\text{-}3.5 \times 10^{0}$
Fourth	4.7×10^{1}	4.9×10^{0}	$<2.2 \times 10^{0}$	$<1.4 \times 10^{0}$	
Average	4.8×10^{1}	1.1×10^{2}	$<1.8 \times 10^{0}$	$<1.8 \times 10^{0}$	
Radiation Concentration Guide (16)	------------------------ 2×10^{5} ----------------------------------				

[a] Station P-9 vandalized during this quarter.

[b] The variable range for the MDL results from the tritium determination procedure and is a function of counting efficiency, counting time, sample volume, and relative humidity.

[c] See Figure 2 for location of stations.

TABLE 9

1982 BNL Environmental Monitoring
Quarterly Average Gross Beta Concentration
Total Gross Beta, Tritium and Radionuclide Activity in Precipitation

Quarterly Period	Rainfall (cm)	Average Gross β Concentration (10^{-9} μCi/mℓ)	Gβ	^{90}Sr	^{3}H	^{7}Be	^{137}Cs	^{131}I
			(10^{-3} μCi/m^2)					
First	34.2	10.84	3.71	0.008	68.4	13.0	0.04	b
Second	50.8	5.45	2.77	0.012	101.4	21.0	0.09	b
Third	17.0	3.03	0.51	0.010	34.04	5.6	0.01	b
Fourth	21.1	3.80	0.80	b	42.02	7.0	0.04	2.11
Total	123.1	-	7.79	0.03	245.9[a]	46.6	0.19	2.11
Average[c]	30.8	6.33	2.38	0.008	72.75	14.0	0.06	0.36
Radiation Concentration Guide {16}	-	$3x10^3$	$8x10^2$	$8x10^1$	$8x10^5$	$5x10^5$	$5x10^3$	

[a] Site wide deposition of 5.22 Ci of ^{3}H.

[b] Below the Minimum Detection Limit (MDL) of the System used in analyzing the same (See Table 18).

[c] Average concentrations are weighted averages.

to protect crops which were grown for biological research purposes. All of these pesticides are considered biodegradable, with persistence times in the order of a week. Furthermore, they were applied with a "sticker" additive to minimize their becoming airborne.

3.2.4 Precipitation:

Two pot-type rain collectors, each with a surface area of 0.33 m^2, are situated adjacent to the sewage treatment plant (see Fig. 2). A routine collection was made from these whenever precipitation was observed during a previous 24 hour (or weekend) period. Part of each collection was evaporated for gross beta counting, a small fraction was composited for monthly tritium analysis, and the balance was put through ion exchange columns for subsequent quarterly ^{90}Sr and gamma analyses. The data for 1982 are reported in Table 9. Besides tritium (as vapor) there was no detectable indication of Laboratory released airborne radioactivity in precipitation collected on site. Variation in the deposition of ^{7}Be is dependent upon the interaction of cosmic rays with atmospheric nucleii along with trophospheric/stratospheric mixing and would not necessarily parallel that of the fallout of radioactive debris from the atmospheric testing of nuclear weapons.

To obtain an indication of the washout of tritium from local airborne releases, small precipitation collectors are located at the perimeter stations (P-2, P-4, P-7, P-9), and at Blue Point, some 20 km southwest of the Laboratory site. The average tritium concentrations were all reduced significantly when compared to previous years (10) and were at or below the MDL (Table 18). At the MDL, the average concentration (on site) would have been less than 1% of the EPA Drinking Water Standard (16).

3.3 Liquid Effluent Monitoring:

The basic principle of liquid waste management at the Laboratory is confinement and concentration to minimize the volumes of liquids requiring decontamination prior to on-site release or processing into solid form for off-site burial. Accordingly, liquid wastes are segregated at the point of origin on the basis of their anticipated concentrations of radioactivity or other potentially harmful agents.

Small volumes (up to a few liters) of concentrated liquid wastes containing radioactivity or other hazardous agents are withheld from the Laboratory waste systems. They are stored at their sources of generation in small containers, collected by the Laboratory waste management group, and subsequently packaged for off-site disposal (in the case of hazardous agents as defined by DOE Order 5480.2).

Facilities which may routinely produce larger volumes (up to several hundred liters) of radioactive or otherwise contaminated waste liquids are provided with dual waste handling systems, one for "active" (D-probably contaminated) and one for "inactive" (F-probably uncontaminated) wastes. As shown in Figure 4, wastes placed into the "active" or D system are collected in holdup tanks. After sampling and analysis, they are either transferred by installed pipelines

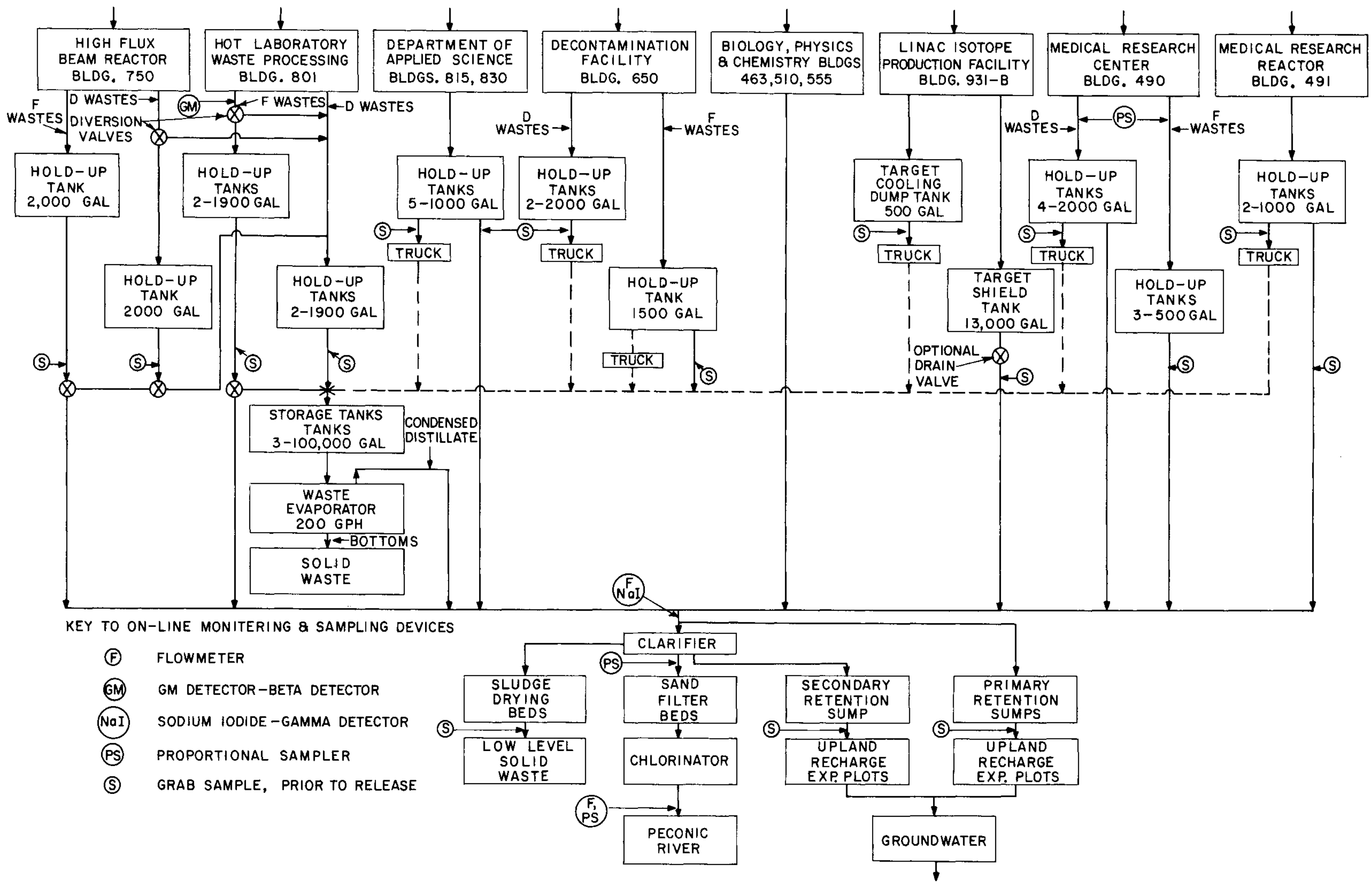


Figure 4. Liquid effluent systems Brookhaven National Laboratory.

or by tank truck to storage tanks adjacent to the Laboratory liquid waste evaporator. At this facility, liquids are concentrated about a hundred fold and ultimately disposed of as solid wastes. If found to be of sufficiently low concentration (17), D wastes may be routed directly from holdup tanks to the Laboratory sanitary waste system.

Subject to the results of analysis, "inactive" wastes are routed directly to the Laboratory sanitary waste system, where they are mixed with large quantities (approaching 4,000,000 $l\ d^{-1}$) of cooling and other uncontaminated water routinely produced by diverse Laboratory operations. Sampling and analysis of the waste in facility holdup tanks is done to facilitate waste management; while effluent sampling is performed at the sewage treatment plant to establish the concentration and amounts of environmental releases.

The small amounts of low level radioactive waste effluents that may be routinely disposed of by release into the Laboratory sanitary waste system are established by administrative limits (17). Within these limits, individual releases are kept as low as practicable.

3.3.1 National Pollutant Discharge Elimination System (NPDES) Permit:

As of January 31, 1975, the effluent from the Laboratory sewage treatment plant was subject to the conditions of the National Pollutant Discharge Elimination System (NPDES) Permit No. NY 000 5835. Quarterly reports have been prepared in accordance with this permit, using data obtained by the sewage treatment plant operators. A yearly summary of these data is shown in Table 10, which includes permit conditions. The Laboratory effluent was within all of these conditions, with the exception of some daily pH levels and two instances of suspended solids percent removal.

The effluent pH levels were below the lower limit of 5.8 on 35 occasions. They were not related to the influent pH, which averaged 6.7. However, the effluent pH variations were within the local natural range of groundwater (pH 5.5-6.0). A Laboratory study has indicated that the low pH of rainfall (pH 2.5-4.9) on Long Island is a significant factor in lowering the pH of the Laboratory effluent as it passes through the sand filter beds.

3.3.2 Peconic River:

Primary treatment of the liquid stream collected by the sanitary waste system to remove suspended solids is provided by a 950,000 liter clarifier. The liquid effluent from it flows onto sand filter beds, from which about 75-80% of the water has typically been recovered by an underlying tile field. This recovered water is chlorinated and then released into a small stream that forms one of the headwaters of the Peconic River.

A schematic of the sewage treatment plant and its related sampling arrangements is shown in Figure 5. In addition to the influent flow measurement and sampling instrumentation, totalizing flowmeters (Leopold and Stevens TP 61-2), with provision for taking a sample for each 7576 liters of flow are installed in combination with positive action battery operated samplers

TABLE 10

1982 BNL Environmental Monitoring
National Pollutant Discharge Elimination System
Data Summary

Parameter	Status	Quantity Minimum	Quantity Mean	Quantity Maximum	Quantity Units	Quantity Number[a] of Exceptions	Concentration Minimum	Concentration Mean	Concentration Maximum	Concentration Units	Concentration Number[a] of Exceptions	Frequency of Analysis	Sample Type
Flow	Sample measurement	0.3	0.7	1.3	MGD	0	-	-	-	-	-	Continuous	NA
	Permit requirement	-	2.3	-			-	-	-				
pH Influent	Sample measurement	5.1	7.0	7.8	SU	-	-	-	-	-	-	Daily	GRAB
	Permit requirement	-	-	-			-	-	-				
pH Effluent	Sample measurement	4.6	6.1	6.8	SU	35	-	-	-	-	-	Daily	GRAB
	Permit requirement	5.8	-	9.0			-	-	-			Daily	GRAB
BOD_5 Influent	Sample measurement	58.6	82.8	138.6	kg/day	-	16.1	26.0	47.9	mg/ℓ	-	Weekly	8 hr.
	Permit requirement	-	-	-			-	-	-			Monthly	8 hr.
BOD_5 Effluent	Sample measurement	4.3	7.3	18.9	kg/day	0	0.6	1.7	3.2	mg/ℓ	0	Weekly	8 hr.
	Permit requirement	-	262.0	391.0			-	30.0	45.0			Monthly	8 hr.
Percent removal BOD_5	Sample measurement	-	-	-	-	-	86.0	91.3	96.0	%	0	Weekly	-
	Permit requirement	-	-	-			85.0	-	-			Monthly	-
Suspended solids, Influent	Sample measurement	44.9	90.0	193.4	kg/day	-	3.0	28.2	69.0	mg/ℓ	-	Weekly	8 hr.
	Permit requirement	-	-	-			-	-	-			Monthly	8 hr.
Suspended solids, Effluent	Sample measurement	0.0	9.0	25.3	kg/day	0	0.0	3.4	10.0	mg/ℓ	0	Weekly	8 hr.
	Permit requirement	-	262.0	391.0			-	30.0	45.0			Monthly	8 hr.
Percent removal Suspended solids	Sample measurement	-	-	-	-	-	63.0	89.3	100.0	%	2	Weekly	
	Permit requirement	-	-	-			85.0	-	-			Monthly	
Settleable solids, Influent	Sample measurement	-	-	-	-	-	0.1	0.7	2.0	mℓ/ℓ	-	Daily	GRAB
	Permit requirement	-	-	-			-	-	-			Daily	GRAB
Settleable solids, Effluent	Sample measurement	-	-	-	-	-	0.0	0.0	0.0	mℓ/ℓ	-	Daily	GRAB
	Permit requirement	-	-	-			-	-	-			Daily	GRAB
Residual chlorine, Effluent	Sample measurement	-	-	-	-	-	0.5	0.7	1.5	mg/ℓ	-	Daily	GRAB
	Permit requirement	-	-	-	-		-	-	-			Daily	GRAB
Temperature, Effluent	Sample measurement	2.0	16.1	26.0	°C	-	-	-	-	-	-	Daily	GRAB
	Permit requirement	-	-	-				-	-	-			
Fecal coliform, Effluent	Sample measurement	-	-	-	-	-	0	0	1	n/100mℓ	0	Weekly	GRAB
	Permit requirement	-	-	-			-	200	400			Monthly	GRAB

[a] Total for the year

(Brailsford DU-1), at the chlorine house, at the former site boundary which is 0.8 km downstream on the Peconic River, and at the site boundary, 2.6 km downstream.

