Chapter 8

Radiological Dose Assessment

Radioactive materials are used in many research activities at Brookhaven National Laboratory. The radiological impact of these materials and potential effective dose equivalents to members of the public from various pathways such as inhalation, ingestion, and skin absorption were evaluated to show compliance with EPA and DOE regulatory limits. During 2000, very low levels of radioactive gaseous and particulate emissions were released from facility operating stacks and ventilation exhausts.

BNL operations had minimal radiological dose impact to the public and the environment. The ambient external dose measured at BNL was similar to background levels. The effective dose equivalent to the maximally exposed individual from air emissions was calculated to be 0.18 mrem (1.8 μSv). This dose is insignificant when compared to the EPA regulatory public air-dose limit of 10 mrem/yr (100 μSv/yr). The annual effective dose equivalent to an individual consuming contaminated fish and deer was 3.10 mrem (31 μSv). The maximum dose impact to the individual from both the air and food pathways combined was 3.28 mrem (33 μSv). This is less than 4% of the DOE regulatory dose limit for members of the public from all pathways which is 100 mrem (1000 μSv).

Five remediation projects with potential air emissions of radionuclides in excess of 1% of the National Emissions Standards for Air Pollutants were also evaluated. This evaluation showed that the cumulative effective dose equivalent from all of these sources was 0.11 mrem (1.1 μSv).

In 2000, the dose to aquatic and terrestrial biota was also evaluated. No radiological doses either to aquatic or terrestrial animals or plants above natural background were recorded from BNL operations.

8.1 AMBIENT RADIATION

8.1.1 ONSITE AND OFFSITE AMBIENT RADIATION MONITORING

BNL continuously monitors ambient radiation doses from Laboratory operations using a system of passive area monitors called thermoluminescent dosimeters (TLDs). The TLDs are located onsite and offsite and measure direct external beta and gamma radiation. These TLDs are made of crystals, known as chips, that are made of calcium fluoride (Ca F_2:Dy) and lithium fluoride (LiF: Mg, Ti). The TLDs are suspended free in ambient air approximately three feet (one meter) above the ground surface.

Thirty-six TLDs were posted on the BNL site and 18 posted at offsite monitoring locations in 2000 as shown on Figures 8-1 and 8-2, respectively. Figure 8-1 does not show the location of 044-400 and 045-400 TLD as GPS readings were not available. The BNL site is divided into grids and the TLDs are assigned numbers based on these grids. The offsite TLDs do not have grid numbers and are assigned a grid of 000 followed by a unique numerical identifier. The offsite TLD locations are divided into 16 sectors for wind directions. The onsite and offsite TLDs were exchanged on a quarterly basis to determine whether BNL operations had any impact on the ambient external radiation levels of the surrounding area. The Table 8-1 correlated TLD number to location.

The control TLD 075-000 dose was calculated as an arithmetic average of 30 TLDs stored in a lead-shielded container (in Bldg. 535) to reduce dose from

