8 Radiological Dose Assessment

Brookhaven National Laboratory routinely evaluates site operations to ensure that the radiological dose impact to members of the public, BNL workers, and the environment is "As Low As Reasonably Achievable" (ALARA). All scientific and operational processes and activities that can in any way impact the health and safety or potentially contribute to radiological dose are reviewed for their environmental impacts. The potential radiological dose to the public is calculated as the maximum dose to a hypothetical Maximally Exposed Individual (MEI) at the BNL site boundary. Doses are calculated by considering all direct and indirect sources and pathways, such as inhalation of air emissions, ingestion of deer meat and fish, and any immersion dose. The dose assessment has routinely shown that the total Effective Dose Equivalent from Laboratory activities is well below the EPA regulatory dose limits for the public, workers, and the environment.

The average annual external dose from all potential ambient sources was 67 ± 12 mrem (670 ± 120 µSv) on site and 64 ± 9 mrem (640 ± 90 µSv) at off-site locations. Both measurements include contributions from natural background and cosmic radiation sources. A statistical comparison of the average doses measured at 47 on-site and 16 off-site locations using thermoluminescent dosimeters (TLDs) showed that there was no additional external dose contribution from BNL operations above the dose from natural background radiation. In addition to measuring background, nine TLDs were used to monitor known radiation source areas. The results of these measurements are described in Section 8.1.2.

The effective dose from air emissions was calculated as 5.30E-02 mrem (0.53 µSv) to the MEI. The ingestion pathway dose was estimated as 0.32 mrem (3.2 µSv) from consumption of deer meat and 0.08 mrem (0.8 µSv) from consumption of fish caught on the BNL site. The total annual dose to the MEI from all pathways was estimated as 0.45 mrem (4.5 µSv). The BNL dose from the air inhalation pathway was less than 10 percent of EPA's annual regulatory dose limit of 10 mrem (100 µSv), and the total dose less than 1 percent of DOE's annual dose limit of 100 mrem (1,000 µSv) from all pathways.

Doses to aquatic and terrestrial biota were also evaluated and found to be well below the DOE regulatory limits. Other short-term projects conducted in 2005, such as remediation work and waste management disposal activities, were evaluated for their radiological emissions and potential dose impact; there was no radiological risk to the public, BNL workers, or the environment from these activities. In conclusion, the overall dose impact from all Laboratory activities in 2005 was indistinguishable from natural background radiation levels.

8.1 DIRECT RADIATION MONITORING

A direct radiation-monitoring program is used to measure the external dose contribution to members of the public and workers from radiation sources at BNL. This is achieved by measuring direct penetrating radiation exposures both on and off site. The direct measurements taken at the off-site locations are with the premise that off-site exposures are true natural background radiation (contribution from cosmic and terrestrial) exposures and represent no contribution from BNL operations. On- and off-site external doses were measured, averaged, and then compared using the statistical t-test to evaluate any variations and the contribution, if any, from Laboratory operations.

Direct penetrating beta-gamma radiation is measured using TLDs. The principle of TLD operation is that when certain crystals are exposed to radiation, impurities in the crystals' low-temperature trapping sites are excited to higher energy states. These electrons remain in a high-energy state at normal ambient temperature. When the TLDs are heated (annealed), the electrons return to the lower energy state, emitting photon energy (light), which is measured with a photomultiplier tube; the light intensity is directly proportional to the absorbed radiation dose. The environmental TLDs used at BNL are composed of calcium fluoride and lithium fluoride crystals. The TLDs' accuracy is verified by comparing the absorbed dose of a TLD exposed to a known and characterized radiation source. BNL participates in the inter-comparison proficiency testing programs sponsored by DOE as a check of its ability to measure radiation doses accurately.

8.1.1 Ambient Monitoring

To assess the dose impact of direct radiation from BNL operations, TLDs are deployed on the BNL site and in the surrounding communities. On-site TLD locations are determined based on the potential for exposure to gaseous air plumes, atmospheric particulates, scattered radiation, and the location of historical radiation-generating facilities. The BNL perimeter is also posted with TLDs to assess the dose impact, if any, beyond the Laboratory boundary. On- and off-site locations are divided into grids and each TLD is assigned an identification code based on these grids.

