Chapter 8

Radiological Dose

During 2001, the radiological dose to members of the public and the environment from the many research facilities and scientific activities conducted at Brookhaven National Laboratory was minimal and well below regulatory limits. The radiological dose was calculated for inhalation, ingestion, and skin absorption pathways to show compliance with National Emissions Standard for Hazardous Air Pollutants, and Department of Energy regulatory dose limits.

The ambient on-site external dose was 75.5 ± 10 mrem (755 ± 100 µSv) per year and the off-site ambient external dose was 71.5 ± 7.9 mrem (715 ± 79 µSv) per year, both of which include natural background. A statistical comparison of the on-site and off-site average dose values indicated that there was no additional dose contributed by BNL operations above the natural background. The effective dose to the maximally exposed individual from the air pathway was estimated at 0.14 mrem (1.4 µSv) per year. The annual effective dose equivalent to an individual from consuming venison and fish (ingestion pathway) was estimated at 2.4 mrem (24 µSv). The total dose impact to an individual from all pathways was estimated to be 2.5 mrem (25 µSv). In comparison, the EPA regulatory limit for the air pathway is 10 mrem (100 µSv) and the DOE limit from all pathways is 100 mrem (1,000 µSv).

Additionally, 16 on-site remediation projects were evaluated for radiological air emissions; the dose impact from all of them was determined to be insignificant. The dose from BNL operations to aquatic and terrestrial biota was also found to be insignificant and comparable to natural background levels.

8.1 DIRECT RADIATION MONITORING

In addition to monitoring effluents and performing pathway analysis, BNL measures direct penetrating radiation exposures to determine possible external doses of radiation that may be received by the public. The primary purpose of this monitoring is to measure the background level of radiation and the maximum radiation doses, if any, received by members of the public from direct gamma radiation that originates with BNL operations.

Direct penetrating gamma radiation cannot be collected by filters or chemically trapped in any media, but is directly measured using thermoluminescent dosimeters (TLDs). The principle of TLD operation is that when crystals are exposed to penetrating gamma radiation, impurities are excited to higher energy states and remain in that state at normal ambient temperature. When the TLDs are heated, electrons are released and the crystal returns to the lower state of energy. The released electrons are in the form of photon energy, which is measured with a photomultiplier tube; the light intensity is proportional to the absorbed dose of radiation.

The environmental TLDs at BNL are composed of calcium fluoride (CaF_2: Dy) and lithium fluoride (LiF: Mg, Ti). The accuracy of the TLDs is tested with known sources of radiation exposure and using inter-comparison participation programs. The device that reads the dosimeter is calibrated to read *absorbed* dose, the quantity of energy deposited by radiation in the given material.

To evaluate the potential impact of BNL operations, TLDs are deployed at BNL and off site, where members of the public reside. On-site locations are selected based on the potential for exposure to gaseous plumes, atmospheric particulates, and radiation-generating facilities. The BNL site is divided into grids and the TLDs are assigned numbers based on these grids. The off-site TLDs do not have the grid numbers; instead, each is assigned a unique numerical identifier. The on-site and off-site TLDs are collected and read quarterly to determine the direct external radiation dose to members of the public and the environment.

Forty-one TLDs were posted on the BNL site and 17 were deployed off site in 2001, as shown in Figures 8-1 and 8-2, respectively. An additional 30 control TLDs were stored in a lead-shielded container in the Instrumentation Building, Bldg. 535. Note that it is not possible to completely shield the control devices from all natural and cosmic radiation.

Table 8-1 shows the quarterly on-site radiation measurements registered by the TLDs. The average on-site external doses for the first, second, third, and fourth quarters were

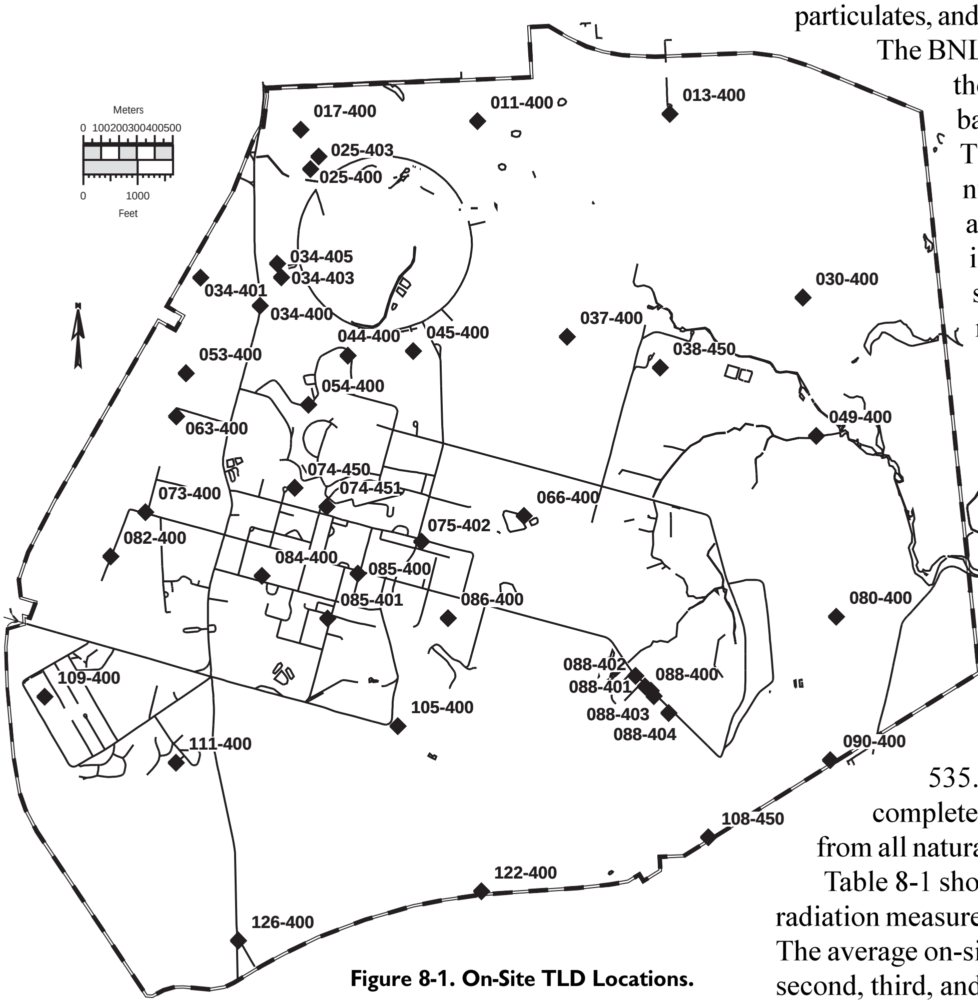

Figure 8-1. On-Site TLD Locations.