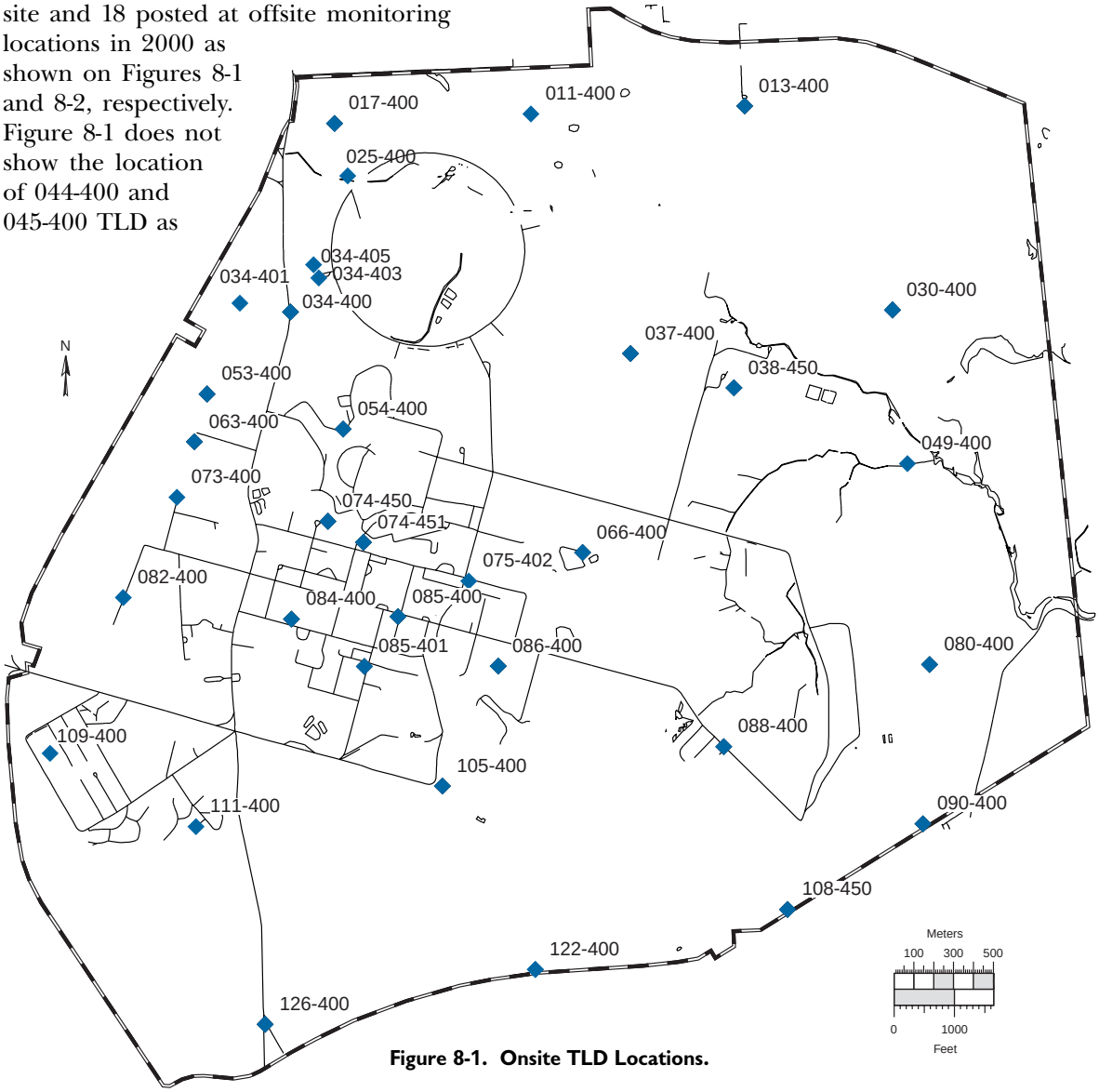

Figure 8-1. Onsite TLD Locations.

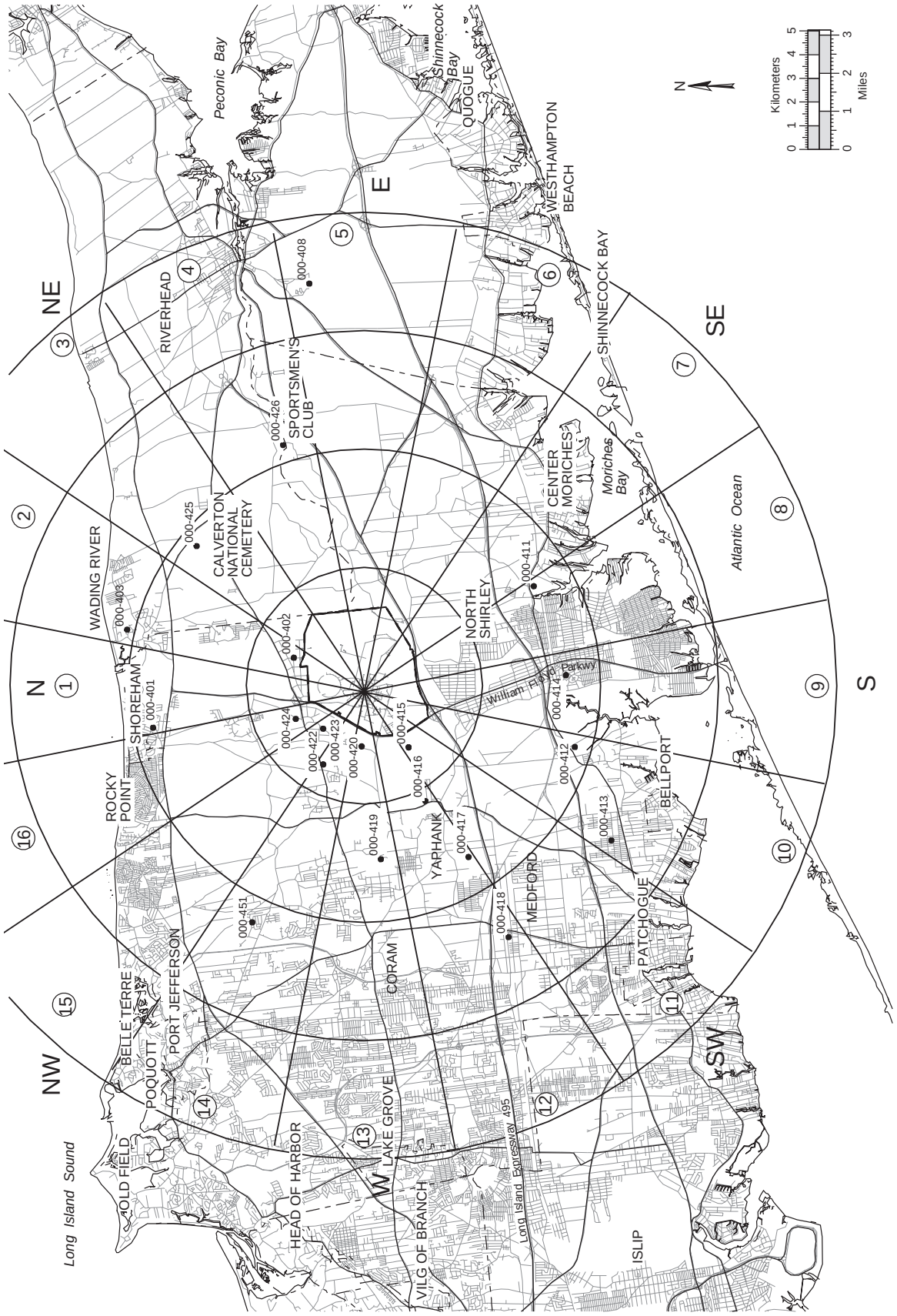

Figure 8-2. Offsite TLD Locations.

natural sources and cosmic radiation. The measured dose of the control TLD was 16 ± 10 mrem (0.16 ± 0.1 mSv) for each of the four quarters and 64 ± 40 mrem (0.64 ± 0.40 mSv) for the entire year. The highest dose recorded (104 ± 40 mrem /year [1.0 ± 0.4 mSv]) was measured at the West Firebreak (053-400). However, the large standard deviation associated with that measured value indicates significant variation in dose measurements at 95% probability. During 2000, the onsite and offsite ambient doses for all quarters were similar to natural background doses, with a few exceptions. The onsite average dose calculated for the 34 onsite TLDs was 88 ± 7 mrem (0.88 ± 0.07 mSv) per year. In comparison, the average of the 17 offsite TLDs was 86 ± 9 mrem (0.86 ± 0.09 mSv) per year.