In 2005, 55 TLDs were deployed on site; nine were placed in known radiation areas (i.e., facility area monitoring TLDs) and 16 were deployed off site (see Figures 8-1 and 8-2 for locations). An additional 30 control TLDs were stored in a lead-shielded container in Building 490; the average of the control TLDs is

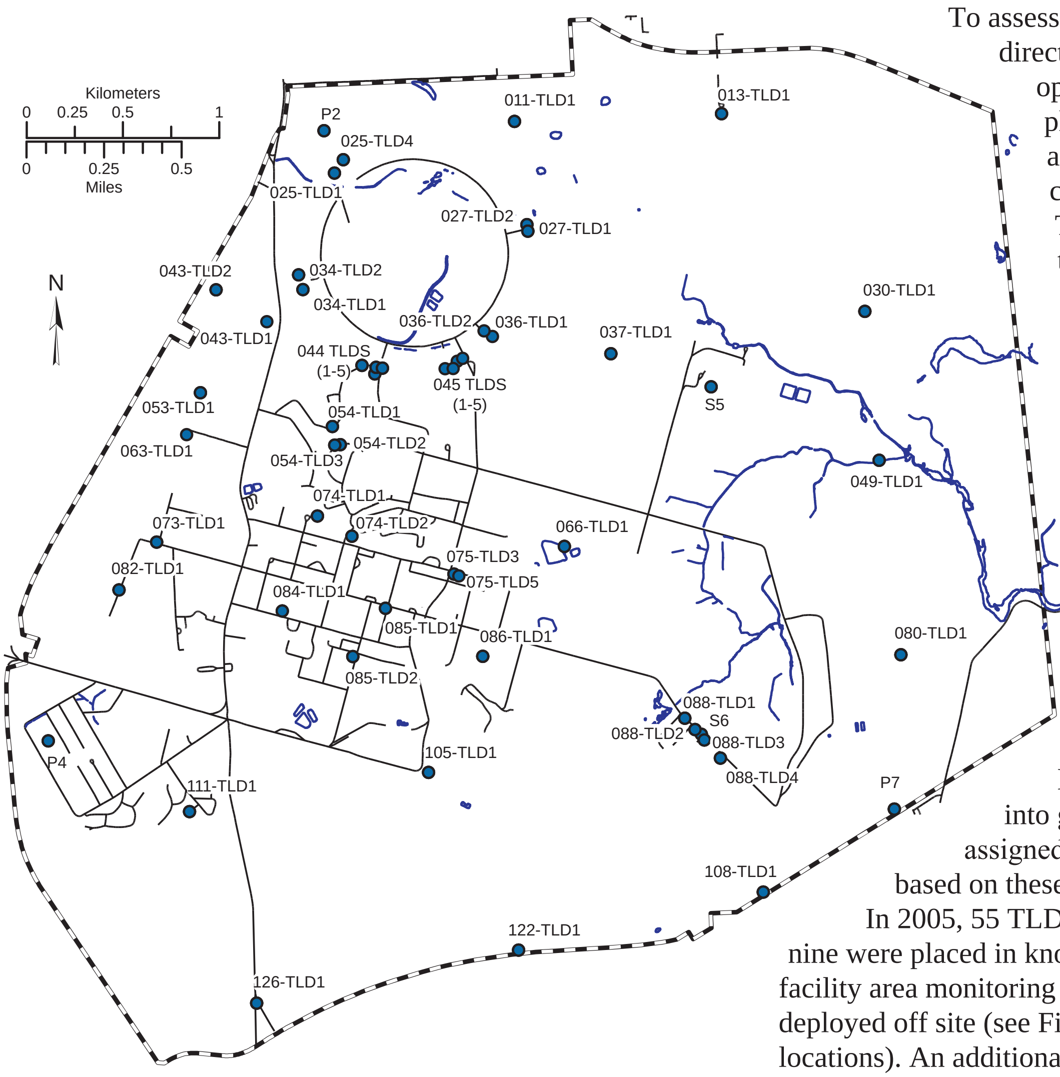

Figure 8-1. On-Site TLD Locations.