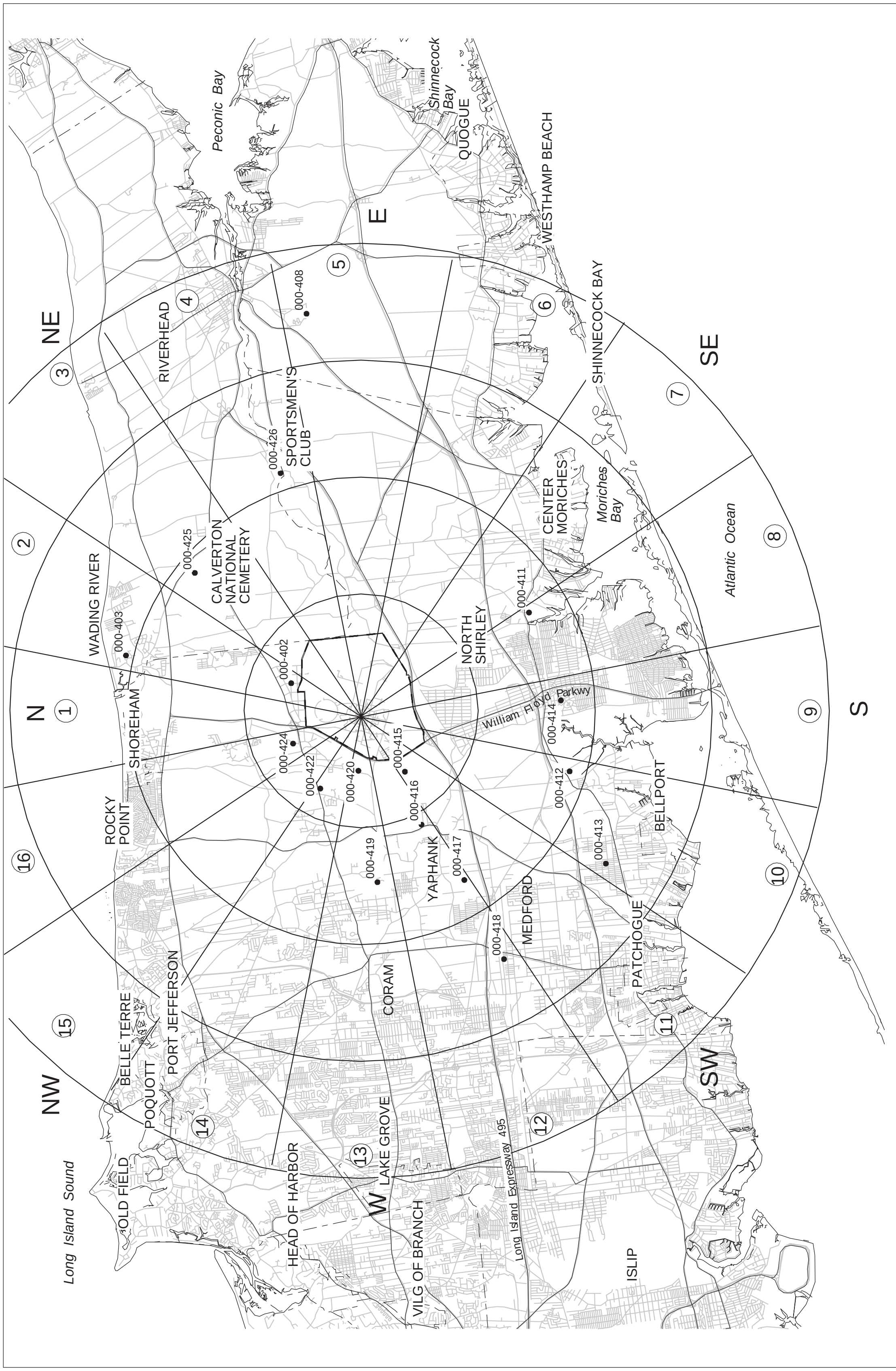

Figure 8-2. Off-Site TLD Locations.

Table 8-1. On-Site Direct Radiation Measurements.