The quarterly average and yearly dose for TLD 054-400 (Bldg. 914) was not calculated into the onsite average in Table 8-1 due to the large difference between the first and subse-

Table 8-1. Onsite Ambient Radiation Measurements (CY 2000).

TLD #	Location	1st Quarter (mrem)	2nd Quarter (mrem)	3rd Quarter (mrem)	4th Quarter (mrem)	Average (mrem)	Annual Dose (mrem/year)
011-400	N. Firebreak	NR	NR	18.1	22.0	20 ± 5	80 ± 20
013-400	N. Firebreak	21.4	19.3	18.7	22.4	21 ± 3	84 ± 12
017-400	P2	19.3	NR	18.2	NP	19 ± 1	76 ± 4
030-400	NE Firebreak	21.1	18.9	18.8	NP	20 ± 3	80 ± 9
034-400	N. Access Rd	22.0	18.4	19.4	25.7	21 ± 6	84 ± 24
034-401	N. Met	24.0	21.8	21.2	24.9	23 ± 4	92 ± 12
037-400	S13	22.0	19.8	19.8	23.0	21 ± 3	85 ± 12
038-450	S5	20.5	18.6	18.4	22.8	20 ± 4	80 ± 16
049-400	E. Firebreak	20.3	17.3	18.5	21.4	19 ± 4	76 ± 16
053-400	W. Firebreak	26.7	32.8	20.1	25.7	26 ± 10	104 ± 40
063-400	W. Firebreak	23.3	19.1	20.4	25.2	22 ± 6	88 ± 24
066-400	Sump H0	19.4	17.7	17.3	20.3	19 ± 3	76 ± 12
073-400	W. Met / B#51	23.8	NP	22.4	28.0	25 ± 6	100 ± 24
074-450	Bldg. 197	NP	23.8	22.4	26.6	24 ± 4	96 ± 16
074-451	Bldg. 907	27.2	22.2	20.8	24.8	24 ± 6	96 ± 24
075-402	Bldg. 356	26.8	22.4	25.4	29.9	26 ± 6	104 ± 24
080-400	E. Firebreak	22.9	18.2	19.6	25.6	22 ± 7	88 ± 28
082-400	W. Firebreak	NP	20.9	21.0	25.3	22 ± 5	88 ± 20
084-400	Tennis Courts	22.9	18.7	20.1	24.2	22 ± 5	88 ± 20
085-400	TFCU	23.7	19.6	NP	25.7	23 ± 6	92 ± 24
085-401	Upton Gas Station	27.1	18.8	20.0	26.9	23 ± 9	92 ± 36
086-400	BERA Ball Fields	22.9	21.1	20.3	26.0	23 ± 5	92 ± 20
090-400	P7	23.1	20.6	20.0	23.6	22 ± 4	88 ± 12
105-400	S. Firebreak	23.2	21.0	19.6	25.2	22 ± 5	88 ± 20
108-450	Water Tower	21.7	21.3	20.5	24.2	22 ± 3	88 ± 12
109-400	P4	22.7	19.9	20.6	24.0	22 ± 4	88 ± 12
111-400	Trailer Park	22.1	18.7	20.1	24.9	21 ± 5	84 ± 20
122-400	S. Firebreak	21.5	18.3	18.8	23.1	20 ± 4	80 ± 16
126-400	S. Gate	22.2	21.7	20.7	26.4	23 ± 5	92 ± 20
025-400	Bldg. 1010 Beam Stop 1	22.3	NR	20.7	23.8	22 ± 3	88 ± 12
034-403	Bldg. 1008 Collimator 2	23.7	19.0	22.4	NR	22 ± 5	88 ± 20
034-405	Bldg. 1008 Collimator 4	23.8	23.9	23.2	NR	22 ± 1	88 ± 3
044-400	Bldg. 1006	24.4	22.9	23.4	26.9	24 ± 3	96 ± 12
045-400	Bldg. 1005	22.3	23.8	23.1	28.4	24 ± 5	96 ± 20
088-400*	S6	66.8	65.9	68.0	68.1	67 ± 2	268 ± 8
054-400*	Bldg. 914	543.3	18.3	19.0	NR	NC	NC
075-000*	Control TLD (Avg.)	20.5	20.5	11.3	12.8	16 ± 10	64 ± 40
Average of 34 Onsite TLDs							88 ± 7

Notes:
See Figure 8-1 for TLD locations.
Doses are not corrected for background level.
NC = Not Calculated (Average)
NP = TLD was not posted in the field.
NR = TLD dose not reported from the reader.
*TLD not included in onsite average. See explanation in text.

quent quarter measurements, and the loss of the TLD in the fourth quarter. This TLD had an extreme value for the first quarter (543.3 mrem) and is not an accurate representation of environmental dose in this area. After an investigation, it was determined that the high reading for this quarter may be attributable to the sky-shine phenomenon that occurs during the operation of the g-2 experiment. This experiment was operational only during the first quarter of 2000. The impact on dose from the g-2 experiment will be evaluated further in 2001. The second and third quarter measured doses of 18.3 and 19.0 (respectively) are representative of doses normally observed in the environment. Statistical comparison with data from previous years also indicates that the overall trend of environmental dose in this area was in the 17- to 20-mrem range for each quarter. The fourth quarter TLD was not recovered due to construction activities at the Booster Application Facility. It was decided that inclusion of this TLD in the sitewide average would skew the mean, thus making it difficult to interpret the data now and in the future.