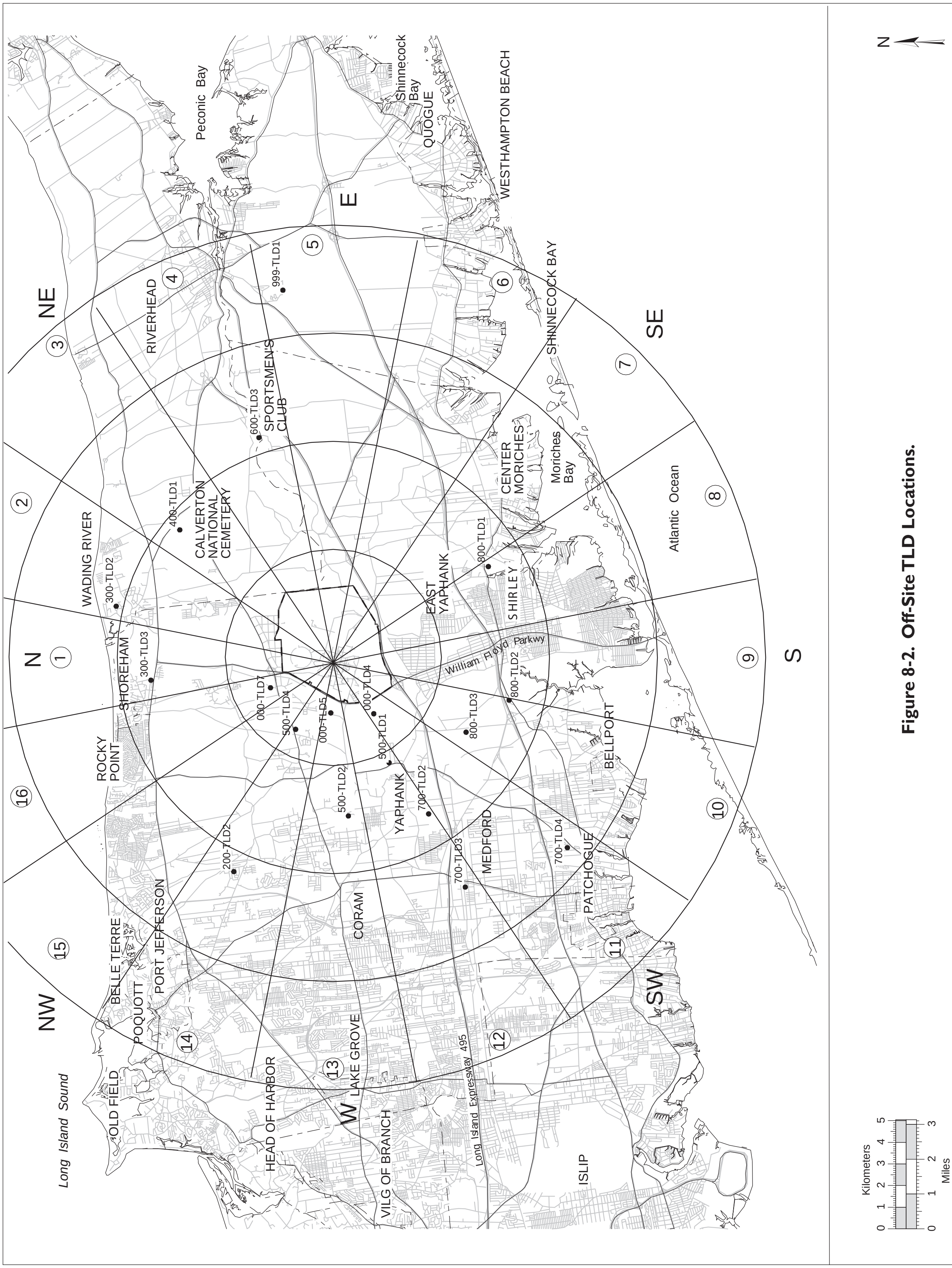

Figure 8-2. Off-Site TLD Locations.

reported as “075-TLD4” in Tables 8-1 and 8-2, for comparison. Note that some residual dose remains on the control TLDs when they are annealed and it is impossible to completely shield the control devices from all natural background and cosmic radiation sources. Therefore, small doses are measured by the control TLDs. The on- and off-site TLDs are collected and read quarterly to determine the external radiation dose measured.

Table 8-1 shows the quarterly and yearly on-site radiation dose measurements. The on-site average external dose for the first, second, third, and fourth quarters was 17.7 ± 3.2, 15.7 ± 3.0, 15.3 ± 3.1, and 18.2 ± 3.5 mrem, respectively. The on-site average annual external dose from all potential environmental sources, including cosmic and terrestrial radiation sources, was 67 ± 12 mrem (670 ± 120 µSv).

Table 8-2 shows the quarterly and yearly off-site radiation dose measurements. The off-site average external dose for the first, second, third, and fourth quarters was 17.1 ± 4.5, 14.8 ± 2.5, 14.8 ± 1.8, and 17.0 ± 2.2 mrem, respectively. The off-site average annual ambient dose from all potential environmental sources, including cosmic and terrestrial radiation sources, was 64 ± 9 mrem (640 ± 90 µSv).

To determine the BNL contribution to the external direct radiation dose, a statistical t-test between the measured on- and off-site external dose averages was conducted. The t-test showed no significant difference between the off-site dose (64 ± 9 mrem) and on-site dose (67 ± 12 mrem) at the 95 percent confidence level. From these measured doses, it can be safely concluded that there was no external dose contribution to on- and off-site locations from BNL operations in 2005.