TLD#	Location	1st Quarter (mrem)	2nd Quarter (mrem)	3rd Quarter (mrem)	4th Quarter (mrem)	Average 2 σ (95%) (mrem)	Annual Dose 2 σ (95%) (mrem)
011-400	North Firebreak	17.0	16.9	18.7	18.9	17.9 ± 2.1	71.5 ± 8.4
013-400	North Firebreak	17.6	19.3	17.7	18.0	18.2 ± 1.5	72.6 ± 6.1
017-400	P-2	16.5	15.9	15.2	17.2	16.2 ± 1.7	64.8 ± 6.6
025-400	Bldg.1010 beam-stop 1	20.2	18.5	16.7	18.3	18.4 ± 2.8	73.7 ± 11.2
025-403	Bldg.1010 beam-stop 4	20.5	20.3	17.3	20.1	19.6 ± 2.9	78.2 ± 11.8
030-400	NE Firebreak	16.9	15.7	14.7	17.8	16.3 ± 2.6	65.1 ± 10.6
034-400	North Access Rd	19.9	19.5	17.9	20.1	19.4 ± 1.9	77.4 ± 7.8
034-401	North Met.	19.9	18.7	20.1	20.7	19.9 ± 1.6	79.4 ± 6.5
034-403	Bldg.1008 collimator 2	19.7	20.1	17.8	18.9	19.1 ± 2.0	76.5 ± 7.9
034-405	Bldg.1008 collimator 4	22.5	20.0	NR	22.9	21.8 ± 3.1	87.2 ± 12.3
037-400	S-13	19.7	16.9	16.2	18.4	17.8 ± 3.1	71.2 ± 12.2
038-450	S-5	17.6	15.6	16.3	18.2	16.9 ± 2.3	67.7 ± 9.3
044-400	Bldg. 1006	35.4	23.7	18.7	20.7	24.6 ± 14.6	98.5 ± 58.3
045-400	Bldg.1005S	27.1	24.4	18.8	20.7	22.8 ± 7.2	91 ± 29.0
049-400	East Firebreak	16.8	14.7	14.6	17.8	16.0 ± 3.1	63.9 ± 12.4
053-400	West Firebreak	21.4	18.2	17.7	19.9	19.3 ± 3.3	77.2 ± 13.2
063-400	West Firebreak	19.4	17.2	17.7	21.3	18.9 ± 3.6	75.6 ± 14.5
066-400	Sump H-0	16.7	15.4	13.8	16.4	15.6 ± 2.5	62.3 ± 10.2
073-400	West Met/Bldg. 51	19.5	19.3	20.6	20.5	20.0 ± 1.3	79.9 ± 5.2
074-450	Bldg. 197	21.2	19.9	25.5	21.2	22.0 ± 4.8	87.8 ± 19.1
074-451	Bldg. 907	23.6	17.5	18.2	18.9	19.6 ± 5.4	78.2 ± 21.5
075-402	Bldg. 356	26.0	19.6	21.7	30.1	24.4 ± 9.1	97.4 ± 36.4
080-400	East Firebreak	18.7	16.6	17.1	22.5	18.7 ± 5.2	74.9 ± 20.8
082-400	West Firebreak	20.6	20.1	19.2	21.8	20.4 ± 2.1	81.7 ± 8.5
084-400	Tennis Courts	19.2	17.6	18.8	20.1	18.9 ± 2.0	75.7 ± 8.1
085-400	TFCU (Credit Union)	21.1	19.1	21.3	19.1	20.2 ± 2.4	80.6 ± 9.5
085-401	Upton gas station	20.0	17.5	17.1	20.0	18.7 ± 3.1	74.6 ± 12.2
086-400	BERA ball fields	20.2	18.4	18.8	21.5	19.7 ± 2.8	78.9 ± 11.0
090-400	P-7	17.8	17.8	16.8	17.5	17.5 ± 0.9	69.9 ± 3.7
105-400	South Firebreak	18.1	18.1	18.0	23.9	19.5 ± 5.7	78.1 ± 22.8
108-450	Water Tower	17.8	19.0	18.5	18.2	18.4 ± 1.0	73.5 ± 3.9
109-400	P-4	17.9	17.5	16.5	17.7	17.4 ± 1.2	69.6 ± 4.9
111-400	Trailer Park	17.5	16.8	17.4	18.4	17.5 ± 1.3	70.1 ± 5.1
122-400	South Firebreak	17.2	15.1	16.6	18.2	16.8 ± 2.5	67.1 ± 10.1
126-400	South Gate	19.0	17.4	16.8	20.0	18.3 ± 2.9	73.2 ± 11.4
On-Site Average		20.0	18.2	17.4	19.9	18.9 ± 2.5	**75.5 ± 10.0**
2 sigma (95%)		± 7.1	± 4.1	± 4.3	± 4.8		
075-000	Control TLD average	9.2	9.9	9.3	10.3	9.7 ± 1.0	38.7 ± 4.0

Notes:
NR = TLD dose not reported from the device.
See Figure 8-1 for TLD locations.

20.0 ± 7.1, 18.2 ± 4.1, 17.4 ± 4.3, 19.9 ± 4.8 mrem, respectively. The yearly on-site external dose was 75.5 ± 10 mrem from all potential sources, which includes the contribution from natural radiation sources.

Table 8-2 shows off-site TLD readings, for comparison. The on-site and off-site external dose averages were 75.5 ± 10 and 71.5 ± 7.9 mrem, respectively. A statistical t-test result showed no variability in the two averages; therefore, it can be concluded that there was no dose contribution from BNL operations.

8.1.1 Facility Area Monitoring

Six of the 41 on-site TLDs were posted near facilities that had greater probability to

Table 8-2. Off-Site Direct Radiation Measurements.

TLD#	Location	1st Quarter (mrem)	2nd Quarter (mrem)	3rd Quarter (mrem)	4th Quarter (mrem)	Average 2 σ (95%) (mrem)	Annual Dose 2 σ (95%) (mrem)
000 - 402	Private Property	20.1	20.8	16.9	N.P	19.3 ± 4.1	77.1 ± 16.2
000 - 403	Private Property	NP	18.0	19.1	20.9	19.3 ± 2.9	77.4 ± 11.5
000 - 408	Private Property	NP	17.9	15.8	17.7	17.2 ± 2.2	68.6 ± 9.0
000 - 411	Private Property	20.0	17.1	17.6	18.5	18.3 ± 2.5	73.1 ± 10.0
000 - 412	Private Property	NP	19.4	19.8	21.5	20.2 ± 2.2	80.9 ± 8.9
000 - 413	Private Property	19.8	15.7	14.9	NP	16.8 ± 5.1	67.2 ± 20.3
000 - 414	Suffolk County CD	17.9	17.7	18.6	19.4	18.4 ± 1.5	73.7 ± 6.0
000 - 415	Private Property	16.5	15.6	17.1	17.0	16.5 ± 1.4	66.2 ± 5.4
000 - 416	Private Property	14.9	14.6	15.0	16.8	15.3 ± 1.9	61.3 ± 7.8
000 - 417	Private Property	17.0	17.0	17.1	19.7	17.7 ± 2.5	70.8 ± 10.2
000 - 418	Private Property	17.4	16.8	17.4	18.6	17.6 ± 1.5	70.2 ± 5.9
000 - 419	Private Property	15.8	15.7	15.2	19.1	16.5 ± 3.5	65.8 ± 14.1
000 - 420	Smith Estate	16.8	16.7	16.3	20.3	17.5 ± 3.6	70.1 ± 14.4
000 - 422	Private Property	14.7	19.8	16.4	19.5	17.6 ± 4.8	70.5 ± 19.4
000 - 424	Mid-Isl. Game Farm	18.2	17.7	17.5	20.1	18.4 ± 2.3	73.5 ± 9.2
000 - 425	Calverton Nat. Cem.	19.1	19.0	18.5	21.8	19.6 ± 2.9	78.4 ± 11.6
000 - 426	Sportsmen's Club	17.3	19.0	16.4	19.3	18.0 ± 2.7	72.1 ± 10.9
Off-Site Average		17.5	17.6	17.0	19.4	17.9 ± 2.0	**71.5 ± 7.9**
2 sigma (95%)		± 3.4	± 3.3	± 2.8	± 2.9		

Notes:
NP = TLD not posted at the location.
See Figure 8-2 for TLD locations.

contribute to the external dose. Table 8-3 shows the external TLD dose measurements from facility area monitoring. The TLDs posted at the S-6 location adjacent to the old Waste Management Facility, and on the fence there, showed higher external dose than normal background. This can be attributed to the presence of radioactive materials, contaminated soils, and radioactive sources being repackaged for shipment to an off-site disposal site. The old Waste Management facility is posted as a radiological area; only appropriately trained personnel with dosimeters are allowed inside the facility. The TLD near Building 914 (device 054-400) showed 237 mrem external dose for the first quarter and within the natural background for the third and fourth quarters. The higher reading was attributable to sky-shine phenomenon that occurs during the operation of the g-2 experiment.