An aliquot of each daily (or weekend) sample of the input to the sand filter beds and of their output to the chlorine house outfall was evaporated for the analysis of gross alpha and gross beta activity. Another aliquot was counted directly for tritium. Samples from the two downstream locations were obtained three times a week. Aliquots of each were analyzed for gross beta, gross alpha, and tritium. Another aliquot, proportional to the measured flow during the sampling period, was passed through ion exchange columns for subsequent analysis as an integrated sample. Unless the gross beta count at a given location indicated the need for immediate radionuclide identification, one set of these columns was analyzed directly on a monthly or quarterly basis for gamma emitting nuclides and the other was eluted for radiochemical processing for ^{90}Sr analysis. The monthly minimum, maximum and average flow, the gross beta activity and that of the principal individual nuclides at the clarifier (input to the filter beds), the chlorine house (output from the beds), the former perimeter and the site perimeter are shown in Table 11. Yearly totals and average concentrations are also indicated. During 1982, about 82% of the total flow into the clarifier appeared in the output at the chlorine house after passing through the sand filter beds. The balance was assumed to have percolated to the ground water flow under the beds. Estimates of the amount of radioactivity released to the groundwater in this manner during 1982 are shown in Table 11. These were calculated on the additional assumption that the average concentrations of the contained nuclides corresponded to those in the output from the beds, as observed at the chlorine house.

An analysis of the radionuclide concentrations at the chlorine house over the past several years has indicated a time lag between input and output from the sand filter beds. This lag appears to be greater for ^{134}Cs and ^{137}Cs than for ^{90}Sr, which explains why larger amounts of the latter were found in the effluent relative to those in the influent. During 1982, other radionuclides such as ^{58}Co, ^{95}Zr-Nb, ^{125}Sb, ^{140}Ba-La and ^{144}Ce, which have been detected in previous years, were all at or below MDL (Table 18) and as such were not reported in Table 11.

Flow and activity concentration data for the former site boundary sampling location, 0.8 km downstream (see Fig. 5), and at the present site boundary are also shown in Table 11. The site perimeter was characterized by a very low flow, which was essentially zero during most of the year except during summer and early fall. Due to the sporadic nature of the flow over the measuring weir, the flows at the site perimeter were measurable only during the months of July to September. Based on the decrease in total flow between the former site boundary and the perimeter, upper limit estimates of the activity that may have percolated to the underlying aquifier are also shown in Table 11.

Analysis of monthly composite samples of the Peconic River at the former site boundary (0.8 km downstream from the chlorine house) during this period showed that, on the average, <5% of the annual total activity (excluding tritium) consisted of ^{90}Sr and that no appreciable amounts of long-lived

TABLE 11

1982 NBL Environmental Monitoring
Total Activities and Concentrations of Identifiable Nuclides[(a)] in Liquid Effluents from the Sewage Treatment Plant and in the Peconic River

	Flow $\times 10^{10}$ mℓ	Gross α	Gross β	^{90}Sr	^{3}H	^{54}Mn	^{60}Co	^{134}Cs	^{137}Cs	^{40}K	^{65}Zn
Clarifier (mCi)											
Monthly (Minimum)	7.78	0.11	0.73	0.01	364	0.002	0.01	0.01	0.01	0.11	0.01
Monthly (Maximum)	13.69	0.67	3.91	0.23	1558	0.03	0.26	0.05	0.16	0.26	0.04
Average (Monthly	10.02	0.28	1.81	0.09	690	0.01	0.09	0.01	0.05	0.15	0.01
Total (Annual)	120.27	3.38	21.69	1.06	8284	0.12	1.06	0.08	0.60	1.80	0.12
Mean Concentration (10^{-9} μCi/mℓ)	-	2.81	18.03	0.88	6880	0.10	0.88	0.07	0.50	1.50	0.10
Groundwater (Sand-Filter Beds) (mCi)											
Total (Annual)	21.50[(d)]	0.53	3.92	0.18	1838	0.02	0.15	0.15	0.68	0.81	0.04
Average Concentration (10^{-9} μCi/mℓ)	-	2.48	18.25	0.85	8550	0.07	0.68	0.71	3.17	3.78	0.18
Chlorine House (mCi)											
Monthly (Minimum)	6.15	0.10	0.58	0.03	327	b	b	0.01	0.05	0.09	b
Monthly (Maximum)	11.02	0.62	4.56	0.17	2037	0.07	0.29	0.58	1.91	2.12	0.16
Average (Monthly)	8.23	0.21	1.50	0.07	704	0.01	0.06	0.06	0.26	0.31	0.01
Total (Annual)	98.77	2.45	18.02	0.84	8445	0.07	0.67	0.70	3.13	3.73	0.18
Average Concentration (10^{-9} μCi/mℓ)	-	2.48	18.25	0.85	8550	0.07	0.68	0.71	3.17	3.78	0.18
Former Perimeter (mCi)											
Quarterly (Minimum)	1.47	0.02	0.26	0.02	23	b	0.01	b	0.01	0.04	b
(d) Quarterly (Maximum)	10.86	0.19	2.58	0.14	667	0.004	0.14	0.11	1.06	1.49	b
(d) Average (Monthly)	5.78	0.10	0.78	0.06	365	<0.0003	0.03	0.01	0.10	0.17	-
Total (Annual)	69.32	1.16	9.33	0.73	4381	0.004	0.32	0.14	0.19	1.98	-
Average Concentration (10^{-9} μCi/mℓ)	-	1.67	13.45	1.05	6320	0.005	0.46	0.20	1.72	2.87	b
Groundwater (Stream Bed) (mCi)											
Total (Annual)	67.59[(d)]	1.13	9.09	0.71	4272	0.003	0.31	0.14	1.16	1.94	-
Average Concentration (10^{-9} μCi/mℓ)	-	1.67	13.45	1.05	6320	0.005	0.46	0.20	1.72	2.87	b
Site Perimeter (mCi)											
Quarterly (Minimum)[(e)]	0.21	0.002	0.01	-	8.3		Flow inadequate to collect representative sample for γ analysis.				
Quarterly (Maximum)[(e)]	0.83	0.01	0.04	-	36						
Average (Monthly)[(e)]	0.14[(e)]	0.002	0.01	0.001	7						
Total (Annual)	1.73	0.02	0.08	0.02	80						
Average Concentration (10^{-9} μCi/mℓ)	-	1.30	4.73	0.99	4360						
Radiation Concentration Guide (15) (10^{-9} μCi/mℓ)	-	15[(f)]	3×10^{3}[(c)] 50[(f)]	3×10^{2} 8[(f)]	3×10^{6} 20,000[(f)]	1×10^{5}	5×10^{4}	9×10^{3}	2×10^{4}	3×10^{5}	1×10^{5}

(a) Other nuclides such a ^{7}Be, ^{22}Na, ^{47}Sc, ^{83}Rb, ^{84}Rb, ^{141}Ce, ^{57}Co, and ^{51}Cr were detected in the influent and effluent from the laboratory, but are not reported in the above table.

(b) Below the MDL of the system used in estimating the activity.

(c) For mixtures of radionuclides containing <10% ^{90}Sr, $^{125-131}I$, or long lived alpha emitters. The concentration guides for unknown RCG's, and the sum of the fractions of the RCG's for all such radionuclides is less than 0.25.

(d) Estimated loss to groundwater; this loss is considered conservative as no corrections have been made for spreading and evaporation.

(e) This station is characterized by low flow rates. Quantities reported result from periods of measurable flow rates.

(f) EPA drinking water standards apply to groundwater on Long Island.

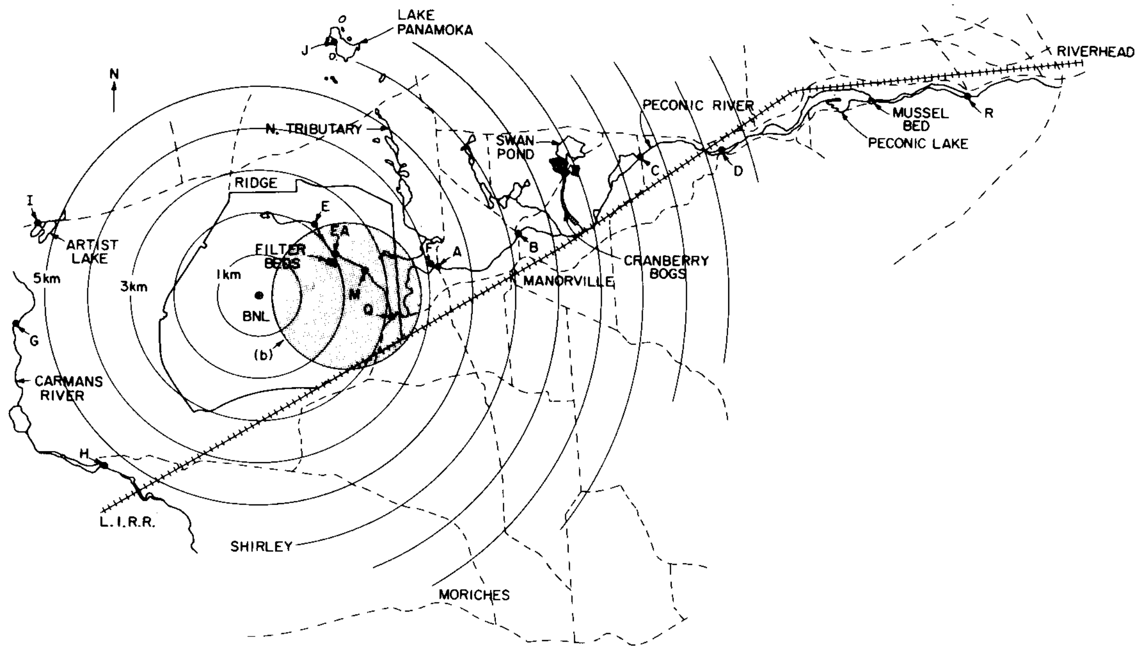


Figure 5. (a) Peconic River: On-site and downstream sampling locations.

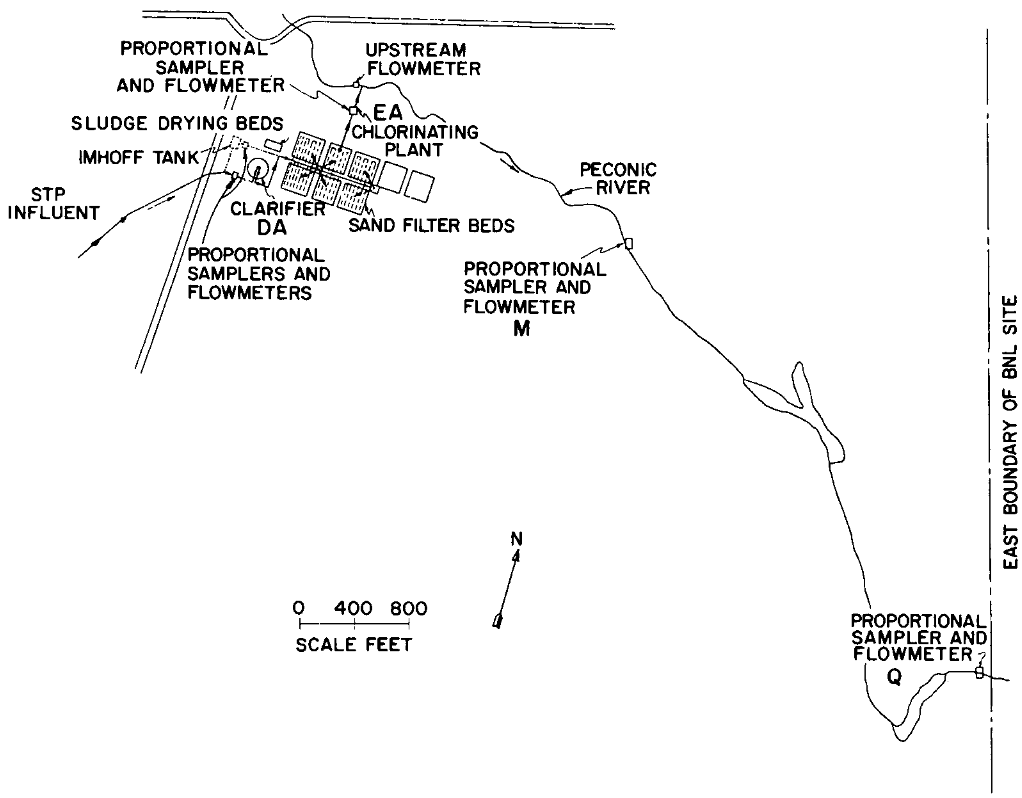


Figure 5. (b) Sewage treatment plant: Sampling locations.

radioactive iodine or bone-seeking nuclides such as radium were present. Under these circumstances, the applicable RCG was 300 pCi 1^{-1} (0.3×10^{-6} μCi ml^{-1}).