The 088-400 TLD (S6) location had an extreme value in the data set that was so far removed from other external dose values that the chance probability of it being a valid member of the data set was remote. The proximity of TLD 088-400 to the radiologically posted Waste Management Facility is known to have contributed to high radiation dose for this TLD. Public access to radiological contamination areas is not permitted and authorized workers are routinely monitored. Therefore, the dose values for this TLD are reported in this SER but excluded from averaging because it was not an accurate representation of onsite environmental dose.

During 2000, the ambient dose was based on the average of the two LiF: Mg, Ti chips. Prior to 2000, all four chips (including the two CaF_2:Dy chips) were used to calculate dose. This change was made based on the results of a fade study (Harshaw Type 8807 Environmental Dosimeter [TLD Card 2211]) done on environmental dosimeters (EML-DOE 2000). The study concluded that the CaF_2 element showed much higher fading after 60 days of exposure in the field, and would therefore underestimate the dose. The LiF element fade was negligible for extended periods of exposure in the field. Normally, environmental TLDs are posted in the field for about 90 days but can be posted for extended periods, sometimes up to 120 days. Due to this change in monitoring, the environmental ambient dose for 2000 is about 20-30% higher than in previous years.

The average doses measured by the unshielded TLDs offsite were not significantly different from the average doses measured by the shielded TLDs. Therefore, it can be concluded that BNL operations had no measurable impact to the environment. The offsite TLD doses are summarized in Table 8-2.

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 area of contamination is being addressed under the Environmental Restoration Program (Operable Unit 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 any unauthorized entry. Twenty-one TLDs are located within the sump area; and an additional four TLDs are located on the fence, one at each (north, east, west, and south) compass direction (see Figure 8-3). Additionally, two control TLDs are kept in a lead-shielded container as background TLDs for comparison.

The quarterly TLD doses measured in 2000 for the Building 650 Sump Outfall are given in Table 8-3. 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 1.47 rem (15 mSv). The doses decrease south of the C4 grid towards D4 location and west grid at C3 location to 0.8 rem (8 mSv) and 0.7 rem (7 mSv), respectively. The dose measured at the A1 location was higher than expected for the first quarter because the TLD was found on the ground instead of the three foot (one meter) height above the ground. The dose was higher due to the shorter distance from the radiological source. The annual dose measured at the sump fence was similar to the control TLDs, demonstrating that the radia-

Table 8-2. Offsite Ambient Radiation Measurements (CY 2000).

TLD #	Location	1st Quarter (mrem)	2nd Quarter (mrem)	3rd Quarter (mrem)	4th Quarter (mrem)	Average (mrem)	Annual Dose (mrem/year)
000 – 401	Private Property	23.4	15.3	17.6	NR	19 ± 3	76 ± 12
000 – 402	Private Property	25.3	21.9	20.4	24.2	23 ± 2	92 ± 7
000 – 403	Private Property	22.3	26.3	19.7	42.0	28 ± 7	112 ± 28
000 – 408	Private Property	NP	19.3	20.2	21.5	20 ± 1	80 ± 4
000 – 411	Private Property	NP	19.6	20.6	23.1	21 ± 1	84 ± 4
000 – 412	Private Property	NP	21.2	25.6	NR	23 ± 2	92 ± 8
000 – 413	Private Property	26.9	17.1	20.2	22.6	22 ± 3	88 ± 12
000 – 414	Suffolk County CD	21.0	19.1	20.4	25.0	21 ± 4	88 ± 16
000 – 416	Private Property	18.0	19	17.9	19.6	19 ± 1	76 ± 4
000 – 417	Private Property	NP	12.6	21.6	19.7	18 ± 4	72 ± 12
000 – 418	Private Property	23.1	17.4	20.0	21.6	21 ± 2	84 ± 8
000 – 419	Private Property	18.3	19.5	19.6	22.4	20 ± 1	80 ± 4
000 – 420	Smith Estate	21.1	19.2	20.3	23.1	21 ± 1	84 ± 4
000 – 422	Private Property	19.3	20.6	22.9	22.5	21 ± 1	84 ± 4
000 – 424	Mid. Isl. Game Farm	21.9	19.5	20.5	23.7	21 ± 1	84 ± 4
000 – 425	Calverton Nat. Cem.	24.0	21.7	22.7	26.6	24 ± 2	96 ± 8
000 – 426	Sportsmen's Club	20.8	19.9	20.3	22.5	21 ± 1	84 ± 4
075- 000*	Control TLD (Avg.)	20.5	20.5	11.3	12.8	16 ± 10	64 ± 40
Average of 17 Offsite TLDs							86 ± 9

Notes:
See Figure 8-2 for TLD locations.
NR = TLD dose Not Reported from the reader.
NP = TLD was Not Posted in the field.
*TLD not included in offsite average.