Table 8-3. Facility Area Monitoring.

TLD#	Location	1st Quarter (mrem)	2nd Quarter (mrem)	3rd Quarter (mrem)	4th Quarter (mrem)	Average 2 σ (95%) (mrem)	Annual Dose 2 σ (95%) (mrem)
088-400	S-6	47.6	41.9	42.4	47.9	45.0 ± 6.3	179.8 ± 25.3
088-401	S-6 Fence	67.8	52.8	60.8	212.4	98.5 ± 148.6	393.8 ± 594.5
088-402	S-6 Fence	82.8	68.4	73.1	60.6	71.2 ± 18.1	284.9 ± 72.4
088-403	S-6 Fence	64.3	51.0	79.7	81.1	69.0 ± 27.7	276.1 ± 110.9
088-404	S-6 Fence	85.0	NR	55.2	53.5	64.6 ± 34.5	258.3 ± 138.2
054-400	Bldg. # 914	237.4	NR	34.7	34.7	102.3 ± 228.2	409.1 ± 912.8

Notes:
See Figure 8-1 for TLD locations.
NR = TLD dose not reported from the device.

8.1.2 Building 650 Sump Outfall Monitoring

The Building 650 sump outfall is a localized area of radiologically contaminated soils approximately 800 feet northeast of Building 650. This contamination area is being addressed under the Environmental Restoration Program as Operable Unit (OU) IV, Area of Concern (AOC) 6. Radionuclides identified in the AOC 6 soil include strontium-90, cesium-137, and isotopes of europium and plutonium. The area around the sump is fenced and posted as a radiological area to prevent unauthorized entry. Twenty-one TLDs are located within the sump area; an additional four TLDs are located on the fence, one at each compass direction (north, south, east, and west) (see Figure 8-3). Additionally, two control TLDs are kept in a lead-shielded container to provide background readings for comparison.

The TLD dose was measured for the first, second, and third quarters of 2001, as shown in Table 8-4. The fourth-quarter TLDs were not posted, as soil remediation work started during this period. Consistent with previous years, the data show that the highest concentration of radionuclides was at the C4 location. The annual dose measured at C4 was 1.18 rem (11.8 mSv). The external dose was highest along the grid line C4, D4, and E4. The second highest dose was along the C3, D3, and E3 grid lines. The third highest dose was measured along the C5, D5, and E5 grid lines. The monitoring data and soil characterization data suggest that the soil contamination was mostly spread from B4 to D2 and from B2 to E5 grid locations. The contamination reduces to normal background levels toward the fence line.

The dose measurements in all four directions at the fence line of the Building 650 sump area were similar to those of the control background TLDs, demonstrating that the radiation field was localized to the immediate area mentioned above. Entry into the sump outfall area is restricted to authorized personnel, and therefore, there was no exposure hazard to members of the public. Radiological dose to authorized personnel is monitored to ensure that their dose stays below BNL administrative control levels, and is As Low As Reasonably Achievable (ALARA).

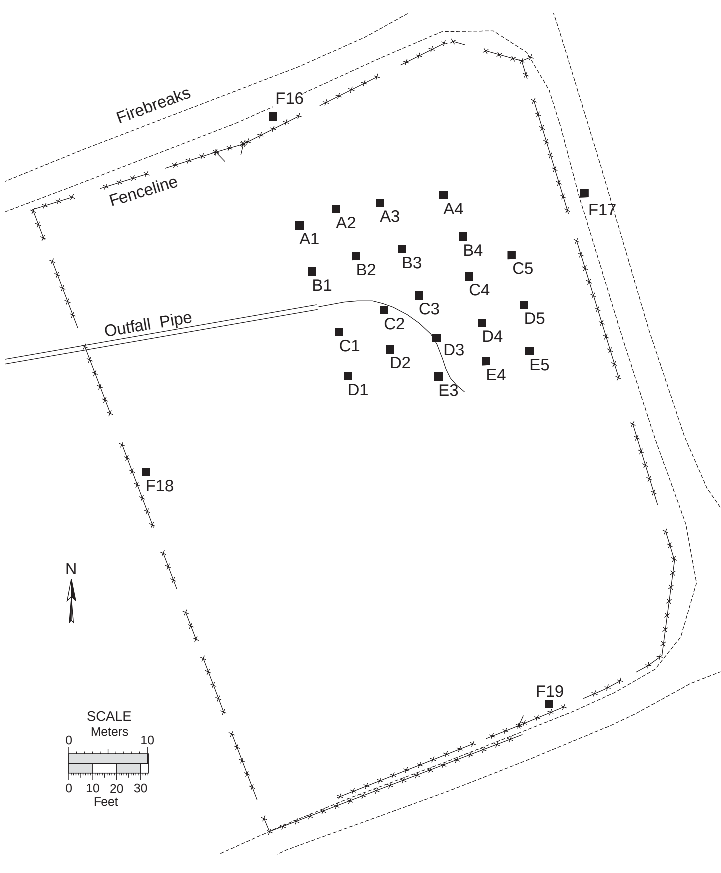

Figure 8-3. Building 650 Sump Outfall TLD Network.

8.2 AIR EMISSIONS

The U.S. Environmental Protection Agency (EPA) regulates the airborne emissions from DOE facilities under the 40 CFR 61, Subpart H, *National Emissions Standard for Hazardous Air Pollutants* (NESHAPs) requirements. This regulation specifies the compliance monitoring and requirements for reporting radiation doses received by members of the public from airborne radionuclide emissions. The regulations mandate that no member of the public shall receive a dose from air emissions greater than 10 mrem (100 μSv) per year from DOE operations. The emissions monitoring requirements set forth in Subpart H of 40 CFR Section 61.93(b) include the use of a reference method for continuous monitoring at major release points (those with a potential to exceed 1 percent of the 10-mrem/yr standard), and a periodic confirmatory measurement program for all other release points. The regulations also require DOE facilities to submit

Table 8-4. Building 650 Sump Outfall TLD Network (2001).