At the Laboratory perimeter (2.6 km downstream from the chlorine house), where flows were estimated, the average concentration of ^{90}Sr was 0.99 pCi ℓ^{-1}. Since the Peconic is not a direct source of drinking water, the applicable RCG was 300 pCi 1^{-1} (0.3×10^{-6} μCi ml^{-1}) (15).

The Safety and Environmental Protection Division also performed routine water quality measurements on samples of the filter beds effluent, of the Peconic River upstream of the effluent discharge point, of the river at the former Laboratory perimeter (0.8 km downstream), of the river at the present Laboratory perimeter (2.6 km downstream), and at downstream sampling stations A (4.85 km) and R (19.35 km). A summary of these data for 1982 is shown in Table 12. From the table it is seen that the portion of the Peconic River within the Laboratory site showed compliance with the New York State Department of Environmental Conservation Water Quality Standards (18). After mixing with the upstream flow, the temperature increment was within the standard (20) at the Laboratory perimeter. With the exception of that for Fe at Station A, yearly average concentrations of metals for which analyses were made were all at or within the standard for the receiving body of water (14,19).

Monthly "grab" water samples were obtained at on- and off-site locations along the Peconic River. A battery operated fixed flow sampler was operated at Riverhead (at the mouth of the Peconic River) between March and December. Reference "grab" samples were obtained from other nearby streams and bodies of water outside the Laboratory drainage area. As shown in Figure 5, the sampling locations were as follows:

Off-Site (Peconic River, proceeding downstream)

A - Peconic River at Schultz Road, 4.85 km downstream,

R - Peconic River at Riverhead, 19.35 km downstream,

Controls (Not in the Laboratory drainage area)

E - Peconic River, upstream from the Laboratory effluent outfall,

F - Peconic River, north tributary (independent of the Laboratory drainage area),

H - Carmans River, outfall of Yaphank Lake,

Yearly average gross beta, tritium and ^{90}Sr concentrations at downstream (A and R) and control locations (E,F) are reported in Table 12.

Measurements of selected water quality and purity parameters were performed at downstream locations on the Peconic River and at control locations in order to provide a comparison with the same parameters in the Laboratory effluent. These limited "grab" sample data are also shown in Table 12. Other con-

TABLE 12

1982 BNL Environmental Monitoring
Sewage Treatment Plant, Peconic River and Offsite Location
Average Radionclide, Metals and Water Quality Data

Location[a]	Gross α	Gross β	^{90}Sr	^{3}H	Dissolved Oxygen	Chlorides	Nitrate-Nitrogen	Total Phosphoros	Dissolved Solids	Conductivity (μmhos/cm)	Temperature °C	pH	Coliform - Fecal #/100 mℓ	Coliform - Total #/100 mℓ	Ag	Cd	Cr	Cu	Fe	Hg	Pb	Zn
Peconic River	10^{-9} μCi/ml				ppm										ppm							
Sewage Treatment Plant Influent (DA)	2.81	18.03	0.88	6880			b				21	7.0	1	1	0.005	0.0017	0.005	0.078	0.576	b	0.024	0.113
Sewage Treatment Plant Effluent (EA)	2.48	18.25	0.85	8550	8.5	31.6	3.61	0.83	116	165	15	6.4	1	1	0.002	0.001	0.003	0.157	0.256	0.004	0.017	0.246
Former Perimeter (M)	1.67	13.45	1.05	6320	8.8	28.0	3.48	0.69	112	158	14	5.7	0	0	0.002	0.0013	0.003	0.154	0.525	0.0001	0.010	0.094
Site Perimeter (Q)	1.30	4.73	0.99	4630	5.4	26.5	1.97	0.58	102	138	14	6.0	1	1	0.002	0.0006	0.003	0.075	0.232	b	0.004	0.289
4.85 km Downstream (A)	0.24	1.99	b	260	7.5	7.4	0.52	0.02	61	51	13	6.6	0	b	0.002	0.0006	0.003	0.003	0.662	b	0.004	0.015
19.35 km Downstream (R)	0.53	4.65	0.49	200	9.8	12.7	0.53	0.04	78	90	16	6.5	12	b	0.002	0.0006	0.003	0.003	0.509	b	0.004	0.004
Control																						
Upstream of Laboratory Outfall (E)	2.35	8.49	b	1220	5.5	8.6	0.26	0.01	65	69	10	5.6	12	2	0.001	0.0006	0.003	0.003	0.850	b	0.004	0.029
North Tributary into Peconic River (F)	0.34	2.36	b	180	6.0	8.6	0.66	0.01	62	43	13	6.2	0	b	0.002	0.0006	0.003	0.006	0.451	b	0.006	0.013
Carmen's River (H)	0.24	1.44	b	180	10.6	10.5	1.33	0.01	78	117	15	6.8	b	b	0.002	0.0006	0.003	0.003	0.165	b	0.004	0.004
Radiation Concentration Guide {16}	$6x10^{2}$	$3x10^{3}$	$3x10^{2}$	$3x10^{6}$																		
New York State Water Quality Standard {19,20}					-	500	20	-	1000	-	-	-	-	4	0.1	0.2	0.1	0.2	0.6	0.5	0.1	0.3

[a] Locations are shown in Figure 5.

[b] Not done

trol locations (E, F and H as indicated in Figure 5) were also monitored for the same parameters. The results (Table 12) indicate that, in general, the levels are comparable to that seen in the Peconic River downstream of the site perimeter.

3.3.3 Recharge Basin:

After use in "once through" heat exchangers and process cooling, on the average 17.6 million l d^{-1} (MLD) of water was returned to the aquifer through on-site recharge basins; 5.23 MLD to basin N located about 610 m northeast of the AGS; 5.32 MLD to basin O about 670 m east of the HFBR; and 4.0 MLD to basin P located 305 m south of the MRR (see Figs. 6 and 7). A polyelectrolyte and dispersant is added to the AGS cooling and process water supply, to maintain a phosphate concentration of about 2 ppm in order to maintain the ambient iron in solution. Of the total AGS pumpage, on the average, 1.83 MLD was discharged to the N basin, and 3.67 MLD to the O basin. The HFBR secondary cooling system water recirculates through mechanical cooling towers and is treated with inorganic polyphosphate and mercaptobenzothiozone to control corrosion and deposition of solids. Blowdown from this system, 1.65 MLD, which contained about 6-8 ppm inorganic polyphosphate and 3-4 ppm mercaptobenzothiozone, was also discharged to the O basin. The untreated MRR-MRC "once through" coolant, which amounted to 4.0 MLD, was discharged to the P basin.

Concentrations of radioactivity and other constituents in the water discharged into these basins are monitored on a weekly basis by grab sampling. The average concentrations of gross beta and tritium activity, water quality parameters, and concentrations of heavy metals are given in Table 13. The average concentrations of gross beta activity in the basins were slightly above background. The N basin receives water that has been used to cool the LINAC beam stops at the AGS, which process results in the formation of short lived activation products that are released to it. The average concentration of gross beta activity discharged to the N basin was about 28% of the EPA Drinking Water Compliance Standard (16). In general, the average concentrations of gross beta and tritium activity in the other basins were slightly above those in the Laboratory supply wells and on the average, were about 9% of the applicable EPA Drinking Water Standards (16,24).

All water quality results were within established standards for ground water quality. Elevated metal concentrations, such as for Cu, Fe, and Zn, indicate effects of chemical treatment in the cooling water systems.

3.3.4 Aquatic Biological Surveillance:

Samples of fish were collected at Station Q (site boundary) and were analyzed for gamma emitters and ^{90}Sr. The analyses were limited to ^{90}Sr and ^{137}Cs, since these radionuclides were the only ones found in detectable concentrations above the MDL. The activity level of ^{137}Cs ranged from 644-823 pCi/kg(wet) and for ^{90}Sr from 3.2-6.9 pCi/kg(wet) in edible portions of the fish.

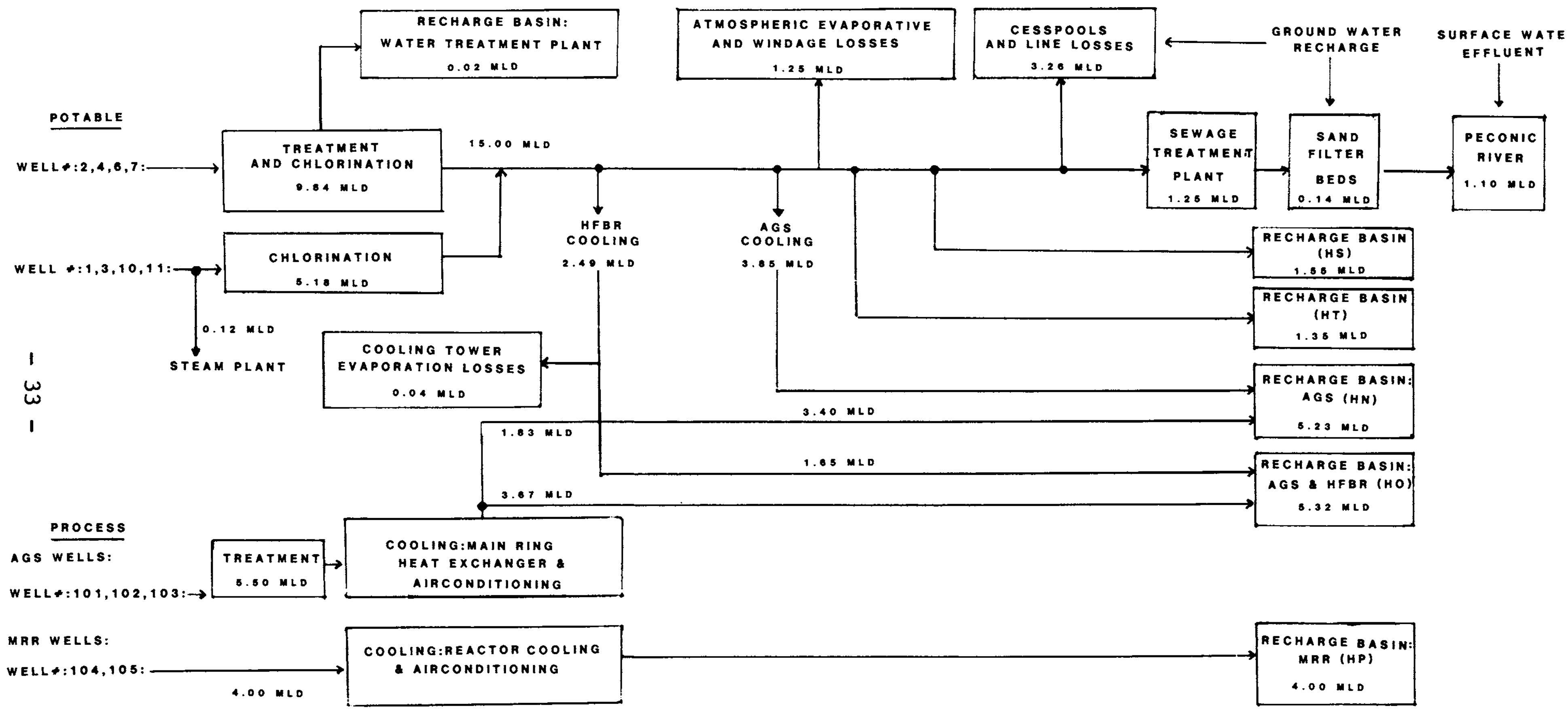


Figure 6. Brookhaven National Laboratory: Schematic of water use and flow.