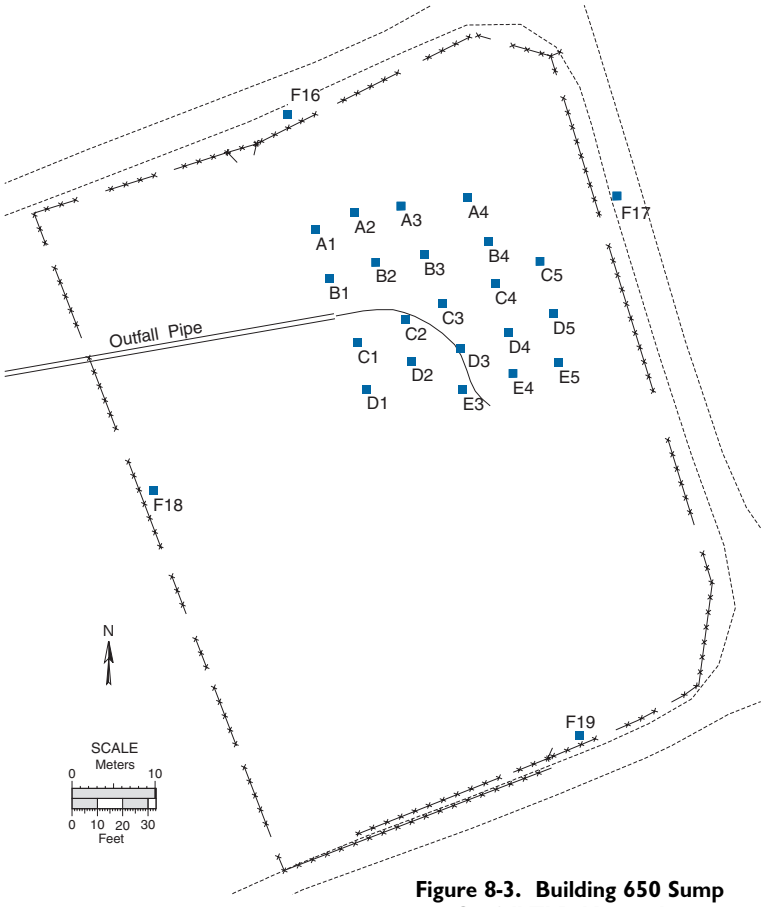

Figure 8-3. Building 650 Sump Outfall TLD Network.

tion field was localized to the immediate area. Entry into the sump outfall area was restricted to authorized personnel and therefore was not an exposure hazard to site workers or members of the public. Radiological dose to authorized personnel is monitored to ensure that their dose is below all DOE limits.

8.2 AIR EMISSIONS

The U.S. Environmental Protection Agency (EPA) has established radiation dose limits to members of the public from airborne radionuclide emissions released from DOE facilities. BNL operations are subject to the requirements of 40 CFR Part 61, Subpart H, "National Emission Standards for Hazardous Air Pollutants" (NESHAPs). This regulation specifies the monitoring and reporting requirements for various types of radionuclides and mandates that no member of the public receives a dose greater than 10 mrem (0.1 mSv) per year from exposure to airborne radionuclide emissions, other than radon, released from a DOE facility. The regulation also requires the DOE facility to submit an annual report to EPA that describes the atmospheric emissions for the preceding year and associated offsite impacts.

Table 8-3. Building 650 Sump Outfall TLD Network (CY 2000).

TLD Location	1st Quarter (mrem)	2nd Quarter (mrem)	3rd Quarter (mrem)	4th Quarter (mrem)	Annual Dose (rem/year)
A1	189 ± 12	22 ± 2	23 ± 2	24 ± 2	0.26 ± 0.012
A2	79 ± 5	81 ± 7	85 ± 6	79 ± 7	0.32 ± 0.013
A3	28 ± 3	28 ± 3	31 ± 2	31 ± 3	0.12 ± 0.005
A4	22 ± 2	24 ± 2	24 ± 2	22 ± 2	0.09 ± 0.004
B1	20 ± 1	20 ± 1	21 ± 2	20 ± 2	0.08 ± 0.003
B2	40 ± 3	42 ± 3	44 ± 3	42 ± 4	0.17 ± 0.007
B3	86 ± 6	84 ± 7	94 ± 7	89 ± 7	0.35 ± 0.013
B4	41 ± 3	42 ± 3	45 ± 3	43 ± 4	0.17 ± 0.007
C1	24 ± 2	23 ± 2	22 ± 2	23 ± 3	0.09 ± 0.005
C2	50 ± 3	51 ± 4	51 ± 5	52 ± 5	0.23 ± 0.009
C3	177 ± 12	177 ± 13	180 ± 18	190 ± 16	0.72 ± 0.030
C4	375 ± 29	361 ± 34	361 ± 46	371 ± 36	1.47 ± 0.073
C5	34 ± 3	36 ± 2	35 ± 3	35 ± 4	0.14 ± 0.006
D1	23 ± 2	21 ± 2	22 ± 3	22 ± 2	0.09 ± 0.004
D2	32 ± 2	33 ± 3	32 ± 2	35 ± 4	0.13 ± 0.006
D3	140 ± 10	132 ± 10	137 ± 15	161 ± 13	0.57 ± 0.024
D4	194 ± 13	202 ± 16	195 ± 13	211 ± 21	0.82 ± 0.032
D5	64 ± 4	63 ± 6	63 ± 6	68 ± 7	0.26 ± 0.012
E3	103 ± 7	105 ± 8	101 ± 7	107 ± 9	0.42 ± 0.015
E4	144 ± 10	147 ± 11	143 ± 10	165 ± 12	0.60 ± 0.021
E5	107 ± 7	103 ± 7	108 ± 8	115 ± 10	0.44 ± 0.016
F16 (Fence N)	16 ± 1	15 ± 1	16 ± 1	16 ± 1	0.063 ± 0.002
F19 (Fence S)	15 ± 1	14 ± 1	15 ± 1	16 ± 2	0.060 ± 0.003
F17 (Fence E)	17 ± 1	16 ± 1	18 ± 2	15 ± 1	0.066 ± 0.003
F18 (Fence W)	17 ± 1	16 ± 1	17 ± 1	17 ± 1	0.068 ± 0.003
Control TLD 1*	13 ± 8	18 ± 2	19 ± 1	20 ± 2	0.069 ± 0.009
Control TLD 2*	18 ± 1	16 ± 1	18 ± 1	18 ± 2	0.070 ± 0.003

Notes:
See Figure 8-3 for TLD locations.
*Distant background locations used for comparison purposes.