TLD# Location	1st Quarter (mrem)	2nd Quarter (mrem)	3rd Quarter (mrem)	Average 2 σ (95%) (mrem)	Annual Dose 2 σ (95%) (rem)
A1	19.5	20.3	18.5	19.4 ± 1.8	0.08 ± 0.01
A2	60.2	70.5	62.7	64.5 ± 10.5	0.26 ± 0.04
A3	23.6	23.7	23.8	23.7 ± 0.2	0.09 ± 0
A4	18.4	19.9	18.5	18.9 ± 1.6	0.08 ± 0.01
B1	17.6	16.9	16.0	16.8 ± 1.5	0.07 ± 0.01
B2	30.3	36.2	31.0	32.5 ± 6.3	0.13 ± 0.03
B3	60.3	76.3	68.3	68.3 ± 15.6	0.27 ± 0.06
B4	29.9	37.4	26.6	31.3 ± 10.8	0.13 ± 0.04
C1	18.8	20.7	20.6	20.0 ± 2.1	0.08 ± 0.01
C2	36.0	45.8	44.7	42.2 ± 10.5	0.17 ± 0.04
C3	118.4	153.6	159.7	143.9 ± 43.5	0.58 ± 0.17
C4	249.7	317.2	316.1	294.3 ± 75.4	1.18 ± 0.30
C5	24.6	31.5	29.5	28.5 ± 6.9	0.11 ± 0.03
D1	18.3	19.2	21.5	19.7 ± 3.2	0.08 ± 0.01
D2	24.0	29.6	28.0	27.2 ± 5.6	0.11 ± 0.02
D3	95.1	119.4	118.8	111.1 ± 27.1	0.44 ± 0.11
D4	159.7	171.3	179.9	170.3 ± 19.8	0.68 ± 0.08
D5	46.4	56.5	54.7	52.5 ± 10.5	0.21 ± 0.04
E3	83.5	94.5	90.8	89.6 ± 10.9	0.36 ± 0.04
E4	115.9	132.9	128.8	125.9 ± 17.3	0.5 ± 0.07
E5	90.5	92.8	ND	91.6 ± 3.2	0.37 ± 0.01
Fence N	13.6	13.7	12.7	13.3 ± 1.1	0.05 ± 0
Fence S	13.2	12.5	12.2	12.6 ± 1.0	0.05 ± 0
Fence E	15.8	14.1	16.7	15.5 ± 2.6	0.06 ± 0.01
Fence W	16.3	14.2	15.1	15.2 ± 2.1	0.06 ± 0.01
BKGD1	15.4	15.5	15.9	15.6 ± 0.2	0.06 ± 0
BKGD2	13.2	14.6	14.8	14.2 ± 0.7	0.06 ± 0.01

Notes:
ND = No dose (TLD lost in the field).
See Figure 8-3 for TLD locations.

an annual NESHAPs report to EPA that describes the air emissions from all sources.

As part of the NESHAPs review process, all BNL programs and diffuse sources that have any potential to produce radioactive airborne emissions were evaluated. Although activities conducted by the Environmental Restoration Division (ERD) that generate airborne emissions are exempt under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), all activities with any potential to emit radioactive emissions were assessed for potential dose to the members of the public. Using the above criteria, a number of ERD and waste management operations were evaluated in 2001 using a computer modeling program (see Section 8.2.1 for details). The program that is used is explicitly designed to model continuous airborne radioactive emissions that occur over the course of a year. It is not well-suited for estimating short-term or acute releases. Given this limitation, the evaluations conservatively treated potential emission sources as if they were continuous annual sources that do not end with the cessation of ERD activities. Since these were diffuse sources with short-term activities, their potential dose impact was not included in the BNL summary of point sources, discussed in Section 8.2.4. Dose from air emissions sources at BNL is presented in Table 8.5.

8.2.1 Dose Modeling Program

Compliance with NESHAPs regulations is demonstrated through the use of EPA's CAP88-

PC (Clean Air Act Assessment Package-1988), version 2. This computer code uses a Gaussian plume model equation to estimate the average dispersion of radionuclides released from elevated stacks or diffuse sources (EPA 1992). The program computes radionuclide concentrations in air, rates of deposition on ground surfaces, and concentrations in food (where applicable) to calculate a final value for projected dose at the specified distance from the release point. The program supplies both the calculated effective dose equivalent (EDE) to the maximally exposed individual (MEI) and the collective population dose within a 50-mile radius of the emission source. This model provides very conservative dose estimates in most cases. For purposes of modeling the dose to the MEI, all emission points are located at the center of the developed portion of the BNL site. The modeling programs are based on low-level environmental releases and chronic intakes. Model input parameters include radionuclide type, emission rate in curies per year, stack parameters such as height and diameter, and emission exhaust velocity. Site-specific weather and population data were factored into the assessments. Weather data from BNL's meteorological tower included wind speed, direction, frequency, and temperature (details in Climatic data section of Chapter 1). Population data used in the model were based on the Long Island Power Authority population survey (LIPA 1999). Since visiting researchers and their families may reside at the BNL on-site apartment area for extended periods of time, these residents were also included in the population file used for dose assessment.

8.2.2 Maximally Exposed Individual

The MEI is defined as a hypothetical person with residence and lifestyle such that no other member of the public can receive a higher dose than this individual. This person is assumed to live 24 hours a day, 365 days a year at the BNL boundary in the downwind direction, and consume contaminated fish and deer during the year. In reality, it is a highly unlikely worst-case scenario that such a combination of maximized dose to any single individual would occur.

8.2.3 Dose from Diffuse and Nonpoint Sources

Diffuse sources are sources of radioactive contaminants (emissions) released into the atmosphere that do not have a defined point. Such sources are also known as nonpoint sources or area sources. In 2001, 16 nonpoint sources were evaluated for potential dosage.

8.2.3.1 Insulating Gas in the TVDG Accelerator

The Tandem Van de Graaff Generator (TVDG) Accelerator contains an insulating gas composed of SF_6 (50 percent), N_2 (35 percent), CO_2 (10 percent) and O_2 (5 percent) by volume. Due to the deuteron beam loss/interaction at the charge-exchange region, thermal neutrons are produced that activate the insulating gas in the accelerator. The total volume of the insulating gas was estimated at 11,250 cubic feet, with a 3 percent loss of insulating gas over the course of one year. A NESHAPs evaluation was completed to assess dose impact to members of the public and the environment. The neutron activation of the insulating gas and air emissions were based on calculations in Appendix 3, Table 6, of Unreviewed Safety Issues (USI) memo dated September 14, 2001 (BNL 2001). A conservative estimate of the effective dose equivalent was 1.9E-08 mrem/year to the MEI at 100 meters northwest of the source.