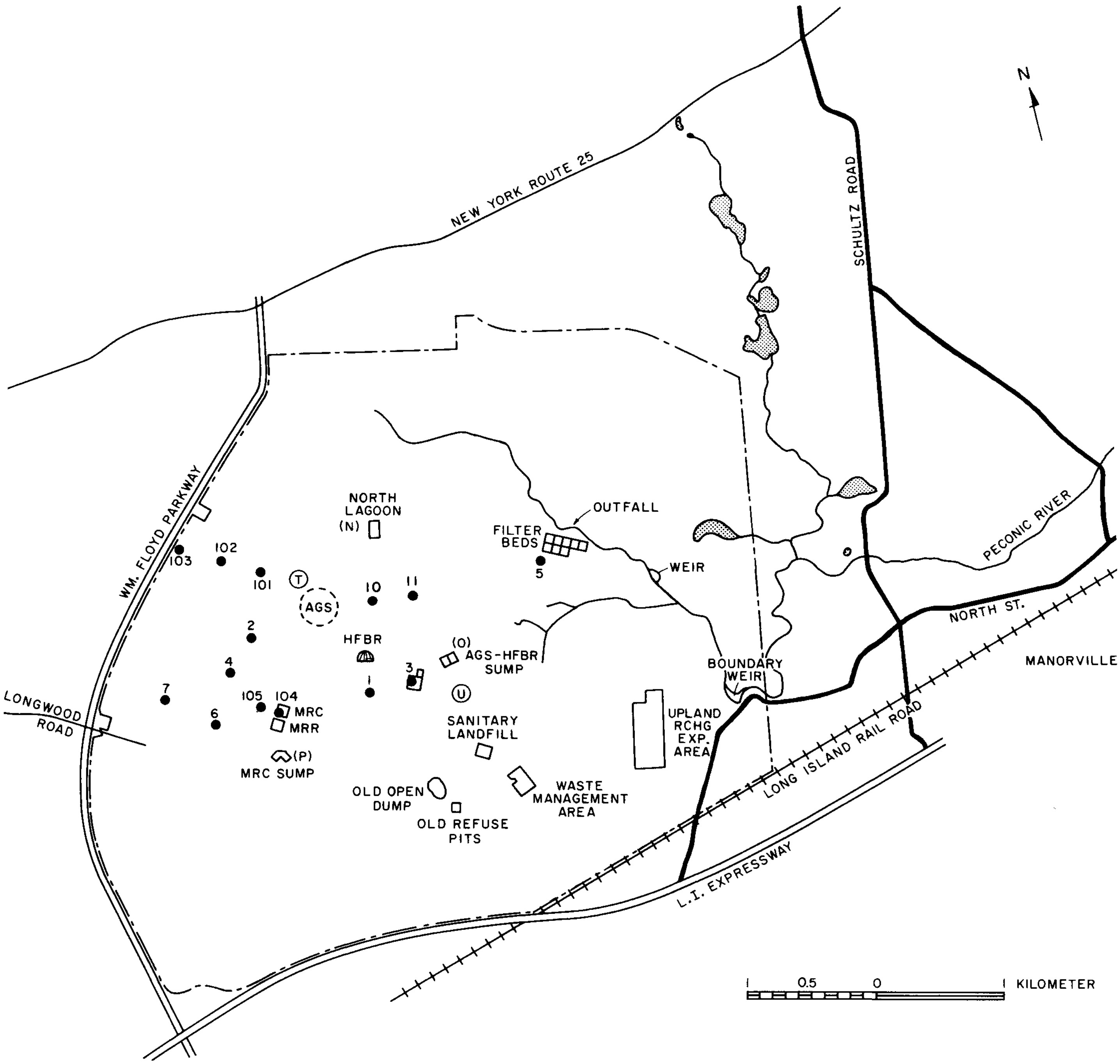


Figure 7. On-Site: Potable and supply wells and recharge sumps.

TABLE 13

1982 BNL Environmental Monitoring

Recharge Basins: Average Radionclide, Metals and Water Quality Data

Location (a)	# of Samples		Gross α	Gross β	Tritium (^3H)	Dissolved Oxygen	Chlorides	Nitrate-Nitrogen	Total Phosphoros	Dissolved Solids	Conductivity (µmhos/cm)	Temperature °C	pH	Coliform - Fecal (#/100mℓ)	Coliform - Total (#/100mℓ)	Ag	Cd	Cr	Cu	Fe	Pb	Zn
			10^{-9} µCi/ml			ppm										ppm						
N (North of AGS)	8	Minimum	0.18	0.80	170	8.3	13.0	0.04	0.01	70	85	13	5.9	0								
		Maximum	2.45	33.13	260	12.2	18.0	0.90	0.18	134	100	20	7.2	0								
		Mean	0.78	14.08	190	10.0	15.4	0.50	0.10	87	93	17	6.5	0	-	0.002	0.0006	0.003	0.042	1.112	0.004	0.019
O (East of HFBR)	8	Minimum	0.08	0.88	170	8.3	12.5	0.08	0.01	74	9	12	5.9	0	2							
		Maximum	0.43	9.11	890	11.8	20.9	0.79	0.45	137	154	19	6.8	0	10							
		Mean	0.31	3.69	280	10.1	16.6	0.55	0.17	101	98	16	6.2	0	6	0.002	0.0006	0.003	0.009	0.601	0.004	0.029
P (South of MRR)	7	Minimum	0.22	1.16	170	5.4	12.5	0.86	0.01	73	100	13	5.7	0	0							
		Maximum	0.95	4.68	380	8.5	29.0	1.76	0.32	163	168	21	6.1	0	0							
		Mean	0.44	2.46	230	6.8	21.5	1.44	0.05	118	143	15	5.9	0	0	0.002	0.0006	0.003	0.006	0.264	0.004	0.003
T (North of Linac)	8	Minimum	0.18	0.81	170	8.1	12.5	0.22	0.01	68	100	15	6.1	0	0							
		Maximum	0.38	2.42	260	12.7	21.4	0.82	0.24	122	118	21	7.9	0	0							
		Mean	0.29	1.36	190	10.1	17.5	0.53	0.07	92	109	17	6.8	0	0	0.002	0.0006	0.003	0.037	0.113	0.004	0.014
U (East of Steam Plant)	1	Minimum	0.70	10.37	170	9.3	32.1	0.77	0.02	99	120	7	6.8	0								
		Maximum	0.70	10.37	170	9.3	32.1	0.77	0.02	99	120	7	6.8	0								
		Mean (c)	0.70	10.37	170	9.3	32.1	0.77	0.02	99	120	7	6.8	0	-	0.002	0.0007	0.003	0.027	1.500	0.004	0.974
S (South of Warehouse)	0	Minimum				7.1	13.0	0.05	0.01	81	82		5.5	0	0							
		Maximum				16.2	77.5	2.48	0.95	140	305	23	7.6	0	0							
		Mean	b			9.9	24.8	1.01	0.18	108	145	14	6.5	0	0	b						
EPA Drinking Water Standard {17}			15	50	20	-	-	10	-	-	-	-	-			0.05	0.01	0.05	-	-	0.05	-

(a) Locations of Recharge Basins are shown in Figure 7.

(b) Not done.

(c) Flow to Recharge Basin "U" has been reduced since 1980 (BNL 5147-1981), sample collected only when flow is observed.

For New York State Standards, See Table 18.

TABLE 14

1982 BNL Environmental Monitoring

Potable and Cooling Water Wells - Average Radionclide, Metals and Water Quality Data

Well # (a)		Number of Samples	Gross α	Gross β	^{3}H	Ag	Cd	Cr	Cu	Fe	Pb	Zn	Dissolved Oxygen	Chlorides	Nitrate-Nitrogen	Total Phosphoros	Dissolved Solids	Conductivity (µmhos/cm)	Temperature °C	pH	Coliform Fecal (#/100ml)	Coliform Total (#/100ml)
			10^{-9} µCi/ml			ppm																
1	FA	4	0.51	5.04	240	0.002	0.0006	0.003	0.140	0.067	0.010	0.023	7.7	11.2	1.02	0.21	90	100	12	6.1	0	0
2	FB	4	0.42	2.13	220	0.002	0.0006	0.003	0.045	0.762	0.007	0.009	5.8	20.9	1.68	0.03	105	140	13	6.3	0	0
3	FC	4	0.35	6.97	730	0.002	0.0006	0.003	0.095	0.250	0.004	0.009	7.2	16.2	0.64	0.06	90	94	15	5.9	0	0
4	FD	4	0.58	1.48	190	0.002	0.0006	0.003	0.010	1.588	0.004	0.005	7.3	14.5	0.39	0.01	63	84	12	5.9	0	0
5	FE	1	0.25	0.72	230	0.002	0.0006	0.003	0.018	0.214	0.004	0.064	8.7	4.5	0.24	0.01	48	50	12	5.9	0	0
6	FF	4	0.79	1.53	190	0.002	0.0006	0.003	0.011	2.745	0.004	0.004	7.1	25.0	0.99	0.01	99	140	12	5.9	0	0
7	FG	4	0.32	1.41	190	0.002	0.0006	0.003	0.008	2.180	0.004	0.006	7.0	15.9	0.26	0.25	74	78	11	5.7	0	0
10	FO	3	b	b	b	0.002	0.0006	0.003	0.010	0.344	0.017	0.018	6.7	14.5	0.35	0.02	72	96	12	6.1	0	0
11	FP	3	b	b	b	0.002	0.0006	0.003	0.005	0.852	0.004	0.004	6.3	11.4	1.02	0.01	80	101	11	5.4	0	0
102	FI	3	0.35	2.51	220	0.002	0.0006	0.003	0.015	3.430	0.004	0.012	6.4	12.1	0.44	0.46	93	78	11	5.9	0	0
103	FJ	1	0.25	1.78	180	0.002	0.0006	0.003	0.006	3.470	0.004	0.004	4.6	24.5	0.64	0.74	70	98	11	5.8	b	
104	FK	1	0.23	1.20	180	0.002	0.0006	0.003	0.003	0.680	0.004	0.020	5.8	23.5	1.42	0.79	114	140	13	6.3	b	
105	FL	3	0.39	2.55	240	0.002	0.0006	0.003	0.036	1.293	0.004	0.015	5.9	24.7	1.62	0.03	117	143	14	5.8	0	b
(FN) Tap Water[c]										b				17.8	0.62	0.01			b			
EPA Drinking Water Standard {17}			15	50[d]	20,000	0.050	0.010	0.050	-	-	0.050	-										
New York State Drinking Water Standard {25}			-	-	-	0.050	0.010	0.050	1.0	0.3	0.025	5.0	>4	250	10.0	-	500	-	<30	6.5-8.5		

(a) Locations of Potable and Cooling Water Wells given in Figure 7.

(b) Not done.

(c) Tap Water from Building 535.

(d) Compliance Level.

For New York State Standards, See Table 18.

Using an assumed intake of 1.36 kg/yr (23) of fish flesh (edible portions) by adults and the indicated range of concentrations of ^{90}Sr and ^{137}Cs in fish flesh (edible portions), the committed effective dose-equivalent for these radionuclides to an adult man was estimated to be ranging from 0.01% to 0.02%, for ^{90}Sr and ^{139}Cs respectively, of the permissible dose limits to the general public under the DOE Standard (15).

3.3.5 Surveillance Wells:

3.3.5.1 Potable Water and Process Supply Wells:

The Laboratory's potable water wells and cooling water supply wells are screened at a depth of about 30 m, about 15 m below the water table, in the Long Island surface layer of glacial outwash, sand and gravel. As shown in Figure 7, most of these wells are located west to northwest of the Laboratory's principal facilities which is 'upstream' of the local groundwater flow pattern. About 25 MLD was pumped from them in 1982.

Quarterly grab samples were obtained from these wells. These were analyzed for radioactivity and water quality. The results are shown in Table 14. All gross alpha concentrations were <1 pCi/liter. All tritium concentrations were <1.0 nCi/liter ($<10^{-6}$ μCi/ml). There are some fluctuations in the gross beta concentrations among these wells but the variations are not considered significant. Concurrently, potable water is routinely tested for water quality as part of the Suffolk County Water Authority Compliance Assurance Program.

3.3.5.2 Groundwater Surveillance:

Samples of groundwater were obtained from a network of shallow surveillance wells which have been installed in the vicinity of several locations where a potential has existed for the percolation of radioactivity from the surface downward into the saturated zone of groundwater. These include areas adjacent to the on-site recharge basins, the sand filter beds, the Peconic River, the solid waste management area, the former open dump, the sanitary landfill and the decontamination facility sump. The locations of most of these groundwater surveillance wells are shown in Figure 8, except for those installed at the landfill and solid waste management area which are shown in Figure 9.