8.1.2 Facility Area Monitoring

Nine of the 56 on-site TLDs were designated as Facility Area Monitors (FAM). These TLDs are deployed at locations known in the past to have radiation contamination, possible radiation scatter, or that are near radiological posted areas, as these areas have a higher probability to contribute to external radiation doses. Table 8-3 shows the external doses measured with the FAM TLDs. Environmental TLDs 088-TLD1 through 088-TLD4 are posted at the S-6 blockhouse location and on the fence of the

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

TLD#	Location	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	Avg./Qtr. ± 2σ (95%)	Annual Dose ± 2σ (95%)
		(mrem)					
011-TLD1	North firebreak	15.3	13.8	14.9	15.7	15 ± 2	60 ± 6
013-TLD1	North firebreak	17.3	15.5	14.0	16.9	16 ± 3	64 ± 12
025-TLD1	Bldg. 1010 beam stop 1	16.2	14.0	15.0	18.5	16 ± 4	64 ± 15
025-TLD4	Bldg. 1010 beam stop 4	16.9	13.9	13.7	18.9	16 ± 5	63 ± 20
027-TLD1	Bldg. 1002A South	17.0	14.0	13.0	15.8	15 ± 3	60 ± 14
027-TLD2	Bldg. 1002D East	15.3	15.5	13.9	14.7	15 ± 1	59 ± 6
030-TLD1	NE Firebreak	20.0	15.6	14.5	17.6	17 ± 5	68 ± 19
034-TLD1	Bldg. 1008 collimator 2	17.7	15.3	14.5	18.2	16 ± 4	66 ± 14
034-TLD2	Bldg. 1008 collimator 4	16.6	15.5	14.4	18.2	16 ± 3	65 ± 13
036-TLD1	Bldg. 1004B East	15.5	14.0	13.4	18.1	15 ± 4	61 ± 16
036-TLD2	Bldg. 1004 East	20.4	18.7	15.7	18.9	18 ± 4	74 ± 16
037-TLD1	S-13	15.8	13.6	14.0	17.0	15 ± 3	60 ± 13
043-TLD1	North access road	18.3	18.0	16.7	18.8	18 ± 2	72 ± 7
043-TLD2	North of Meteorology Tower	17.5	16.5	16.9	18.9	17 ± 2	70 ± 8

(continued on next page)

Table 8-1. On-Site Direct Radiation Measurements *(concluded).*

TLD#	Location	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	Avg./Qtr. ± 2σ (95%)	Annual Dose ± 2σ (95%)
		(mrem)					
044-TLD1	Bldg. 1006	16.7	14.5	14.5	18.2	16 ± 4	64 ± 14
044-TLD2	South of Bldg. 1000E	18.0	15.8	14.8	18.1	17 ± 3	67±13
044-TLD3	South of Bldg. 1000P	16.0	13.9	13.1	17.7	15 ± 4	61±16
044-TLD4	NE of Bldg. 1000P	18.0	16.5	15.6	19.6	17 ± 3	70±14
044-TLD5	N of Bldg. 1000P	20.6	17.4	15.5	21.1	19 ± 5	75±21
045-TLD1	Bldg. 1005S	17.2	14.9	15.0	16.7	16 ± 2	64±9
045-TLD2	East of Bldg. 1005S	18.3	17.0	16.5	19.6	18 ± 3	71±11
045-TLD3	SE of Bldg. 1005 S	17.8	16.5	15.1	18.6	17 ± 3	68±12
045-TLD4	SW of Bldg. 1005 S	17.2	15.2	15.0	16.8	16 ± 2	64±9
045-TLD5	WSW of Bldg. 1005 S	16.0	14.2	13.7	14.7	15 ± 2	59±8
049-TLD1	East firebreak	16.7	14.4	14.6	16.4	16 ± 2	62±9
053-TLD1	West firebreak	17.9	17.7	16.5	19.6	18 ± 2	72±10
054- TLD1	Bldg. 914	21.5	16.6	L	17.7	19 ± 5	74±20
063-TLD1	West firebreak	18.4	17.3	17.3	21.9	19 ± 4	75±17
066-TLD1	Waste Management Facility	16.1	13.4	12.5	17.3	15 ± 4	59±17
073-TLD1	W Meteorology Tr. /Bldg. 51	17.9	16.8	18.0	17.8	18 ± 1	71±5
074-TLD1	Bldg. 560	17.9	17.4	16.1	19.2	18 ± 3	71±10
074-TLD2	Bldg. 907	17.7	16.1	14.9	16.1	16 ± 2	65±9
080-TDL1	East firebreak	19.4	17.3	16.7	20.0	18 ± 3	73±12
082-TLD1	West firebreak	21.2	17.5	17.9	21.0	19 ± 4	78±15
084-TLD1	Tennis courts	19.7	16.5	17.4	17.5	18 ± 3	71±11
085-TDL2	Upton gas station	18.3	17.1	15.3	18.9	17 ± 3	70±13
085-TLD1	TFCU (Credit Union)	19.3	NP	16.5	17.7	18 ± 3	71±11
086-TLD1	Baseball fields	21.1	18.7	18.2	22.3	20 ± 4	80±15
105-TLD1	South firebreak	19.7	17.1	18.3	20.3	19 ± 3	75±11
108-TLD1	Water tower	17.0	15.9	15.8	19.0	17 ± 3	68±12
111-TLD1	Trailer park	17.2	15.6	15.6	20.3	17 ± 4	69±17
122-TLD1	South firebreak	16.8	15.0	15.7	18.0	16 ± 3	65±10
126-TLD1	South gate	18.4	17.3	18.9	21.4	19 ± 3	76±14
P2		15.0	12.4	12.6	14.4	14 ± 3	54±10
P4		16.6	14.4	14.5	17.6	16 ± 3	63±12
P7		17.2	15.0	13.9	16.9	16 ± 3	63±12
S5		16.0	14.4	14.1	16.9	15 ± 3	61±11
On-site average		17.7	**15.7**	**15.3**	18.2	17 ± 3	67±12
Std. dev. (2 σ)		3.2	3.0	3.1	**3.5**		
075-TLD4	Control TLD average	**9.0**	8.6	**9.3**	**8.9**	**8.9 ± 1**	36±2