8.2.3.2 Brookhaven Graphite Research Reactor – Below Ground Duct Filters/Coolers Removal

During 2001, the BGRR work package included removing the primary exhaust filters and exhaust air-cooling coils, then removing and remediating dust and debris left behind. In the Safety Evaluation (BGRR-SE-01-03), a NESHAPs evaluation was completed on the potential reasonable inventory of radionuclides that could be released to the environment. The potential source term was based on 50 percent of the entire maximum inventory listed in the safety scenario as "potentially" released into the environment for the purpose of dose calculations. The remediation project was initiated on November 19, 2001, and was completed on January 15, 2002. The work was performed under a temporary portable tent with HEPA filtration. The potential radiological dose impact from the removal of belowground ducts and a cooler was evaluated for NESHAPs compliance, and the potential effective dose equivalent was estimated as 8.7E-02 mrem/year to the MEI at the west-southwest location.

8.2.3.3 Brookhaven Graphite Research Reactor – Water Treatment House, Building 709A

The purpose of this phase of the BGRR decommissioning project was to remove the aboveground Canal House (Building 709) and Water Treatment House (Building 709A). The first part of the activity was to de-energize and remove abandoned equipment from the Canal and Water Treatment Houses; the second part was to demolish the houses to grade elevation. Building 709 had a canal that was connected into the deep pit area of Building 701. Building 709 was metal framed and sided with "cemestos," a mixture of cement and asbetos. It was approximately 39 feet long, 15 feet wide, and 19 feet high, with a layered, builtup roof. When the reactor was refueled, spent fuel was placed into the deep pit and moved underwater to the Canal House, where it was prepared and loaded into casks for shipment. Attached to Building 709 was Building 709A, a concrete block structure approximately 39 feet long, 14 feet wide, and 12 feet high, with a layered builtup roof. It had cells, separated by walls, that contained the water filtering and purification equipment used to maintain the canal's water chemistry and clarity.

The interior surface of both buildings had loose surface contamination that was handled in accordance with the radiological control procedures. The cemestos siding was handled with asbestos abatement procedures. The project was initiated on July 09, 2001 and continued into 2002. When a NESHAPs evaluation was completed for potential radioactive airborne emissions, the calculation for potential EDE yielded a conservative estimate of 1.9E-03 mrem/year to the MEI at the northeast location.

8.2.3.4 Brookhaven Graphite Research Reactor – Lower Canal and Water Treatment House Removal

The purpose of this project (BGRR-SE-01-02) was to remove the pad area that surrounds the canal and water treatment house, the lower canal-piping system, and the east yard sump, and to remediate surface soil to meet cleanup criteria. The surface soils extended about 120 feet east of Building 701 and 160 feet south of Building 703. The project was carried out with proper safety and health procedures and in accordance with the radiological control procedures. The potential for radioactive emissions during the removal of this structure was evaluated for NESHAPs compliance. The synopsis report from CAP88-PC, version 2.0, provided a conservative EDE estimate of 1.7 mrem/year to the MEI at the southwest location. Therefore, continuous air sampling and analysis was implemented. The project was started on March 26, 2001 and completed on July 10, 2001. Continuous air sampling of air emissions from the remediation project showed no measurable radioactivity above background on the filters; therefore, there was minimal impact from the project.

8.2.3.5 Brookhaven Graphite Research Reactor – Temporary HEPA Filtered Hood

During the Geoprobe™ soil boring beneath the belowground ducts at the BGRR, contaminated soil was encountered with readings greater than 140 μR/hr. Therefore, it was decided to perform the work under a temporary portable hood with HEPA filtration. The project lasted for a few weeks in August 2001.When the potential effective dose equivalent was evaluated for NESHAPs compliance, the potential effective dose equivalent was estimated as 1.1E-04 mrem/year to the MEI at the northwest location.

8.2.3.6 Building 830 Vault, B-25s, and Drums

The scope of this project was to characterize and develop a radiological waste profile for the Building 830 vault, ten B-25 containers, and three 55-gallon drums. The waste content consisted of process pipes, tanks, and sludge and/or tree branches. Characterization and a waste stream profile were necessary, in accordance with waste acceptance criteria (WAC) of the disposal site, before proper shipping and disposal could be accomplished. The waste was repackaged and shipped in accordance with the WAC outlined by Envirocare of Utah. The waste characterization process, carried out in August 2001, included a combination of process knowledge, sampling and analysis of the waste, and the In-Situ Object Counting System (ISOCS). When the potential dose from radioactive air emissions was evaluated for NESHAPs compliance, a conservative estimate of the effective dose equivalent was 1.7E-04 mrem/year to the MEI at the north-northwest location.

8.2.3.7 Building 650 Sump Outfall

Radiological contamination is present in soils at Building 650 (the reclamation facility) and in the sump outfall east of the facility. This facility was used from the late 1950s through late 1960s to clean radioactive contaminants from clothing and equipment. Radiologically contaminated heavy equipment was decontaminated on a concrete pad adjacent to Building 650. The liquid drained from this pad was contained in underground storage tanks. In 1969, it was determined that under certain valve conditions, liquid from the underground tanks was inadvertently being routed to a depression in a wooded area approximately 800 feet northeast of Building 650. This depression is referred to as the Building 650 Sump Outfall. The sump outfall is a source of localized radiological soil and groundwater contamination that will be remediated under the Environmental Restoration Program (Operable Unit IV, Area of Concern 6). Radionuclides identified in the soil include americium-241, strontium-90, cesium-137, cobalt-60, and isotopes of europium and plutonium. The potential for radioactive emissions from the Building 650 Sump Outfall were evaluated for NESHAPs compliance. The potential effective dose equivalent was estimated as 4.0E-02 mrem/year to the MEI at the southwest location.

8.2.3.8 Building 811, Underground Storage Tanks

The remedial action plan for AOC 10C (the Building 811 Waste Concentration Facility) includes removal of six 8,000-gallon stainless steel underground storage tanks (USTs) located about 23 feet below the existing grade. These USTs were used to store Class A and B radioactive liquid wastes. The radioactive sludge and liquids from the six USTs were removed and stabilized. The USTs were rinsed and an absorbent material was placed at the bottom of the tanks. Small amounts of radioactive materials, as removable and nonremovable contamination, may be present in these tanks. During the dismantling and size reduction process, there was a potential for airborne particulates, so a NESHAPs evaluation was performed in January 2001. The potential effective dose equivalent from radioactive emissions during the dismantling and size reduction phase of the remediation activity was 6.0E-03 mrem/year to the MEI at the southwest location.

8.2.3.9 Building 811 Soil Removal

This remedial action involved the removal of approximately 700 cubic yards of soil in the vicinity of Building 811. The soil was sprayed with water mist to reduce or eliminate chance that particulates would become airborne during the soil disturbance. Safety standards called for work to be halted if the sustained wind speed reached greater than 25 miles per hour. The immediate area of excavation was monitored and the potential for radioactive emissions from soil excavation activity in the vicinity was evaluated for NESHAPs compliance in May 2001. The effective dose equivalent was estimated to be 8.5E-3 mrem/year to the MEI at the northeast location.