For convenience in assessing the data, the wells have been divided into several groups. Yearly average gross alpha, gross beta, and tritium activity concentrations of the wells adjacent to the sand filter beds, and downstream on the Peconic River are summarized in Table 15. During the year, at least one sample each from locations adjacent to the recharge basins and from locations immediately adjacent to the sand filter beds and the Peconic River were analyzed for ^{90}Sr and ^{137}Cs. Corresponding information for wells downstream (with reference to groundwater movement) of the solid waste management area, the landfill and former dump zones, and the decontamination facility sump (about 1 km east of the HFBR) are also summarized in Table 15. Since the aquifer underlying Nassau and Suffolk Counties has been designated as a "Sole Source" (24), the EPA Drinking

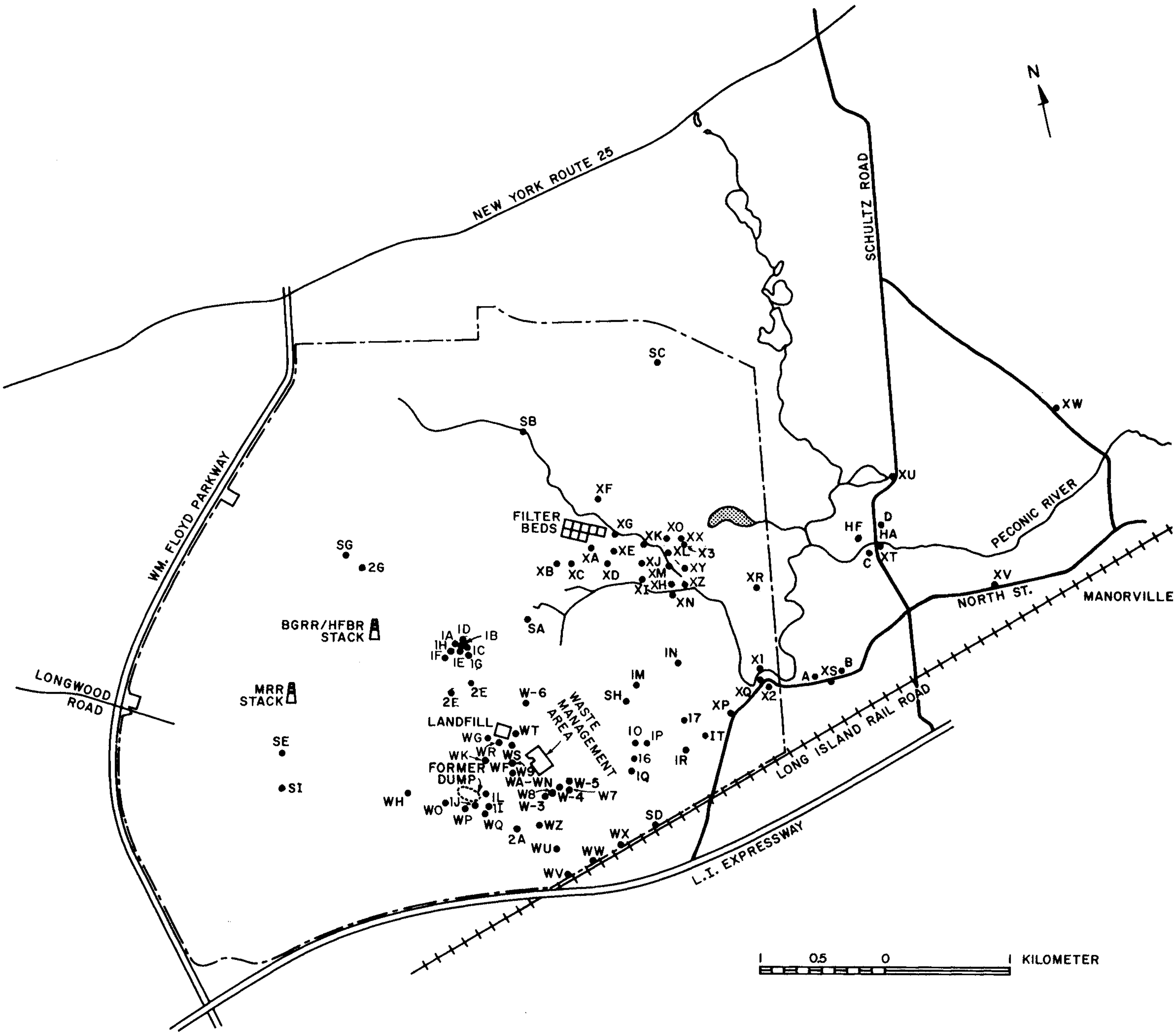


Figure 8. Location of groundwater surveillance wells.

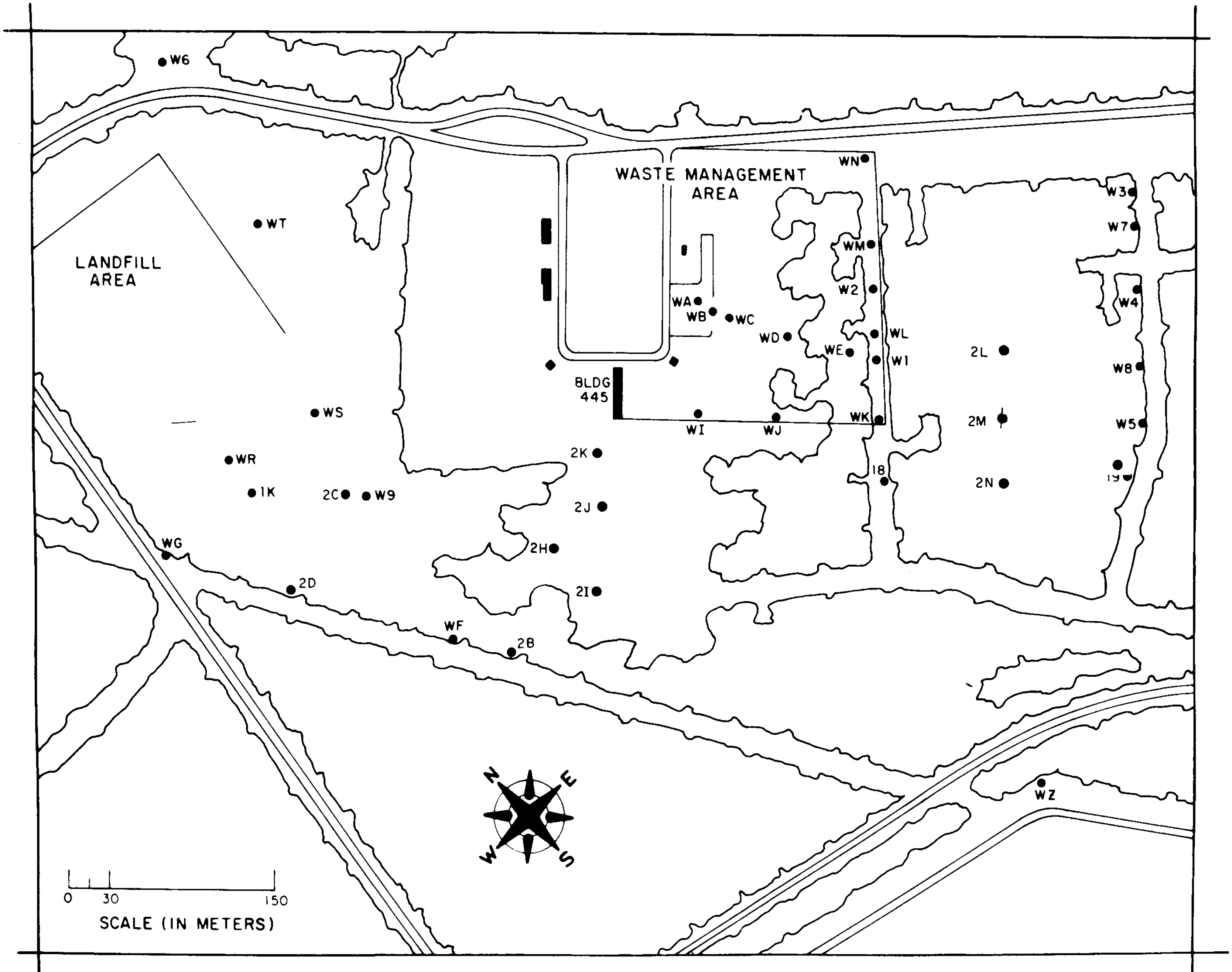


Figure 9. Landfill and waste management area surveillance wells.

TABLE 15

1982 BNL Environmental Monitoring

Groundwater Surveillance Wells: Average Radionclide, Metals, and Water Quality Data

Well #	# of Samples Analyzed	Gross α	Gross β	^{90}Sr	^{3}H	Ag	Cd	Cr	Cu	Fe	Pb	Zn	Dissolved Oxygen	Chlorides	Nitrate Nitrogen	Total Phosphates	Dissolved Solids	Conductivity (μmhos/cm)	Temperature °C	pH
		10^{-6} μCi/ℓ				ppm														
Sand Filter Beds and Peconic River Area																				
XA	1	0.53	8.54	0.80	5280	0.002	0.0011	0.003	0.008	0.144	0.004	0.253	7.7	25.0	0.73	0.01	190	200	12	5.2
XB	1	0.69	7.10	0.35	170	0.002	0.0006	0.003	0.003	0.255	0.004	4.280	7.5	5.5	0.37	0.01	45	62	10	5.6
XC	1	0.60	7.06	1.34	170	0.002	0.0006	0.003	0.006	1.280	0.004	0.582	10.5	7.5	0.35	0.01	86	49	9	5.1
XD	1	0.28	3.69	<0.09	170	0.002	0.0006	0.003	0.003	0.250	0.004	0.242	8.3	5.0	0.13	0.01	31	42	9	4.8
XE	1	0.29	4.18	0.30	1290	0.002	0.0006	0.003	0.012	0.124	0.004	0.568	7.2	8.5	2.31	0.01	66	75	12	4.9
XF	2	0.30	1.38	<0.09	170	0.002	0.0008	0.002	0.014	0.326	0.010	1.450	4.8	7.4	0.14	0.01	66	45	11	5.7
XH	1	0.31	3.61	0.14	170	0.002	0.0006	0.003	0.017	4.020	0.004	1.050	4.2	7.5	0.09	0.01	52	45	11	5.1
XI	1	0.62	7.68	0.85	170	0.002	0.0006	0.003	0.003	0.012	0.004	0.192	5.0	8.0	0.09	0.01	40	47	9	4.8
XJ	1	0.24	1.37	0.63	170	0.002	0.0006	0.003	0.003	0.327	0.004	0.193	8.4	7.5	0.77	0.01	40	50	9	4.9
XK	1	1.52	11.89	1.88	2160	0.002	0.0006	0.003	0.004	2.190	0.004	0.110	2.7	23.0	0.33	0.05	141	170	9	5.8
XL	1	1.15	19.71	2.45	3140	0.002	0.0006	0.003	0.004	2.510	0.004	0.090	3.1	26.0	0.72	0.02	130	163	11	5.5
XM	1	0.77	14.35	0.49	136,000	0.002	0.0017	0.003	0.593	0.896	0.004	1.120	6.9	25.0	4.06	0.24	141	160	18	5.5
XN	1	1.53	4.86	0.22	170	0.002	0.0006	0.003	0.010	4.020	0.004	0.250	2.5	7.0	0.90	0.01	90	49	8	5.0
XO	1	b	b	1.23	b	0.002	0.0006	0.003	0.003	0.015	0.004	0.222	4.8	10.5	0.21	0.01	47	58	8	4.5
XR	1	0.57	3.07	1.33	250	0.002	0.0006	0.003	0.080	0.040	0.014	1.910	11.2	9.0	0.05	0.01	39	36	11	d
XS[a]	1	1.32	3.93	0.25	300	0.002	0.0006	0.003	0.006	4.340	0.004	0.130	10.1	9.0	0.25	0.44	57	63	11	4.8
XT[c]	1	0.25	0.55	0.47	300	0.002	0.0006	0.003	0.003	1.880	0.004	0.080	1.2	5.5	0.05	0.63	66	76	11	5.8
XU	1	b	b	0.66	b	0.002	0.0006	0.004	0.007	5.670	0.004	0.196	3.5	11.0	0.09	0.01	123	70	10	4.6
XV	1	b	b	<0.09	b	0.002	0.0006	0.003	0.003	0.002	0.004	0.110	4.2	9.5	1.36	0.59	97	115	11	5.8
XW[c]	1	0.34	3.33	0.18	170	0.002	0.0006	0.003	0.008	0.680	0.004	0.144	2.6	24.5	0.05	0.27	115	109	11	4.9
XX	1	0.65	9.13	2.21	960	0.002	0.0006	0.003	0.003	9.810	0.004	0.104	4.2	15.5	0.12	0.01	111	99	9	5.5
XY	1	0.27	3.97	0.93	170	0.002	0.0006	0.003	0.003	0.222	0.004	0.263	4.0	7.0	0.28	0.01	50	59	10	5.0
XZ	1	0.52	3.96	<0.09	2000	0.002	0.0006	0.003	0.007	0.029	0.004	0.302	0.8	16.5	0.30	0.01	71	88	9	5.5
X1	1	0.26	1.44	0.25	250	0.002	0.0006	0.003	0.003	0.010	0.004	0.330	9.5	7.0	0.44	0.31	41	36	11	3.2
X2	1	0.24	1.32	<0.09	4240	0.002	0.0006	0.003	0.003	0.050	0.004	0.570	2.9	24.0	0.05	0.01	88	90	11	2.4
X4	1	b	b	0.93	b	0.002	0.0006	0.003	0.003	0.630	0.004	0.020	1.3	21.5	0.05	0.06	104	135	8	5.8
X5	2	b	b	0.24	b	0.002	0.0006	0.002	0.004	0.023	0.004	0.115	5.6	6.1	0.17	0.01	51	44	11	5.2
Waste Management Area																				
WB	1	0.79	10.64	5.85	960	0.002	0.0006	0.002	0.004	0.160	0.004	0.277	3.4	8.0	0.05	0.01	b	70	11	5.2
WC	1	0.28	10.61	7.20	950	0.002	0.0006	0.021	0.005	0.550	–	0.220	2.8	10.5	0.28	0.01	96	68	11	4.9
WD	1	0.82	23.38	9.05	3050	0.002	0.0006	0.002	0.004	0.130	0.010	0.476	9.2	6.5	1.10	0.01	77	85	10	5.1
WE	1	0.46	24.52	8.88	1380	0.002	0.0006	0.002	0.002	0.030	0.004	0.216	9.2	5.5	1.34	0.01	55	70	9	5.1
WI	1	0.49	5.42	<0.09	170	0.002	0.0006	0.003	0.022	0.506	0.004	0.305	3.7	6.0	0.36	0.01	53	58	10	5.1
WJ	1	0.42	7.87	1.16	390	0.002	0.0006	0.003	0.003	0.523	0.014	0.377	6.2	7.0	0.69	0.01	57	68	9	4.7
WK	1	0.70	104.40	32.20	16,900	0.002	0.0006	0.003	0.019	0.164	0.004	0.259	6.4	7.5	2.97	0.01	102	110	10	4.9
WL	1	1.29	103.30	29.40	b	0.002	0.0006	0.003	0.008	0.235	0.014	0.303	6.6	12.0	3.05	0.01	101	128	9	5.3
WN	1	0.12	2.36	<0.09	170	0.002	0.0061	0.003	0.003	0.111	0.004	0.096	7.2	10.0	0.51	0.01	82	100	8	5.2
WW	1	0.27	1.27	<0.09	170	0.002	0.0006	0.003	0.043	0.216	0.004	1.420	9.7	12.9	0.32	0.20	59	70	11	5.4
W1	1	0.61	82.62	24.60	7780	0.002	0.0006	0.003	0.003	0.009	0.004	0.364	7.1	5.5	1.49	0.01	58	80	10	5.1
W2	1	0.49	24.74	8.62	450	0.002	0.0006	0.018	0.110	0.647	0.112	0.677	8.6	11.5	1.18	0.01	90	128	9	5.5
W3	1	0.24	1.75	0.42	170	0.002	0.0006	0.003	0.004	0.310	0.004	0.315	5.9	7.5	0.69	0.01	68	65	9	5.1
W4	1	0.21	1.66	<0.09	170	0.002	0.0006	0.003	0.004	0.024	0.004	0.555	8.9	6.0	0.15	0.10	32	38	9	5.2
W5	1	0.38	2.42	<0.09	170	0.002	0.0006	0.003	0.003	0.240	0.004	0.346	7.8	3.5	0.57	0.28	58	42	9	4.9
W6	2	0.40	2.48	b	180	0.002	0.0006	0.002	0.004	0.219	0.022	0.247	6.2	15.8	0.65	0.01	204	318	10	6.4
W7	1	0.28	1.90	<0.09	170	0.002	0.0006	0.003	0.003	0.050	0.004	0.444	3.7	10.0	1.27	0.01	78	118	9	5.3
W8	1	0.38	3.15	0.16	170	0.002	0.0006	0.003	0.003	0.044	0.004	0.688	7.6	9.0	0.54	0.01	135	42	9	5.0
18	1	0.42	6.70	<0.09	1320	0.002	0.0006	0.003	0.003	0.124	0.004	0.009	5.8	9.0	0.91	0.07	67	78	9	4.8
19	1	0.28	2.43	0.26	170	0.002	0.0006	0.003	0.004	0.017	0.004	0.020	7.9	11.5	0.33	0.01	41	50	9	4.8
2L	1	0.25	0.71	<0.09	180	0.002	0.0006	0.003	0.005	0.030	0.004	0.150	4.8	13.5	0.82	0.01	85	95	11	5.0
2M	2	0.29	3.29	0.18	210	0.002	0.0006	0.003	0.003	0.040	0.004	0.190	3.6	13.3	0.42	0.01	68	104	11	5.0
2N	2	0.32	1.99	<0.09	210	0.002	0.0006	0.003	0.006	0.080	0.004	0.150	4.3	10.3	0.22	0.01	57	77	11	5.0