Notes:
See Figure 8-1 for TLD locations.
L = TLD lost
NP = TLD not posted

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

TLD#	Location	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	Avg./Qtr. +/- 2σ (95%)	Annual Dose +/- 2σ (95%)
		(mrem)					
000-TLD4	Private property	23.4	14.7	13.8	16.0	17 ± 9	68 ± 35
000-TLD5	Longwood Estate	16.0	14.5	13.9	16.5	15 ± 2	61 ± 10
000-TLD7	Mid-Island Game Farm	17.0	14.2	14.9	16.1	16 ± 2	62 ± 10
200-TLD2	Private property	18.6	16.7	NP	NP	18 ± 3	71 ± 10
300-TLD2	Private property	NP	NP	NP	NP		
300-TLD3	Private property	16.0	14.6	15.4	P	15 ± 1	61 ± 6
400-TLD1	Calverton Nat. Cemetery	17.7	15.7	16.6	17.9	17 ± 2	68 ± 8
500-TLD1	Private property	14.1	11.9	NP	NP	13 ± 3	52 ± 13
500-TLD2	Private property	15.5	13.4	14.1	16.4	15 ± 3	59 ± 11
500-TLD4	Private property	NP	15.2	16.0	18.3	16 ± 3	66 ± 12
600-TLD3	Sportsmen's Club	17.0	14.6	14.8	16.1	16 ± 2	63 ± 9
700-TLD2	Private property	NP	16.9	NP	NP	17 ± 0	
700-TLD3	Private property	18.5	15.3	15.3	18.4	17 ± 4	67 ± 14
700-TLD4	Private property	16.0	15.3	15.2	17.7	16 ± 2	64 ± 9
800-TLD1	Private property	NP	NP	14.6	16.8	16 ± 3	63 ± 12
800-TLD2	Private property	NP	NP	NP	NP		
800-TLD3	Suffolk County CD	17.2	15.3	15.3	18.8	17 ± 3	67 ± 13
999-TLD1	Private property	15.1	13.6	13.3	15.5	14 ± 2	57 ± 8
Off-site average		17.1	14.8	14.8	17.0	16 ± 2	64 ± **9**
Std. dev. (2 σ)		**4.5**	**2.5**	1.8	2.2		
075-TLD4	Control TLD average	**9.2**	**8.9**	**9.3**	**8.9**	**9.1** ± 0	36 ± 2

Notes:
See Figure 8-2 for TLD locations.
CD = Correctional Department
NP = TLD not posted for the quarter
P = TLD not processed

former Hazardous Waste Management Facility (HWMF). These TLDs measured slightly higher external dose than the typical natural background dose measured in other BNL areas. The slightly elevated external dose measured at the former HWMF can be attributed to the presence of small amounts of contamination in the soils after remediation began in 2004. As part of the CERCLA Program, all former HWMF buildings were demolished in 2003 and excavation of the contaminated soil was completed in 2005. Comparison of the 2005 dose rates with those from previous years clearly shows that dose rates have declined since the removal of the radioactive soil and are now slightly above natural background levels. The former HWMF is fenced, access is controlled, and only qualified staff members are allowed inside the facility. These values should decline further in 2006.