8.2.3.10 Tritium Bottles

Two lecture bottles containing tritium gas were evaluated for release through the High Flux Beam Reactor (HFBR) stack. The total volume of tritium expected to be released from the two lecture bottles was 6.25 cubic feet. The tritium activity in the first lecture bottle, as of 1996, was 20 mCi; the second bottle had 0.5 μCi, as of 1998. After decay correction, the quantity of tritium vented was much lower, but the potential airborne source term was based on the information provided on the 1996 and 1998 inventories. The potential effective dose equivalent was estimated to be 8.7E-08 mrem/year to the MEI at the northwest location.

8.2.3.11 Plasma Torch Cutting Project

This project at the former Hazardous Waste Management Facility entailed using a plasma torch to cut up a stainless steel frame (#35-114 on Radiation Waste Control Form 28098), a half -circle metal plate (# 65 on RWCF 28061), and a carbon steel plate (#04-038 on RWCF 38053). The plasma torch cutting method was chosen as it creates less splatter and contamination than other methods of cutting. The WAC specified that the dimensions of the cut pieces would not exceed 10 inches wide and 10 feet long. Approximately 20 cuts were made to the frame and plates to meet the proper acceptance criteria for packaging, transport, and disposal at the waste site. These materials were activated with possible volumetric contamination but had minimal surface contamination. The potential airborne source term was based on the information provided and on previous sampling results. The EDE was calculated to be 5.3E-1 mrem/year to the MEI at a distance of 105 meters from the cutting operation. The project was completed between September 10, 2001 and December 21, 2001. The emissions from the operation were monitored and there was insignificant dose impact to the members of the public and the environment.

8.2.3.12 Tritium Ball

The tritium ball was a functional part of the Tandem Van de Graaff Generator in the past but was removed from service and placed in storage at the former HWFM awaiting off-site disposal. The ball was a steel sphere mounted on steel supports. The purpose of the tritium ball project was to reduce the size of the ball and then dispose of the pieces. However, before this project could commence, a small residual inventory of tritium in the ball required evaluation as a potential diffuse source for air emissions. The NESHAPs evaluation was completed and the effective dose equivalent was estimated to be 1.5E-6 mrem/year to the MEI at the southwest location.

8.2.3.13 Proposed Booster Applications Facility

The Department of Energy, the National Aeronautical and Space Administration, and the Department of Defense have identified a need for a research facility that could conduct space radiation research. The Booster Applications Facility (BAF) would be such a facility, with a new beam tunnel branching from the AGS Booster ring, a target room, and beam stop. A proton or heavy ion beam from the AGS Booster will travel through a 27-meter beam line tunnel, at which point it will be diverted 20 degrees and travel through an 80-meter long beam tunnel, where it will enter the BAF target room. The radiation fields in the target room have the potential to generate air activation products that could be released to the atmosphere. A NESHAPs evaluation was completed based on the air activation source term and the potential radiological dose impact was estimated to be 9.7E-06 mrem/year at the northeast boundary.

8.2.3.14 The V - Target Area, Building 919

The V-Target project had an expansion tank and vents into an enclosed room. The air was vented through an exterior door. Evaporation of the cooling water from these expansion tanks could potentially generate airborne emissions. Therefore, the project was evaluated for fugitive source emissions. An effective dose equivalent of 5.3E-6 mrem/year to the MEI was estimated at the southwest location.

8.2.3.15 Special Experimental Magnets System Cooling Towers

The Special Experimental Magnets System cooling towers had 200 liters of residual water that was contaminated with tritium, manganese-54, and cobalt-60. It was anticipated that a substantial portion of the liquid would evaporate and could be a potential fugitive source for radiological airborne emissions. Therefore, a NESHAPs evaluation was conducted to assess dose impact to the members of the public and the environment. A conservative estimate of the potential effective dose equivalent was 1.7E-7 mrem/year to the MEI at the west-southwest location.

8.2.3.16 Liquid Effluent Storage Tankers

The Collider-Accelerator Department uses three tankers, each with a capacity of 7,000 gallons, to store radiologically contaminated aqueous waste from the Special Experimental Magnets. The tankers are heated and the lid of the tankers has an open vent. It is anticipated that a substantial amount of the liquid will evaporate during the heating and venting of the tankers, and could be a potential diffuse source for radiological airborne emissions. Since the liquid waste has known quantities of tritium, manganese-54, and cobalt-60, a worst-case scenario with maximum concentrations was assumed. A NESHAPs evaluation provided a conservative estimate of effective dose equivalent of 8.6E-5 mrem/year to the MEI at the southwest location.

8.2.4 Dose from Point Sources

8.2.4.1 Building 931: The Brookhaven Linac Isotope Producer

As stated in last year's *Site Environmental Report*, the Brookhaven Linac Isotope Producer (BLIP) tank experienced corrosion due to an accumulation of moisture at the tank base. To mitigate the problem, a dehumidifier system was installed; the system became operational on February 20, 2001. Heated air from this unit is forced down the 16-inch outer diameter shaft, past shielding plugs and into the airspace below the tank. The entry of the dried air into the hot cell exhaust system is on the upstream side of the HEPA filter.

In the past, the BLIP facility was considered a "minor source" that required only periodic confirmatory sampling to show compliance with NESHAPs regulations. In 2000, the BLIP facility operated for just 63 days, from January 02, 2000 to March 16, 2000. The facility is continuously monitored for particulates and tritium, but the air emissions of both are insignificant. Short- lived gases are the dominant air emissions and were periodically estimated using the conversion factor of 0.30 mCi/μA-hours of operation for oxygen-15. However, a unit conversion error was discovered in March 2001 after the stack emissions were sampled in February 2001. The 2000 air emissions were reported based on a corrected conversion factor of 10.8 mCi/μA-hours. The total air emissions for the BLIP facility were reported in the 2000 SER at 1,070 curies of oxygen-15 and 2.46E-04 curies of tritium, and the effective dose equivalent was estimated to be 2.2E-03 mrem/year.

The BLIP facility was operational throughout calendar year 2001 except for May through July. In August, the short-lived gaseous characterization project was undertaken to: 1) measure and confirm flow rates; 2) sample, analyze, and quantify the short-lived gases; 3) calculate the effective dose equivalent to the MEI; and 4) confirm compliance with NESHAPs regulations. The sampling and analysis were completed in accordance with 40 CFR 61, Appendix B, Method 114. The radioactive gaseous emissions were measured directly with an in-line sampling system from the air exhaust by using a low-level NaI gamma spectrometer.