TABLE 15 - Continued

1982 BNL Environmental Monitoring

Groundwater Surveillance Wells: Average Radionclide, Metals, and Water Quality Data

Well #	# of Samples Analyzed	Gross α	Gross β	^{90}Sr	^{3}H	Ag	Cd	Cr	Cu	Fe	Pb	Zn	Dissolved Oxygen	Chlorides	Nitrate Nitrogen	Total Phosphates	Dissolved Solids	Conductivity (µmhos/cm)	Temperature °C	pH
		10^{-6} µCi/ℓ				ppm														
Landfill Area																				
WG	1	0.78	2.83	0.37	180	0.002	0.0006	0.003	0.004	45.4	0.004	0.080	1.1	12.5	0.08	0.01	90	185	13	5.4
WR	4	2.03	19.68	2.50	190	0.002	0.0006	0.003	0.013	78.0	0.004	0.175	5.4	33.1	0.32	0.01	383	575	13	6.3
WS	4	3.02	37.04	2.17	5690	0.002	0.0023	0.003	0.004	72.1	0.006	0.048	0.9	19.6	0.37	0.01	314	510	11	6.3
WT	4	1.39	4.34	0.10	190	0.002	0.0006	0.003	0.010	1.3	0.006	0.918	3.6	14.5	0.25	0.01	80	92	12	5.2
W9	4	3.27	39.26	3.40	4090	0.002	0.0006	0.003	0.005	70.2	0.004	0.074	3.8	23.9	0.29	0.01	284	583	12	6.5
1K	4	-	31.48	1.90	2010	0.002	0.0006	0.003	0.010	93.4	0.004	0.130	2.6	30.5	0.56	0.01	346	738	13	6.3
2A	1	0.22	0.92	0.33	170	0.002	0.0006	0.003	0.035	0.338	0.004	0.271	9.4	8.9	0.40	0.09	47	-	11	5.3
2K	1	0.65	5.98	1.78	610	0.002	0.0006	0.003	0.008	0.100	0.004	1.250	1.1	13.6	0.33	0.01	82	98	13	5.6
2B	1	0.29	2.45	b	380	0.002	0.0006	0.003	0.005	0.021	0.004	0.006	9.2	7.5	0.39	0.01	60	57	10	4.8
2H	1	0.96	4.39	1.82	620	0.002	0.0006	0.003	0.003	0.050	0.004	0.019	4.3	15.5	0.48	0.01	64	85	11	6.0
2C	3	2.86	55.39	7.37	14510	0.005	0.0019	0.010	0.012	47.63	0.013	0.012	1.6	4.4	0.61	0.01	438	631	13	6.5
2I	1	b	b	4.26	b	0.002	0.0006	0.003	0.012	0.29	0.004	3.250	2.4	11.5	0.93	0.01	86	98	15	6.0
2D	1	0.79	5.20	b	1330	0.002	0.0006	0.003	0.005	51.30	0.004	0.210	0.8	32.0	0.31	0.01	286	450	12	6.1
2J	1	0.34	15.17	7.09	180	0.002	0.0006	0.003	0.003	0.300	0.004	0.120	5.5	14.5	3.94	0.01	76	70	11	5.1
650 Sump Area																				
1A	2	0.43	18.59	5.25	150	0.002	0.0006	0.002	0.004	0.250	0.004	0.420	7.7	1.9	0.21	0.02	52	36	14	5.7
1B	1	0.51	4.57	b	180	—	—	—	— b —	—	—	—	9.4	4.0	0.82	0.01	58	70	17	5.8
1C	1	2.82	67.27	b	8190	—	—	—	— b —	—	—	—	8.2	1.5	0.14	0.07	69	20	18	5.5
1D	1	0.31	1.60	b	180	—	—	—	— b —	—	—	—	8.0	20.0	0.96	0.01	153	100	12	5.6
1E	2	0.52	28.34	6.20	150	0.002	0.0006	0.002	0.008	0.29	0.010	0.600	7.8	3.6	0.68	0.01	37	40	15	5.7
1F	1	0.12	0.99	0.14	180	0.002	0.0006	0.003	0.003	0.122	0.004	0.001	9.6	18.2	0.42	0.01	88	121	13	6.3
1G	2	0.32	3.07	0.24	150	—	—	—	— b —	—	—	—	8.1	12.9	1.56	0.19	97	72	13	5.7
1H	2	0.81	200.69	51.35	150	0.002	0.0006	0.002	0.021	0.104	0.012	0.820	7.6	12.8	2.39	0.01	100	7	12	5.7
Former Dump Area																				
1I	1	0.18	0.62	<0.09	360	0.002	0.0006	0.003	0.006	1.80	0.004	0.030	9.8	4.5	0.39	0.01	38	62	12	5.4
1J	1	0.24	0.33	<0.09	180	0.002	0.0006	0.003	0.003	0.510	0.004	0.015	10.2	8.0	0.66	0.01	51	42	11	5.8
Miscellaneous On-Site Wells																				
SI	1	0.18	0.90	0.16	180	0.002	0.0006	0.003	0.008	5.340	0.004	0.014	9.7	24.2	1.26	0.01	106	151	13	6.2
17	1	0.26	0.92	0.72	180	0.002	0.0006	0.003	0.004	0.210	0.030	0.160	8.4	4.3	0.25	0.01	108	50	11	5.2
EPA Drinking Water Standard {16}		15.0	50.0	8.0	20,000	0.050	0.010	0.050	-	-	0.050	-	-	-	10.0	-	-	-	-	-

(a) Control: Downstream on Hydraulic Gradient

(b) Not done

(c) Off-Site

MDL values:

Ag	0.002	ppm
Cd	0.0006	
Cr	0.002	
Cu	0.003	
Fe	0.003	
Pb	0.004	
Zn	0.0006	
Nitrate-Nitrogen	0.02	
Total Phosphates	0.01	

Water Standards are applicable (16). The data, therefore, are evaluated in terms of the more restrictive EPA standard, and not the DOE RCGs.

In analyzing the data over the past decade, it is apparent that the spread of radioactivity in the groundwater from Laboratory operations has remained within a few hundred meters of the identifiable foci. Above background concentrations of gross beta emitters, tritium, and ^{90}Sr have been found on-site adjacent to the sand filter beds and the Peconic River. In 1982, they were up to 2-10% for gross alpha, 3-40% for gross beta, 1-26% for ^{3}H, and 1-31% for ^{90}Sr of the Drinking Water Standards (16). In 1982, the concentrations of radioactivity were generally less than those noted in 1974 and 1975 (10), and had further decreased when compared to those found during 1976-1980 (10), indicating that radionuclides have not moved significantly since 1976, but have undergone dilution and decay. During May 1982, an elevated level of tritium was observed in well XM, which is situated within the stream bed. The high concentration resulted from a planned release of approximately 810 mCi of tritium from the HFBR. Well XM was sampled several days after this release and the level of activity reflects well infiltration from the surface water flow. Adjacent to the Peconic River at the site boundary, all gross beta and tritium concentrations were less than or equal to 7% of the Drinking Water Standards. In 1978, samples of well water collected from homes (stations A, B, C and D - Figure 8) and well XS (all of which are downstream with reference to groundwater movement of the Laboratory and the Peconic River) had indicated ^{90}Sr concentrations approaching one to two $pCi\ell^{-1}$. In 1982, all were <1 $pCi\ell^{-1}$, less than the EPA drinking water limit of 8 $pCi\ell^{-1}$ (16). An extensive study of wells throughout Suffolk County in 1979 indicated that, on the average, shallow wells contained greater concentrations of ^{90}Sr than deeper wells, regardless of their proximity to the Laboratory. This observation is attributed to fallout from past nuclear tests during the 1950's and early 1960's (10).

In several wells adjacent to the solid waste management area, the concentrations of gross beta activity, tritium and ^{90}Sr activity concentrations for 1982 showed a continuing decline. However, several wells which had shown elevated levels of gross β and ^{90}Sr had increased in concentration for these radionuclides. When compared to 1981, wells WE, WK, WL, and W1 had higher gross β concentrations with WB, WC, WD, WE, WK, WL, W1, and W2 exhibiting elevated ^{90}Sr concentrations. Wells WD, WE, WK, WL, W1 and W2 exceed drinking water standards for ^{90}Sr. They reflect the inadvertent injection in 1960 of approximately one Ci of aged fission products into groundwater at well WA. The concentrations of ^{90}Sr in these wells, however, has decreased over the long term, apparently representing the complex interaction of groundwater movement rates and distribution coefficients of the elements in the soil matrix. The concentrations of gross beta activity and tritium also decreased from those of recent years in several wells immediately adjacent to the landfill. This is attributed both to the discontinuation of the disposal of radioactive waste on the Landfill in 1976, as well as the movement and dilution of radioactivity in the groundwater adjacent to it. The concentration of gross beta activity and tritium in wells WS, W9, 1K, 2C, and 2D decreased in 1982 from those found in 1981. Fluctuations in these concentrations have been seen in these wells for several years in the past. At the decontamination facility (Bldg. 650) sump, the concentrations of gross beta activity and ^{90}Sr in well 1A, and the concentrations of gross beta activity and tritium in other wells have continued to decrease. The ^{90}Sr concentrations in well 1H exceeded the EPA limits for groundwater of 8 pCiℓ^{-1}. However, calculations done using groundwater travel times of 16.2 cm d^{-1} (7), the ^{90}Sr distribution coefficient for ion exchange, and distance to the nearest potential user of drinking water, have predicted travel times of about 60 years for ^{90}Sr to reach the site boundary. In addition to physical decay (covering a period of two ^{90}Sr half-lives), considerable dilution by infiltration of precipitation would also be anticipated. Based on the existing levels in the above wells, the Laboratory does not foresee that this inadvertent discharge of ^{90}Sr into well WA and at the 650 sump area could cause the concentrations of ^{90}Sr in any well off-site to exceed EPA drinking water limits.