Two TLDs (075-TLD3 and 075-TLD5) posted near Building 356 showed higher quarterly averages, 22 ± 3 mrem (220 ± 30 µSv) and 23 ± 4 mrem (230 ± 40 µSv), respectively. The yearly doses were measured at 88 ± 10 mrem (880 ± 100 µSv) for 075-TLD3, and 92 ± 17 mrem (920 ± 170 µSv) for 075-TLD5. The direct doses are higher than the on-site annual average because Building 356 houses a cobalt-60 (Co-60) source, which is used to irradiate materials, parts, and electronic circuit boards. The elevated dose measurements from Building 356 can be attributed to the "sky-shine" phenomenon and shielding of Building 356. Although individuals who use the parking lot outside this building could re-

Table 8-3. Facility Area Monitoring

TLD#	Location	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	Avg./Qtr. +/- 2σ (95%)	Annual Dose +/- 2σ (95%)
		(mrem)					
054-TLD2	N/E of Bldg. 913-B	71.7	28.1	15.2	18.3	33 ± 51	133 ± 205
054-TLD3	N/W of Bldg. 913-B	35.9	15.1	14.1	16.7	20 ± 20	82 ± 81
S6		19.4	18.4	16.4	18.2	18 ± 2	72 ± 10
088-TLD1	HWMF-50' east of S-6	22.3	19.2	18.8	18.9	20 ± 3	79 ± 13
088-TLD2	HWMF-50' west of S-6	20.8	22.5	20.6	19.6	21 ± 2	84 ± 10
088-TLD3	HWMF-100' west of S-6	25.2	20.2	20.3	21.4	22 ± 5	87 ± 19
088-TLD4	HWMF-150' west of S-6	20.0	17.7	17.8	19.7	19 ± 2	75 ± 10
075-TLD3	Bldg. 356	22.0	21.9	20.6	23.7	22 ± 3	88 ± 10
075-TLD5	North Corner of Bldg. 356	23.7	21.0	21.7	25.7	23 ± 4	92 ± 17

Notes:
See Figure 8-1 for TLD locations.
HWMF = Hazardous Waste Management Facility

ceive a dose from this source, the dose would be minimal, due to the fact that an individual would most likely spend limited time in the parking lot.

Two TLDs placed on the fence northeast and northwest of Building 913-B (the AGS Tunnel Access) also showed higher than normal ambient external dose. The 054-TLD2 located on the northeast side of Building 913-B showed higher dose in the first quarter (71.7 mrem, or 717µSv) and the second quarter (28.1 mrem, or 281 µSv). The northwest TLD (054-TLD3) showed higher dose only in the first quarter (35.9 mrem, or 359 µSv). The potential cause of the higher doses during the first and second quarter is associated with skyshine phenomenon from heavy ions and polarized protons during the initial startup of the Alternating Gradient Synchrotron (AGS).

8.2 DOSE MODELING

EPA regulates radiological emissions from DOE facilities under the requirements set forth in 40 CFR 61, Subpart H, National Emission Standards for Hazardous Air Pollutants (NESHAPs). This regulation specifies the compliance monitoring and requirements for reporting the radiation doses received by members of the public from airborne radionuclides. The regulation mandates that no member of the public shall receive a dose from DOE operations that is greater than 10 mrem (100 µSv) in a year. The emission monitoring requirements are set forth in Subpart H, Section 61.93(b) and include the use of a reference method for continuous monitoring at major release points (defined as those with a potential to exceed 1 percent of the 10 mrem standard), and a periodic confirmatory measurement for all other release points. The regulations also require DOE facilities to submit an annual NESHAPs report to EPA that describes the major and minor emission sources and dose to the MEI. The dose estimates from various facilities are given in Table 8-4, and are also discussed in detail in Chapter 4.

As a part of the NESHAPs review process at BNL, any source that has the potential to emit radioactive materials is evaluated for regulatory compliance. Although the activities conducted under the Environmental Restoration (ER) Program are exempt under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), these activities are monitored and assessed for any potential to release radioactive materials, and to determine their dose contribution, if any, to the environment. In 2005, new processes or activities were evaluated for compliance with NESHAPs regulations using EPA's approved dose modeling software (see Section 8.2.1 for details). Because this model was designed to treat all radioactive emission sources as continuous over the course of a year,

Table 8-4. MEI Effective Dose Equivalent From Facilities or Routine Processes.

Building No.	Facility or Process	Construction Permit No.	MEI Dose (mrem) (a)	Notes
348	Radiation Protection	None	ND	(b)
463	Biology Facility	None	1.60E-15	(b)
490	Medical Research	BNL-489-01	8.37E-9	(b)
490A	Energy and Environment National Security	None	1.21E-15	(b)
491	Brookhaven Medical Research Reactor	None	ND	(e)
510	Calorimeter Enclosure	BNL-689-01	ND	(f)
510A	Physics	None	ND	(b)
535	Instrumentation	None	ND	(b)
555	Chemistry Facility	None	ND	(b)
725	National Synchrotron Light Source	None	6.84E-16	(b)
750	High Flux Beam Reactor	None	1.16E-4	(c)
801	Target Processing Lab	None	1.19E-6	(b), (c)
802B	Evaporator Facility	BNL-288-01	NO	(e)
820	Accelerator Test Facility	BNL-589-01	ND	(d)
830	Environmental Science Department	None	ND	(d)
865	Reclamation Building	None	ND	(c)
906	Medical-Chemistry	None	ND	
925	Accelerator Department	None	ND	(b)
931	Brookhaven Linac Isotope Producer	None	5.27E-2	(c)
938	REF/NBTF	BNL-789-01	ND	(g)
942	Alternate Gradient Syncrotron Booster	BNL-188-01	ND	(h)
---	Relativistic Heavy Ion Collider	BNL-389-01	ND	(d)
Total Potential Dose from BNL Operations			**5.28E-2**	
EPA Limit			10.0 mrem	