The BLIP facility emissions in 2001 were evaluated as contributing an EDE of 0.14 mrem (1.4 μSv) from short-lived gases O-15 and C-11. This dose exceeded 1 percent of the NESHAPs standard, with large uncertainty associated with sampling and characterization of the short-lived gaseous emissions. This dose estimate requires continuous sampling of the source. Historically, BLIP emissions had been characterized as a "minor emissions" source, but during 2001, the emissions exceeded 1 percent of the standard due to extra beam irradiation time. Discussions with EPA were initiated to determine cost effective and acceptable methods to control and/or monitor air emissions from the BLIP facility.

8.3 INGESTION PATHWAY

As discussed in Chapter 6, fish from Peconic River and deer that could have grazed on the BNL site were analyzed to assess the potential dose estimates to an MEI. To evaluate the dose impact, it was assumed that the MEI consumed 15 pounds of fish and about 64 pounds of venison per year (NYSDOH 1999).

Twenty-six samples of meat and 15 samples of liver were analyzed from the deer that were involved in car accidents on and off site within a 1-mile radius of BNL. Potassium-40 and cesium-137 were the two radionuclides detected in these samples. The average potassium-40 concentrations were 2.8 ± 0.5 pCi/g in the flesh and 2.4 ± 0.6 pCi/g (wet weight) in the liver. The average

Table 8-5. Effective Dose Equivalent from Airborne Emissions.

Building	Facility or Process	Construction Permit No.	MEI Dose (mrem)	Notes (a)
463	Biology Facility	None	2.00E-16	(b)
490	Radiation Therapy Facility	BNL-489-01	2.00E-05	(b)
490D	Environmental Biology& Instrumentation	None	ND	
491	Brookhaven Medical Research Reactor	None	ND	
510	Calorimeter Enclosure	BNL-689-01	6.00E-14	(b)
535	Instrumentation	None	1.40E-09	(b)
555	Chemistry Facility	None	1.20E-14	(b)
703	Analytical Laboratory	None	ND	
725	National Synchrotron Light Source	None	8.00E-09	(b)
750	High Flux Beam Reactor	None	2.30E-05	
801	Target Processing Lab	None	3.00E-05	
802B	Evaporator Facility	BNL-288-01	ND	
820	Accelerator Test Facility	BNL-589-01	ND	(c)
830	Environmental and Waste Mgmt.	None	ND	
919	Liquid Effluent Storage Tankers	None	9.00E-05	
931	Brookhaven Linac Isotope Producer	None	1.40E-01	
938	Radiation Effects Facility	BNL-789-01	ND	(d)
942	Alternating Gradient Synchrotron Booster	BNL-188-01	ND	(e)
—	Relativistic Heavy Ion Collider	BNL-389-01	ND	
Total from BNL Operations			**0.14 mrem**	
EPA Limit			**10.0 mrem**	

Notes:
(a) "Dose" as used in this table means effective dose equivalent.
(b) Calculations are based on 40 CFR 61, Appendix D methodology.
ND = No-dose facility: Not operational or no air emissions in 2001.
(c) This has become a zero facility since the original permit.
(d) This facility is no longer in use.
(e) Booster ventilation system prevents air release through continuous air recirculation.

cesium-137 concentrations were 1.6 ± 0.3 pCi/g in the flesh and 0.6 ± 0.1 pCi/g (wet weight) in the liver. Potassium-40 occurs naturally and is not related to BNL operations. The potential dose from eating deer meat with the average cesium-137 concentration was estimated as 2.3 mrem (23 µSv) per year, about 23 percent of the advisory limit of 10 mrem (100 µSv) set by the New York State Department of Health.

Three fish samples, two largemouth bass and a pumpkinseed fillet, were analyzed for beta/gamma emitters; again, potassium-40 and cesium-137 were detected in these samples. These fish samples were collected from Peconic River at Schulz Road just outside the BNL site boundary. The average potassium-40 concentration was 2.9 ± 0.1 pCi/g and the average cesium-137 concentration was 0.3 ± 0.0 pCi/g wet

Table 8-6. BNL Site Dose Summary.

Pathway	Dose to Maximally Exposed Individual	Percent of DOE 100 mrem/year Limit	Estimated Population Dose
Air	0.14 mrem (1.4 µSv)	0.14%	0.57 person-rem
Water	None	None	None
Ingestion	2.4 mrem (24 µSv)	2.40%	Not tracked
All Pathways	2.5 mrem (25 µSv)	2.50%	0.57 person-rem

weight. The potential dose was estimated to be 0.1 mrem (1 µSv) per year from eating 15 pounds of fish.

8.4 CUMULATIVE DOSE

The cumulative dose impact to the MEI from the air and ingestion pathways was 2.52 mrem (25 µSv), as shown in Table 8-6. This dose is well below the DOE regulatory limits, 100 mrem (1,000 µSv) and within nominal background levels. The potential dose from drinking water was not estimated, as the residents adjacent to the BNL site get their drinking water from the Suffolk County Water Authority. Table 8-6 summarizes the cumulative dose from the BNL site.

To put the potential dose impact into perspective, a comparison was made with other sources of radiation. The annual dose from all natural background sources and radon is about 360 mrem (3.6 mSv) per year. A chest x-ray would result in 5 to 20 mrem per exposure. Using natural gas in homes yields about 9 mrem per year, cosmic radiation gives 26 mrem per year dose to humans, and natural potassium in the body gives about 39 mrem per year internal dose. Furthermore, the dose estimates from deer and fish consumption are overly conservative.

8.5 DOSE TO AQUATIC AND TERRESTRIAL BIOTA

DOE has developed draft screening methods to estimate radiological doses to aquatic animals, terrestrial plants, and terrestrial animals using the environmental surveillance data. These methods can be used to evaluate compliance with the requirements for protection of biota specified in DOE Order 5400.1 (1988), *General Environmental Protection Program*, DOE Order 5400.5 (1990), *Radiation Protection of the Public and the Environment*, and proposed Rule 10 CFR 834, Subpart F (66 FR 25380). The absorbed dose to aquatic animals and terrestrial plants should not exceed 1 rad/day (10 mGy/day). Terrestrial animals should not be exposed to more than 0.1 rad/day (1 mGy/day). Based on the biota screening methods and very low concentrations detected in the samples, it was concluded that there was insignificant radiological dose to aquatic animals, terrestrial plants, and terrestrial animals from BNL operations.

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