In the groundwater surveillance wells, several water quality and purity parameters were also evaluated. The data for wells adjacent to on-site sumps, the sand filter beds, and downstream of the Peconic River on- and off-site, are also shown in Table 15. The data for wells adjacent to the solid waste management area, the landfill, the dump area and the 650 sump, are also shown. Analyses for selected metals were also conducted for a few wells immediately adjacent to the sand filter beds, to the Peconic River, to the waste management, landfill and former dump areas. These data are also shown in Table 15.

In general, the data were comparable to that observed during previous years. With the exception of pH, all analyzed water quality parameters were within New York State Water Quality Standards (18,24). The somewhat lower pH levels appear to reflect natural ambient levels, since higher pH levels were present in the input to and output from the sewage treatment plant (see Table 10). Concentrations of Fe and Zn in excess of water quality standards were found in some of the wells immediately adjacent to the sand filter beds, the Peconic River, landfill areas, and the 650 sump area. Since these results may be an artifact produced by corrosion from well casings, a program to compare effects of well casings was conducted in 1980 and 1981. The results indicate that this effect is measurable. Tracing the levels of these elements in the groundwater system by means of the Laboratory surveillance wells downstream in the direction of the groundwater flow, has indicated significant decreases as one proceeds away from the Laboratory, such as 60-70% along the Peconic River, 25-30% in the waste management area and 50-60% in the 650 sump area. Much lower levels of Zn were found in the Laboratory supply wells. Several contain Fe in excess of the standard, but most of this is removed prior to use. It is to be noted that high Fe concentration is indigenous to groundwater in this region. Zn and Fe are nuisance elements and do not pose significant health hazards.

The general rate and direction of groundwater movement is 16.2 cm d^{-1} and predominantly in the southeast direction (6). It appears, therefore, that many years of travel time would be required for groundwater containing radioactivity or other pollutants to reach an off-site well, during which considerable dilution by infiltration of precipitation would be anticipated. The data from all the surveillance wells are reviewed at frequent intervals in order to evaluate the monitoring program and appropriate action is taken, such as, rescheduling the sampling of wells and follow-up analysis if required.

3.4 Unusual Occurrences:

3.4.1 Oil Spills:

During 1982, two minor oil spills occurred. Clean-up procedures were instituted immediately, preventing potential groundwater contamination. The absorbents used to clean up the spills were disposed of according to New York State Department of Environmental Conservation (NYSDEC) approved procedures.

3.4.2 Nuclear Tests:

No atmospheric nuclear tests were reported during 1982. The concentrations of radionuclides from fallout from previous tests that were detected in milk and soil samples collected from dairy farms in the vicinity of the site are reported in Table 16. As was the case in recent years, the average concentration of ^{90}Sr in the milk from the farm in Center Moriches, was higher than the more remote 'control' location in Southhampton. This effect is attributed to differences in the availability and uptake of radioactivity from fallout from past atmospheric weapon test and to differences in soil conditions and/or farming practices (25).

4.0 OFF-SITE DOSE ESTIMATES

The reported levels of radiation and concentration of radioactivity in air and water, above ambient background, with resulting doses to the public, are attributable to the following Laboratory sources:

1. airborne radioactive effluents, primarily tritium, and

2. radioactive liquid effluents.

These are discussed below, and the collective dose-equivalent rate due to Laboratory operations during 1982 is calculated.

4.1 Collective Dose-Equivalent Rate Due to Airborne Effluents:

As indicated in Table 4, 346 Ci of tritium vapor were released from various Laboratory facilities during 1982. It was the largest source of dose equivalent to persons off-site, relative to other airborne radionuclides in the BNL effluent streams. As previously indicated, the dose equivalents due to ^{41}Ar, ^{15}O, ^{127}Xe, and gaseous ^{3}H were not measurable. The calculated per capita annual average dose-equivalent rates for these radionuclides at the site boundary were 2.3×10^{-2} mrem a^{-1}, 1.6×10^{-2} mrem a^{-1}, 5.4×10^{-5} mrem a^{-1}, and 1.5×10^{-7} mrem a^{-1}, respectively. These are insignificant when compared to the tritium vapor contribution, and thus were not included in the final estimates.

For the calculation of the annual doses at the site boundary and the collective dose-equivalent, the Laboratory site perimeter was divided into four 90° sectors, each sector corresponding to its respective monitoring station, P-9, P-7, P-4, or P-2. Compass and degree headings for each defined sector are given in Table 8. Data given in Table 8 indicates that the highest average site bound-

TABLE 16

1982 BNL Environmental Monitoring
Radionuclide Concentrations in Milk and Soil Samples
Collected from Dairy Farms in the Vicinity of the Site

ID Number	^{90}Sr Milk (pCi/ℓ)	^{90}Sr Soil (pCi/Kg)[c]	^{40}K Milk (pCi/ℓ)	^{40}K Soil (pCi/Kg)[c]	^{137}Cs Milk (pCi/ℓ)	^{137}Cs Soil (pCi/Kg)[c]	^{232}Th Milk (pCi/ℓ)	^{232}Th Soil (pCi/Kg)[c]
OA	10.7	11.7	1300	4300	a	440	a	a
OB	5.7	98.8	1600	3900	a	620	a	650
OC	b	72.2	b	8200	b	470	b	1000
OD	b	48.5	b	5000	b	220	b	590
OE	b	70.5	b	3400	b	610	b	750
Average	8.2	60.3	1450	4960	-	472	-	598

(a) Below the MDL of the System used.

(b) Not done.

(c) Fresh weight.

ary concentration was 1.11 x 10^2 pCi m^{-3} at station P-7. A continuous exposure at the Radiation Concentration Guide (2 x 10^5 pCi m^{-3}) would result in a per capita annual average dose-equivalent rate of 500 mrem a^{-1}. Therefore, the annual average dose-equivalent rate (attributable to Laboratory air effluent tritium vapor) for the hypothetical individual residing at the site boundary in this sector would have been 0.28 mrem a^{-1}. This value is 0.06% of the Radiation Protection Standard (15). Given the individual external background rate of 65.9 mrem a^{-1} in this area (Table 2), the tritium dose-equivalent rate contribution amounts to an increase at this site boundary sector of approximately 0.4%. This is within the temporal and spatial variations of the background itself. Utilizing the same methodology, the per capita dose-equivalent rates for P-4, P-2 and P-9 were determined to be 0.005, 0.005, and 0.12 mrem a^{-1}, respectively.

Table 17 gives the dose-equivalent to the general public due to BNL tritium vapor releases. Beyond the site boundary, the dose rates due to tritium were very small when compared with background (Table 2) and variations in background. The X/Q parameters are the ratio of ground level concentration to rate of emission, and are functions of meterological conditions and distance from the source. They are long-term average values which have been calculated for the 97.5 m release height of the HFBR stack for the entire year and for sixteen tabulated directions. The indicated values of this annual average per capita dose-equivalent rate for each sector have been derived by multiplying the actual measured values for the 1.6 - 3.2 km interval by the appropriate ratios of X/Q with distance. The collective dose-equivalent (total population dose) due to the Laboratory tritium effluent was 2.72 rem a^{-1}. This can be compared to the total population dose-equivalent due to natural background (65.9 mrem a^{-1} in Table 2), of 315,125 rem a^{-1}. The Laboratory tritium effluent contributed <0.001% of the total dose due to natural background.

4.2 Doses Due to Liquid Effluents:

Since the Peconic River is not utilized as a drinking water supply, nor for irrigation, its waters do not constitute a direct pathway for the ingestion of radioactivity. However, the upper portions of the river are utilized for occasional recreational fishing.

Based on discussions with the New York State Department of Environmental Conservation regarding fish productivity in the Peconic River, it was assumed that 100 fishermen caught 500 kg of fish in 1982 and that their families consumed all of these fish. Furthermore, it was assumed that the distribution of adults and children (based on an average family of 2 adults and 2 children) was 368 adults and children above 12 years of age and 66 children below 12 years (4). Thus, the estimated annual average fish consumption by the adult group was 1.36 kg/yr and for children below 12 years was 0.46 kg/yr (as compared to the USNRC Regulatory Guide (23) value of 21 kg/yr and 6.9 kg/yr respectively). Based on these values for consumption of fish and other relevant assumptions recommended in the NRC Regulatory Guide 1.109 (23), and the maximum observed concentration of ^{90}Sr and ^{137}Cs in fish (6.9 and 823 pCi/kg(wet) respectively), the estimated maximum individual dose-equivalent commitment is tabulated below.

TABLE 17

1982 Environmental Monitoring Collective Annual Dose-Equivalent Rate Due to HTO[c] Releases from BNL Facilities

Distance from HFBR Stack (km)	X/Q[a]	Sector	Estimated Population[b]	HTO[c] Per Capita Dose Equivalent Rate mrem Person a^{-1}	HTO[c] Collective-Dose Equivalent Rate (rem a^{-1})
1.6-3.2	2.4×10^{-7}	P-7	228	0.28	0.064
		P-9	98	0.12	0.012
		P-4	655	0.005	0.003
		P-2	650	0.005	0.003
3.2-4.8	1.0×10^{-7}	P-7	779	0.12	0.093
		P-9	334	0.05	0.017
		P-4	2244	0.002	0.004
		P-2	2227	0.002	0.004
4.8-6.4	6.0×10^{-8}	P-7	1654	0.07	0.116
		P-9	709	0.03	0.0213
		P-4	4763	0.001	0.005
		P-2	4728	0.001	0.005
6.4-8.0	3.9×10^{-8}	P-7	2910	0.04	0.116
		P-9	1248	0.02	0.0250
		P-4	8379	0.0008	0.0067
		P-2	8317	0.0008	0.0067
8.0-16.1	1.7×10^{-8}	P-7	32,600	0.02	0.652
		P-9	13,974	0.008	0.112
		P-4	93,860	0.0004	0.038
		P-2	93,160	0.0004	0.037
16.1-24.2	8.0×10^{-9}	P-7	13,352	0.008	0.107
		P-9	4451	0.004	0.018
		P-4	119,429	0.0002	0.024
		P-2	110,032	0.0002	0.022
24.2-32.2	5.5×10^{-9}	P-7	8416	0.006	0.050
		P-9	2805	0.003	0.008
		P-4	75,280	0.0001	0.008
		P-2	69,357	0.0001	0.007
32.2-48.4	3.8×10^{-9}	P-7	16,127	0.004	0.065
		P-9	107,192	0.002	0.214
		P-4	330,768	0.0001	0.033
		P-2	546,648	0.0001	0.055
48.4-64.5	2.7×10^{-9}	P-7	8393	0.003	0.025
		P-9	303,820	0.001	0.304
		P-4	419,582	0.0001	0.042
		P-2	643,890	0.0001	0.064
64.5-80.6	2.1×10^{-9}	P-7	523	0.003	0.002
		P-9	339,823	0.001	0.340
		P-4	754,370	0.00004	0.030
		P-2	634,052	0.00004	0.025
1.6-80.6	-	-	4,781,860	-	2.72

(a) Average X/Q from Final Environmental Impact Statement, Brookhaven National Laboratory, ERDA-15.40 (1977)

(b) Population data estimated from information supplied by the Long Island Regional Planning Board (4).

(c) Tritiated water vapor.

Estimated Maximum Individual Dose-Equivalent Commitment for One Year of Assumed Ingestion of Fish Obtained from the Peconic River (mrem a^{-1})

	^{90}Sr		^{137}Cs	
	Children below 12 yrs	Adults	Children below 12 yrs	Adults
Total Body	0.013	0.002	0.02	0.05

For the above population, the collective dose-equivalent rate to total body from this indirect pathway can be estimated to be 0.019 rem a^{-1} (0.052 mrem x 368 persons) for adults and 0.002 rem a^{-1} (0.033 mrem x 66 persons) for infants.

Although not directly related to the Laboratory liquid effluents during 1982, a ^{90}Sr concentration of 0.25 pCi l^{-1} was found in off-site surveillance well (XS), about 0.35 km east of the Laboratory site boundary along the Peconic River. This level corresponds to 3% of the EPA Drinking Water Standard (16). Assuming that during 1982 all of the 27 people (4) living in the vicinity of this well obtained their drinking water from shallow water supply wells containing ^{90}Sr at the same concentration, then their collective dose equivalent does not exceed 0.003 rem (since 8 pCi/l corresponds to 4 mrem). Their collective dose-equivalent commitment (total dose) from natural background (including internal radiation) would have been about 1.78 rem (person-rem) during 1982.

4.3 Doses Due to Alternating Gradient Synchrotron:

The AGS is located 1180 meters from the nearest site boundary. Although the machine is heavily shielded, some neutrons do penetrate the shield or escape from areas where experiments are in progress. Some of these neutrons reach off-site areas directly, or more likely by scattering from the air which is called skyshine.

With the advent of the CBA project in 1978, the Safety and Environmental Protection Division has instituted an extensive program to evaluate different neutron detectors in the field and also to determine appropriate sampling locations. These studies should provide data on neutron dose distribution around the AGS and CBA (when operational) facilities and thus provide a basis for more accurate estimates of off-site doses.