8.2.1 AIR DISPERSION MODEL

Compliance with NESHAPs regulations is demonstrated through the use of EPA's CAP88-PC (Clean Air Act Assessment Package-1988) computer model program. The CAP88-PC 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. Input parameters used in the model 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 also used for the assessments. Weather data were supplied by measurements from BNL's meteorological tower. Data include wind speed, direction, frequency, and temperature. Population data for the surrounding area were based on a population survey by the Long Island Power Authority (LIPA 1999). Since visiting researchers and their families may reside at the onsite 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 who resides at the nearest location and has a lifestyle such that no other member of the public can receive a higher dose than this individual. The MEI is assumed to reside 24 hours a day, 365 days a year at the BNL boundary in the downwind direction, and consumes 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 DOSES FROM DIFFUSE AND NONPOINT SOURCES

The NESHAPs review process evaluates sources that have any potential to discharge radioactive air emissions at BNL. A number of Environmental Restoration Program operations were evaluated in 2000. Although environmental restoration activities are exempt from permitting requirements under the Comprehensive Environmental Response Compensation and Liability Act, activities with any potential to emit radioactive emissions were assessed for potential dose to the members of the public. The CAP88-PC modeling program is explicitly designed to model continuous airborne radioactive emissions that occur over the course of a single year and is not well suited for estimating short-term or acute releases. Given this limitation, the evaluations treated the potential emission sources as if they were continuous annual sources that do not end with the cessation of the environmental restoration activities. The assessment conclusions for the restoration activities are discussed below. With regard to BNL operations, diffuse sources and nonpoint sources that had a potential to emit radionuclides into the air in quantities that could cause an EDE in excess of 1% of the standard were evaluated, and a detailed discussion of these operations is provided in Chapter 4.

8.2.3.1 CHEMICAL/ANIMAL AND GLASS HOLES PIT SOIL STOCKPILE #6B

The soil in stockpile #6B was generated during pit excavation. Stockpile #6B contained approximately 440 cubic yards (336 m^3) of soil removed from the bottom of several pits located in the animal/chemical pit area. Low concentrations of americum-241, cesium-137, potassium-40, neptunium-237, plutonium-239, plutonium-240, and thorium-232 and natural uranium isotopes were detected in the samples. Because there was a potential for radiologically/mercury-contaminated soil particles to become airborne during loading and shipping, a NESHAPs evaluation was conducted. Using the CAP88-PC model for dose and risk assessment, the effective dose equivalent to the MEI from these activities was estimated at 6.07E-03 mrem/year (6.07E-02 μSv/yr).

8.2.3.2 WASTE CONCENTRATION FACILITY SOIL EVACUATION

Soils were removed from the Waste Concentration Facility yard (Building 811) as part of the underground storage tank and piping removal project. This activity had a release inventory of radionuclides in the soil of cesium-137 (464 pCi/g [17.2 Bq/g]) and strontium-90 (454 pCi/g [16.8 Bq/g]). Using the CAP88-PC model, an effective dose equivalent of 8.52E-03 mrem/year (8.52E-02 μSv/yr) to the MEI was estimated.

8.2.3.3 BROOKHAVEN GRAPHITE RESEARCH REACTOR DUCT REMOVAL

Sections of the Brookhaven Graphite Research Reactor (BGRR) aboveground duct were sectioned and removed. Radiological samples were taken from the interior surface of the ductwork to determine the type and amounts of contamination present. A fixative was used to contain any loose contamination and the duct opening was capped and sealed to prevent the spread of contamination. Using site-specific meteorological data and current population data, the EDE to the MEI estimated with the CAP-88-PC model was 1.5E-04 mrem/year (1.5E-04 μSv/yr).

8.2.3.4 AREA OF CONCERN 16 SOIL REMOVAL ACTION

This environmental restoration action involved the excavation of landscape soil contaminated with low levels of cesium-137 in each of the six Areas of Concern to a depth of approximately one foot (0.36m). Using the CAP-88 model, along with site-specific meteorological data and current population data, the EDE to the MEI was estimated to be 3.66E-02 mrem/year (3.66E-01 μSv/yr).

8.2.3.5 RADIOACTIVE WASTEWATER PROCESSING OPERATIONS

During a process evaluation of radioactive wastewater processing operations associated with the Waste Concentration Facility in

Building 811, waste transfer operations in Building 810, and the Evaporator Facility in Building 802B, a recommendation was made to conduct a NESHAPs evaluation of sources that have the potential to release small amounts of radioactive air emissions that are not directed to the High Flux Beam Reactor stack. Included among the sources evaluated were vent pipes for the four aboveground wastewater storage tanks in Building 811, vent pipes for a 15-gallon (57-liter) condensate storage tank, a 5000-gallon (18,925-liter) tritiated water tank in Building 802B, and potential fugitive emissions from leaks in pumps and pipe valves in the wastewater transfer lines connecting the three buildings. The potential airborne source term was based on the information provided in the BNL Process Assessment Form and emission factors from 40 CFR 61, Appendix D. The CAP88-PC model provided a conservative estimate of the EDE to the MEI of 1.76E-03 mrem/year (1.76E-02 μSv/yr).

8.2.4 AIRBORNE PATHWAY - EFFECTIVE DOSE EQUIVALENT CALCULATIONS

In 2000, the Brookhaven Medical Research Reactor (BMRR) air emissions were monitored continuously. Because the potential for air emission was above 0.1 mrem from the air pathway, continuous monitoring is required. The EDE to the MEI from all radiological airborne emission sources combined was 0.18 mrem (1.8 μSv). Argon-41 (gaseous, half-life=1.8 hours) released from the BMRR was the only contributor of this dose. By comparison, this was less than 2% of the EPA airborne dose limit of 10 mrem (0.1 mSv) and was statistically insignificant compared to the dose received annually from natural background radiation. From a dose perspective, a person living in the state of Colorado would receive 900 mrem per year from natural sources and one living in Spokane, Washington about 1,400 mrem year (NCRP 1987). In comparison, Long Island's natural background dose is relatively low at 300 mrem/year. The estimated doses to the maximally exposed individual for radionuclides released from all potential sources of airborne emissions are given in Table 8-4.