Notes:
Diffuse, Fugitive, and Other sources are not included in this table since they are short-term emissions.
MEI = Maximally Exposed Individual
NBTF = Neutron Beam Test Facility
REF = Radiation Effects Facility
(a) "Dose" in this table means effective dose equivalent to MEI.
(b) Dose is based on emissions calculated using 40 CFR 61, Appendix D methodology.
(c) Emissions are monitored at the facility.
(d) ND = No dose from emissions source in 2005.
(e) NO = Not operational in 2005.
(f) This has become a zero-release facility since original permit application.
(g) This facility is no longer in use; it produces no radioactive emissions.
(h) Booster ventilation system prevents air release through continuous air recirculation.

it is not well suited for estimating short-term or acute releases. Consequently, it overestimates potential dose contributions from short-term projects and area sources. For that reason, the results are considered to be "conservative"—that is, erring on the side of caution.

8.2.1 Dose Modeling Program

Compliance with NESHAPs regulations is demonstrated through the use of EPA software, the Clean Air Act Assessment Package-1988 (CAP88-PC), Version 2.10. This computer program uses a Gaussian plume model to estimate the average dispersion of radionuclides released from elevated stacks or diffuse sources. It calculates a final value of the projected dose at the specified distance from the release point by computing dispersed radionuclide concentrations in air, rate of deposition on ground surfaces, and intake via the food pathway (where applicable). CAP88-PC calculates both the effective dose equivalent (EDE) to the MEI and the collective population dose within a 50-mile radius of the emission source. In most cases, the CAP88-PC model provides conservative doses. 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 dose calculations are based on very low concentrations of the environmental releases and are based on chronic, continuous intakes in a year. The input parameters used in the model include radionuclide type, emission rate in curies (Ci) per year, stack parameters such as height and diameter, and emission exhaust velocity. Site-specific weather and population data are factored into the dose assessment. Weather data are supplied by measurements from BNL's meteorological tower, which includes wind speed, direction, frequency, and air temperature (see Chapter 1 for details). Population data used in the model are based on the Long Island Power Authority population survey (LIPA 2000). Because visiting researchers and their families may reside at the BNL on-site apartment area for extended periods of time, these residents are also included in the population file used for dose assessment.

8.2.2 Dose Calculation Methods and Pathways

8.2.2.1 Maximally Exposed Individual

The MEI is defined as a hypothetical person who resides at the site boundary and has a lifestyle such that no other member of the public could receive a higher dose. This person is assumed to reside 24 hours a day, 365 days a year at the BNL site boundary in the downwind direction, and to consume significant amounts of contaminated fish and deer containing radioactivity attributable to BNL based on projections from the New York State Department of Health (NYSDOH). In reality, it is highly unlikely that such a combination of "maximized dose" to any single individual would occur, but the concept is useful for evaluating maximum potential risk and dose.

8.2.2.2 Effective Dose Equivalent

The EDE to the MEI for low levels of radioactive materials dispersed into the environment was calculated using the CAP88-PC, Version 2.10 dose model program. Site meteorology data were used to calculate annual dispersions for the midpoint of a given wind sector and distance. Facility-specific radionuclide release rates (Ci/year) were used for continuously monitored facilities. For small sources, the emissions were calculated using the method set forth in 40 CFR 61, Appendix D. The Gaussian dispersion model calculated the EDE at the site boundary and collective population dose values from immersion, inhalation, and ingestion pathways. These dose and risk calculations to the MEI are based on low emissions and chronic intakes.

8.2.2.3 Dose Calculation: Fish Ingestion

To calculate the EDE from the fish consumption pathway, the intake is estimated. Intake is the average amount of fish consumed by a person engaged in recreational fishing in the Peconic River. Based on a NYSDOH study, the consumption rate is estimated at approximately 15 pounds (7 kg) per year (NYSDOH 1996). For each radionuclide of concern for fish samples, the dry weight activity concentration was converted to picocuries per gram (pCi/g) wet weight, since "wet weight" is the form in which fish are caught and consumed. A dose conversion factor was used for each radionuclide to convert the activity concentration into the EDE. For example, the committed dose equivalent factor for cesium-137 (Cs-137) is 5.0E-02 rem/µCi, as set forth in DOE/EH-0071. The dose was calculated as: ***dose*** (rem/year) = ***intake*** (kg/year) × ***activity in flesh*** (µCi/kg) × ***dose factor*** (rem/µCi).