Neutron doses were measured at four sites; three Laboratory environmental monitoring stations P-2, P-4, S-5, and the AGS Health Physics Office. Doses at these locations were determined to be 0.44 mRem, 1.26 mRem, 0.45 mRem, and 32 mRem, respectively, for the period October 22, 1982 to March 2, 1983. Using these data, an annual dose equivalent rate at the environmental stations can be extrapolated to be 1.23 mRem, 3.51 mRem and 1.25 mRem respectively. These values correspond to typical dose-equivalent values due to cosmic sources (30). Since the neutron dose due to AGS operations was not detectable, it has not been included in the final collective dose-equivalent rate for BNL.

It is to be noted that the results provided in the past annual reports, which were estimated by comparing total proton flux, were very conservative. The field measurements done in 1982 represent actual conditions.

4.4 Collective Dose-Equivalent Rate (Total Population Dose):

The collective dose-equivalent rate (total population dose) beyond the site boundary, within a radius of 80 km, attributed to Laboratory operations during 1981 is the sum of the values due to the three components discussed above, as shown below:

Pathway	Collective Dose-Equivalent rem a^{-1} (person-rem a^{-1})
External	
AGS Skyshine	ND*
Airborne	
Tritium	2.72
Liquid	
Fish Consumption	0.02**
Well Water	0.003

* ND: Not Detectable

** Infants 0.002, Adults 0.019

The collective dose-equivalent (total annual dose) due to external radiation from natural background, to the population within a 80 km radius of the Laboratory, amounts to about 315,125 rem a^{-1}, to which about 97,008 rem a^{-1} (person-rem a^{-1}), should be added for internal radioactivity from natural sources.

TABLE 18

Maximum Permissible Levels of Contaminants in Air and Water With Their Detection Limits

Contaminant		DOE 5484.1 {16} Radiation Protection Guide (RPG) Air	DOE 5484.1 {16} RPG Water	EPA-Drinking Water {17} and NYS Drinking Water Standard {25} (a) Water	NYS Standard {19,28} Air	NYS Standard {19,28} Water	Minimum Detectable Concentration (b) Air				Water	
Radioactive												
Gross α μCi/ml		1×10^{-13}	6×10^{-7}	1.5×10^{-8}	1×10^{-13}	6×10^{-7}	3×10^{-16}				3×10^{-10}	
Gross β μCi/ml		1×10^{-10}	1×10^{-7}	5×10^{-8} *	1×10^{-10}	1×10^{-7}	1×10^{-15}				1×10^{-9}	
^{3}H μCi/ml		2×10^{-7}	3×10^{-3}	2×10^{-5}	2×10^{-7}	3×10^{-3}	2×10^{-12} (c)				2×10^{-7} (d)	
^{90}Sr	S	3×10^{-11}	3×10^{-7}	8×10^{-9}	3×10^{-11}	3×10^{-7}	Not Determined				1×10^{-10}	
μCi/ml	I	2×10^{-10}	4×10^{-5}									
							Air #1 & 2	Air #3	Intrinsic Detector Well Water #1 & 2	Well Water #3	Surface Water #1 & 2	Surface Water #3
Gamma Emitters												
^{7}Be	S	2×10^{-7}	2×10^{-3}	1.5×10^{-5}	2×10^{-7}	2×10^{-3}	1.1×10^{-14}	1.1×10^{-14}	1.3×10^{-9}	1.2×10^{-9}	2.5×10^{-9}	2.3×10^{-9}
μCi/ml	I	4×10^{-8}	2×10^{-3}									
^{54}Mn	S	1×10^{-8}	1×10^{-4}	7×10^{-7}	1×10^{-8}	1×10^{-4}	2.0×10^{-15}	1.3×10^{-15}	2.3×10^{-10}	1.3×10^{-10}	4.3×10^{-10}	2.5×10^{-10}
μCi/ml	I	1×10^{-9}	1×10^{-4}									
^{60}Co	S	1×10^{-8}	5×10^{-5}	4×10^{-7}	1×10^{-8}	5×10^{-5}	2.6×10^{-15}	2.0×10^{-15}	2.7×10^{-10}	2.0×10^{-10}	5.1×10^{-10}	3.8×10^{-10}
μCi/ml	I	3×10^{-10}	3×10^{-5}									
^{95}Zr	S	4×10^{-9}	6×10^{-5}	4×10^{-7}	4×10^{-9}	6×10^{-5}	3.5×10^{-15}	2.3×10^{-15}	4.0×10^{-10}	2.5×10^{-10}	7.5×10^{-10}	4.6×10^{-10}
μCi/ml	I	1×10^{-9}	6×10^{-5}									
^{95}Nb	S	2×10^{-8}	1×10^{-4}	7×10^{-7}	2×10^{-8}	1×10^{-4}	1.9×10^{-15}	1.4×10^{-15}	2.1×10^{-10}	1.5×10^{-10}	3.9×10^{-10}	2.8×10^{-10}
μCi/ml	I	3×10^{-9}	1×10^{-4}									
^{125}Sb	S	2×10^{-8}	1×10^{-4}	1.5×10^{-7}	2×10^{-8}	1×10^{-4}	4.2×10^{-15}	3.4×10^{-15}	5.4×10^{-10}	4.1×10^{-10}	1.0×10^{-9}	7.6×10^{-10}
μCi/ml	I	9×10^{-10}	1×10^{-4}									
^{131}I	S	1×10^{-10}	3×10^{-7}	1.5×10^{-8}	1×10^{-10}	3×10^{-7}	1.5×10^{-15}	1.4×10^{-15}	1.9×10^{-10}	1.6×10^{-10}	3.6×10^{-10}	3.0×10^{-10}
μCi/ml	I	1×10^{-8}	6×10^{-5}									
^{134}Cs	S	1×10^{-9}	9×10^{-6}	6.5×10^{-8}	1×10^{-9}	9×10^{-6}	2.2×10^{-15}	1.5×10^{-15}	2.5×10^{-10}	1.6×10^{-10}	4.6×10^{-10}	3.0×10^{-10}
μCi/ml	I	4×10^{-10}	4×10^{-5}									
^{137}Cs	S	2×10^{-9}	2×10^{-5}	1.5×10^{-7}	2×10^{-9}	2×10^{-5}	2.1×10^{-15}	1.3×10^{-15}	2.4×10^{-10}	1.5×10^{-10}	4.5×10^{-10}	2.8×10^{-10}
μCi/ml	I	5×10^{-10}	4×10^{-5}									
^{144}Ce	S	3×10^{-10}	1×10^{-5}	7×10^{-8}	3×10^{-10}	1×10^{-5}	8.7×10^{-15}	7.3×10^{-15}	1.2×10^{-9}	9.3×10^{-10}	2.3×10^{-9}	1.8×10^{-9}
μCi/ml	I	2×10^{-10}	1×10^{-5}									
Non-Radioactive												
Temperature °C				$T_{max} < 30$					Water			
				$\Delta T \leq \pm 2.8$								
pH				6.5-8.5								
Dissolved Oxygen	ppm			>4.0					0.2			
Chlorides	ppm			250		500			0.1			
Nitrogen-Nitrate	ppm			10		20			0.05			
Dissolved Solids	ppm			500		1000			20.00			
Coliform	#/100 ml			Zero		4			Zero			
Silver (Ag)	ppm			0.05		0.1			0.001			
Cadmium (Cd)	ppm			0.01		0.2			0.004			
Chromium (Cr)	ppm			0.05		0.1			0.001			
Copper (Cu)	ppm			-		0.2			0.001			
Iron (Fe)	ppm			-		0.6			0.02			
Mercury (Hg)	ppm			0.002		-			0.00007			
Lead (Pb)	ppm			0.05		0.1			0.005			
Zinc (Zn)	ppm			-		0.3			0.002			

(a) Aquifer underlying Long Island declared as "Sole Source" - Applicable Standard is EPA National Interim Primary Drinking Water Regulations {17}

(b) See Appendix B

(c) As tritiated vapor

(d) For ^{3}H: 2×10^{-7} to 1×10^{-6} μCi/ml α Volume

S - Soluble

I - Insoluble

* - EPA Annual Compliance Level

APPENDIX A

QUALITY CONTROL

Radioactive Measurements:

a. Alpha (α), Beta (β) and Gamma (γ):

Certified radioactive standards from the National Bureau of Standards, U.S. Department of Commerce, are used to standardize radiation measurement instruments. These standards are certified to be within 5% of stated values. In some cases, certified standards, traceable to the National Bureau of Standards, were also obtained from Amersham/Searle. Daily checks of instrument performances are made with these standards. Backgrounds are collected daily for gross alpha and beta counting systems. Backgrounds are collected weekly for gamma and alpha spectroscopy equipment. For tritium measurements a number of standards and blanks are included with each run of a liquid scintillator counter which has a programmed automatic sample changer.

The Analytical Laboratory of BNL's Safety and Environmental Protection Division was a participant in an inter-laboratory comparison of samples of different matrices such as water, air filters, soil, vegetation and bone which contain a number of frequently encountered radionuclides. These samples are distributed, on a semiannual basis, by the Department of Energy through its Environmental Measurements Laboratory. The radionuclides assayed were ^{3}H, ^{90}Sr, plutonium isotopes, and several gamma emitting nuclides. Results were usually within the ±20% acceptance criteria. Outliers occasionally occur. These results are examined and corrective action is implemented immediately.

b. TLD Dosimeters:

The Dosimetry Services Group of the Safety and Environmental Protection Division participated in the Sixth International Intercomparison of Environmental Dosimeters conducted at Idaho Falls, Idaho from mid August to mid October 1982. There were a total of 169 participants in this test.

The estimated field exposure, as measured by the BNL environmental monitoring TLD dosimeters, agreed within 7% of the value measured by a continuously recording pressurized ion chamber corrected for energy response. In the Field (preirradiated) exposure test, the BNL dosimeter agreed within 8% for the calculated ($\sim$75 mR) exposure. In the Laboratory exposure test, the BNL agreed exactly with standardized exposure.

Measurements of Water Quality Parameters:

Procedures for nonradioactive contaminants are those presented in Standard Methods for the Examination of Water and Wastewater (14th edition, 1975). All standards are prepared from standard reference grade and analytical grade reagents in accordance with the requirements of standard methods. Standards are run with each set of samples analyzed and at least one duplicate and one blank are run with each set.

APPENDIX B

Minimum Detectable Concentration for Gamma Emitting Radionuclides in Air and Water Samples

Medium	Air		Well Water		Surface Water	
Detector-Intrinsic	#1 & #2	#3	#1 & #2	#3	#1 & #2	#3
Units	← µCi/mℓ →		← µCi/mℓ →		← µCi/mℓ →	
Nuclide						
^{7}Be	$1.1x10^{-14}$	$1.1x10^{-14}$	$1.3x10^{-9}$	$1.2x10^{-9}$	$2.5x10^{-9}$	$2.3x10^{-9}$
^{54}Mn	$2.0x10^{-15}$	$1.3x10^{-15}$	$2.3x10^{-10}$	$1.3x10^{-10}$	$4.3x10^{-10}$	$2.5x10^{-10}$
^{60}Co	$2.6x10^{-15}$	$2.0x10^{-15}$	$2.7x10^{-10}$	$2.0x10^{-10}$	$5.1x10^{-10}$	$3.8x10^{-10}$
^{95}Zr	$3.5x10^{-15}$	$2.3x10^{-15}$	$4.0x10^{-10}$	$2.5x10^{-10}$	$7.5x10^{-10}$	$4.6x10^{-10}$
^{95}Nb	$1.9x10^{-15}$	$1.4x10^{-15}$	$2.1x10^{-10}$	$1.5x10^{-10}$	$3.9x10^{-10}$	$2.8x10^{-1}$
^{125}Sb	$4.2x10^{-15}$	$3.4x10^{-15}$	$5.4x10^{-10}$	$4.1x10^{-10}$	$1.0x10^{-9}$	$7.6x10^{-10}$
^{131}I	$1.5x10^{-15}$	$1.4x10^{-15}$	$1.9x10^{-10}$	$1.6x10^{-10}$	$3.6x10^{-10}$	$3.0x10^{-10}$
^{134}Cs	$2.2x10^{-15}$	$1.5x10^{-15}$	$2.5x10^{-10}$	$1.6x10^{-10}$	$4.6x10^{-10}$	$3.0x10^{-1}$
^{137}Cs	$2.1x10^{-15}$	$1.3x10^{-15}$	$2.4x10^{-10}$	$1.5x10^{-10}$	$4.5x10^{-10}$	$2.8x10^{-1}$
^{144}Ce	$8.7x10^{-15}$	$7.3x10^{-15}$	$1.2x10^{-9}$	$9.3x10^{-10}$	$2.3x10^{-9}$	$1.8x10^{-9}$

ACKNOWLEDGMENTS

The authors would like to take this opportunity to express their sincere thanks to the following people who, in spite of their busy schedule, took time to review the report and offered their valuable comments; the quality of the report has definitely been enhanced through their suggestions: J. Baum, R. Casey, L. Emma, A. Hull, L. Kalbach, C. Meinhold, R. Miltenberger, and J. Steimers.

There are numerous people in Safety and Environmental Protection and throughout the Laboratory who have, in some form or other, assisted in providing the necessary information. Their cooperation is gratefully acknowledged.

This report was typed by members of the Word Processing group. Their painstaking effort is commended and recognized. Special thanks goes to Marie Cooney for typing the tables and to Mary Wigger for her patience in helping us with all the minute details that go into completing the report.

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