Table 8-4. Effective Dose Equivalent to the Maximally Exposed Individual From Airborne Emission Sources (CY 2000).

Building	Facility or Process	MEI Dose (mrem)
491	BMRR	1.8E-01
750	HFBR	2.1E-05
931	BLIP	2.2E-03
801	Target Processing Lab	3.1E-07
802B	Evaporator Facility	1.9E-05
—	RHIC	ND
942	AGS Booster	ND[a]
490	Radiation Therapy Facility	4.5E-07[b]
820	Accelerator Test Facility	ND[c]
938	Radiation Effects Facility/ Neutral Beam Test Facility	ND[d]
510	Calorimeter Enclosure	ND
463	Biology Facility	5.3E-09[e]
555	Chemistry Facility	8.1E-11[e]
830	Environmental & Waste Mgmt.	5.6E-12[e]
490D	Environmental Biology& Ins.	ND
490	Medical Research Center	ND
703	Analytical Laboratory	ND
Total from BNL Operations		0.18 mrem
EPA Limit		10.00 mrem

Notes:
"Dose" as used in this table means effective dose equivalent.
ND = No Dose (facility not operational or no source in 2000).
[a] Booster ventilation system prevents air release through continuous air recirculation.
[b] Based on conservative engineering calulations.
[c] This has become a zero-release facility since original permit application.
[d] This facility is no longer in use, it produces no radioactive air emissions.
[e] All doses based on emissions calculated using 40 CFR 61, Appendix D methodology.

8.3 FISH CONSUMPTION - EFFECTIVE DOSE EQUIVALENT CALCULATIONS

Calculations were made to determine the potential dose impact to the MEI from consuming fish taken exclusively from the Peconic River. As discussed in Chapter 6, fish from the Peconic River and Peconic-fed water bodies continue to be analyzed for radiological content because of known historical radionuclide discharges from the BNL Sewage Treatment Plant. These releases occurred primarily in the 1950s and 1960s. In 2000, fish samples collected from the Peconic River were analyzed for gamma-emitting radionuclides; only potassium-40 and cesium-137 were above the minimum detection limit. The maximum concentration, 1.30 ± 0.16 pCi/g (48 ± 5.9 mBq/g), wet weight of cesium-137, was detected in a composite sample of brown bullhead, a local species of catfish. The cesium-137 concentration in pumpkinseed (a local panfish) from the same location, analyzed as a composite sample, was 1.19 ± 0.14 pCi/g (44 ± 5.2 mBq/g) wet weight. Chain pickerel had a

concentration of 1.13 ± 0.17 pCi/g (42 ± 6.3 mBq/g) of cesium-137. The average concentration of 1.20 ± 0.08 pCi/g (44 ± 2.9 mBq/g) of cesium-137 for all three species of fish was used in dose calculations. By comparison, the concentration of potassium-40, another beta/gamma emitting radionuclide, found in a banana, about 3 pCi/g (111 mBq/g), is higher than the cesium-137 found in the fish collected from the Peconic River.

For dose evaluation, a MEI was assumed to eat 15 pounds of fish during the course of the year (NYSDOH 1996). Exclusive consumption of brown bullhead, pumpkinseed, and chain pickerel at the rate and concentration given above would result in an EDE of 0.42 mrem (4.2 μSv) due to cesium-137 concentrations. By comparison, the average individual EDE caused by ingestion of naturally occurring radionuclides in the U.S. is about 40 mrem (400 μSv) per year (NCRP 1987). There were no radionuclides detected in shellfish, aquatic vegetation, marine waters, and sediments above the minimum detection limit.

8.4 DEER MEAT CONSUMPTION - EFFECTIVE DOSE EQUIVALENT CALCULATIONS

As discussed in Chapter 6, measurements were made of flesh and liver samples collected from deer taken on BNL property as well as from offsite locations. Cesium-137 was detected in flesh samples from onsite deer at concentrations lower than those found in offsite deer. The onsite average concentration found in flesh samples was 1.49 ± 0.27 pCi/g (55 ± 9.9 mBq/g) wet weight. In comparison, the offsite deer flesh sample averaged 1.97 ± 0.34 pCi/g (73 ± 12.6 mBq/g) wet weight of cesium-137. While onsite hunting was not permitted, there are no physical barriers preventing deer from migrating beyond the site boundary. It was, therefore, conceivable that hunters could occasionally take a deer that resides predominantly on the BNL site.

In March 1999, the New York State Department of Health (NYSDOH) Bureau of Environmental Radiation Protection issued a report examining the possible dose impacts to members of the public who consume deer that have grazed extensively on the BNL site (NYSDOH 1999). In the NYSDOH report, a 10mrem/year (100 μSv/year) dose was used as the limit for deer meat consumption. The annual consumption rate of venison was estimated using the EPA's Exposure Factors Handbook, which gives the average intake of game meat (for those who consume it) as approximately 1.1 grams per day per kilogram of body weight (0.018 ounces per day per pound of body weight) (EPA 1996). For a 154 pound (70 kilogram) individual, this corresponds to about 64 pounds (28 kilograms) of venison consumed per year. The same assumptions have been adopted for this report.

The potential dose from deer meat consumption was calculated using the arithmetic average of the cesium-137 concentrations measured in flesh samples collected onsite and one mile radius around the laboratory. In dose calculations, a wet weight average concentration (i.e., the concentration in the flesh sample prior to drying for analysis) of 1.85 ± 0.33 pCi/g (68 ± 12 mBq/g) was used. Under the stated assumptions, the committed EDE due to consumption of 64 pounds (28 kilograms) of local deer meat would be equal to 2.68 mrem (27 μSv) per year. This is 27% of the health advisory limit of 10 mrem (0.1 mSv) established by the NYSDOH. By comparison, the average EDE from eating foods that contain naturally occurring radionuclides is 40 mrem (0.4 mSv) per year (NCRP 1987).

8.5 COLLECTIVE TOTAL EFFECTIVE DOSE EQUIVALENT

Collective total effective dose equivalent (TEDE), a value used to estimate potential health risks to a population, is the summation of the calculated EDE for each individual multiplied by the number of individuals in the population being considered.

Assuming that the total number of individuals who routinely consume fish taken from portions of the Peconic River near the BNL site was 625, the collective TEDE from this pathway was 263 person-mrem (2.6 person-mSv). This value was based on the maximum fish concentrations discussed in Section 8.3 above. In comparison, the collective TEDE to the same population from consumption of naturally occurring radionuclides in food was 25,000 person-mrem (250 person-mSv) annually.

Since onsite deer hunting was prohibited, the individual dose estimate from meat consumption calculated in Section 8.4 was based on the average cesium-137 concentrations. Deer moving beyond BNL boundaries can be legally hunted and consumed, resulting

in collective dose. However, the number of people hunting deer or consuming deer meat taken within a one-mile radius of BNL was not tracked; consequently, the collective dose from deer meat consumption was not calculated.

For the air exposure pathway, the CAP88-PC computer model provides collective TEDE estimates using population data for the area within a 50-mile radius of the BNL site. The population data are broken down into the number of people living within each of the 16 compass sectors at 10-mile radial intervals. Again, argon-41 emitted from the BMRR was the largest contributor to the total collective committed effective dose equivalent of 6,437 person-mrem (64 person-mSv). This constituted 99% of the total collective dose resulting from BNL operations projected for the population within a 50-mile radius of BNL.

8.6 DOSES 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 show compliance with the requirements for protection of biota in the 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), and 0.1 rad/day (1 mGy/day) to terrestrial animals from exposure to radiation or radioactive material released into the environment.

The average concentrations of radionuclides measured at the BNL site were used to show compliance with these proposed limits. The average concentration (0.21 pCi/g or 7.7 mBq/g) of cesium-137 was analyzed in soil samples collected onsite. The draft DOE Technical Standard ENVR–0011 (DOE 2000) was used to evaluate the dose impact to the terrestrial animals. The sum fraction of radionuclides in soil was 1.01E-02 and passed the criteria using the Biota Concentration Guide calculator given in the standard. The site-specific cobalt-60 (0.07 pCi/g or 2.6 mBq/g) and cesium-137 (0.16 pCi/g or 5.9 mBq/g) concentrations in sediments were used to calculate dose impacts to the aquatic animals. The sum fraction of radionuclides was calculated to be 3.77E-03 in this media. The total sum of the fractions was less than one, and therefore passed the screening criteria for dose to the biota. It can be concluded from the biota screening methods that there was no radiological dose to aquatic animals, terrestrial plants and terrestrial animals from BNL operations. Additional information on the body burden in deer is provided in Chapter 6, Section 6.3.1.

8.7 SUMMARY AND CONCLUSION

Calculations of EDE from all BNL facilities that have the potential to release radionuclides to the atmosphere indicated that radiological doses attributable to Laboratory operations were well below the limits established by federal regulations (see Table 8-5). Direct measurement of external radiation levels by TLDs confirmed that exposure rates at the site boundary were consistent with background levels. No dose was calculated for drinking water since the majority of homes have been hooked up to public water supply, and there are no radionuclide plumes above the drinking water standards beyond the BNL boundary. As some residents in the hookup area chose not to accept DOE's water hookup offer, DOE began identifying and contacting these property owners in the summer of 2000 to offer free yearly testing of their water supply.

The EDE calculations presented in this chapter were based on the MEI for each scenario using the stated assumptions. Given this, it is unlikely that any single person could receive a radiological dose equal to the sum of these individual pathways. The hypothetical MEI, defined as residing at the northeast boundary of BNL, breathing the air, and consuming 15 pounds of contaminated fish and 64 pounds of contaminated deer meat from onsite sources, would receive 3.28 mrem/year (32.8 μSv/year) total effective dose equivalent. This highly unlikely worst-case scenario was calculated to show that the dose from all pathways would still be less than 4% of 100 mrem/year (1 mSv/year) dose limit set by DOE for members of the general public, and is insignificant when compared to the average annual dose of 360 mrem/year (3.6 mSv/year) (NCRP 1987) from cosmic, terrestrial and radon sources. These MEI doses

Table 8-5. Summary of Potential Dose from All Environmental Pathways (CY2000).

Matrix	Pathway	Primary Contributing Radionuclide	Maximally Exposed Individual EDE (mrem)	Regulatory Pathway Limit (mrem)	Collective EDE (person-mrem)
Air	Inhalation	Ar-41	0.18	10	6,437
Food	Fish[1]	Cs-137	0.42	SNS	263
	Deer Meat[2]	Cs-137	2.68	SNS	NA
Water	Drinking Water[3]	NA	NA	NA	NA

Notes:
EDE = Effective Dose Equivalent.
NA = Not Applicable
SNS = Standard Not Specified
(1) Fish dose calculation is based on measured Cs-137 concentration only.
(2) Deer dose is based on the average deer concentration in samples collected onsite and one mile radius around BNL. Calculation assumes a consumption rate of 64 lbs/yr.
(3) No drinking water dose projected following connnection of public water supply to homes adjacent to BNL.

demonstrate that in 2000 there was minimal radiological dose impact above the natural background to members of the public and the environment from BNL operations.

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