8.2.2.4 Dose Calculation: Deer Meat Ingestion

The dose calculation for the deer meat ingestion pathway is similar to that for fish consumption. The Cs-137 radionuclide dose conversion factor was used to estimate dose, based on the U.S. Environmental Protection Agency Exposure Factors Handbook (EPA 1996). The total pounds of deer meat ingested during the course of a year was 64 pounds (29 kg) per year (NYSDOH 1999).

8.3 DIFFUSE, FUGITIVE, AND OTHER DOSES

Diffuse sources are described as emissions of radioactive contaminants to the atmosphere that do not have a well-defined emission point, such as a stack. Such sources are also known as non-point or area sources. Fugitive sources include releases to the air that are not released through an actively ventilated air stream (i.e., leaks from vents). The following potential radiological remediation/diffuse sources were evaluated in 2005 for potential contribution to the overall site dose.

8.3.1 Laser Electron Stripping Experiment

A NESHAPs compliance review was performed of the 200 MeV laser electron stripping experiment conducted in the Radiation Effects Facility (REF), Building 937. The source term was based on the production rate of 0.2 thermal and fast neutrons per proton. The proton energy was at 200 MeV with a beam intensity of 1.85E10 protons per second. The REF tunnel is equipped with a 255-cfm fan that vents to the outside via a 2-meter-high stack with a 6-inch inner diameter. A HEPA filtration system was used to prevent the release of any particulate radioactivity to the environment.

The laser electron stripping experiment was scheduled for 3 weeks and operated for 20 hours per week. The principal radionuclides, from an environmental risk and dose compliance perspective, were carbon-11 (C-11, $T_{1/2}$ = 20 min, β^+), nitrogen-13 (N-13, $T_{1/2}$ = 10 min, β^+), oxygen-15 (O-15, $T_{1/2}$ = 2 min, β^+), fluorine-18 (F-18, $T_{1/2}$ = 110 min, β^+), and argon-41 (Ar-41, $T_{1/2}$ = 1.8 hr, β/γ). It was determined that the REF facility was in compliance with the NESHAPs regulations for emissions during the laser stripping experiment. The effective dose equivalent to the MEI was calculated to be 3.24E-07 mrem (3.24 pSv) in a year at the southeast location.

8.3.2 Alternating Gradient Synchrotron Tritium Production

The AGS Snake Magnet is pre-cooled with liquid nitrogen for up to approximately 10 days and then switched over to the helium cooling system. The potential for tritium production in the liquid helium was evaluated in 2004 and the AGS facility was found to be compliant with NESHAPs regulations for fugitive losses of the tritium. However, the scatter and absorption interactions of protons lost from the high-energy polarized beam can produce secondary and tertiary hadrons, which potentially could interact with the liquid nitrogen used to pre-cool the AGS Snake Magnet. Therefore, a NESHAPs compliance review was completed to estimate the production of nitrogen isotopes and their emissions during pre-cooling of the magnet.

Trace amounts of H-3 and Be-7 are produced in the liquid nitrogen during the beam operations and were considered in this risk/dose assessment. Although trace amounts of C-11 and N-13 are also produced in the liquid nitrogen, due to their very low concentrations and short half-lives the fugitive losses to the environment were considered insignificant. The dose assessment showed that the EDE to the MEI from the H-3 and Be-7 emissions in the northwest direction was 9.88E-7 mrem (9.88 pSv) in a year. While there was no dose risk to members of the public, there was potential for radiological hazard to workers from immersion dose in the immediate vicinity of the AGS Ring. Only trained personnel have access to the area.

8.4 Dose from Point Sources

8.4.1 Brookhaven Linac Isotope Producer

Source term descriptions for point sources are given in Chapter 4. The Brookhaven Linac Isotope Producer (BLIP) facility is the only emission source with any potential to contribute dose to members of the public greater than 1 percent of the DOE limit (i.e., 0.1 mrem or 1.0 µSv). The BLIP facility uses the excess beam capacity of the Linear Accelerator (Linac) to produce short-lived radioisotopes for medical diagnostic procedures, medical imaging, and scientific research. During the irradiation process, the targets are cooled continuously by water recirculating in a 16-inch-diameter shaft. The principal gaseous radionuclides produced as a result of activation of the cooling water are O-15 and C-11. Because the BLIP facility has the potential to exceed one percent of the DOE emission limit, the facility emissions are directly measured using a low-resolution gamma spectrometer with an in-line sampling system connected to the air exhaust, to measure the short-lived gaseous products that cannot be sampled and analyzed by conventional methods. Particulates and radioiodine are monitored with paper and granular activated charcoal filters, which are exchanged weekly for analysis by a contract analytical laboratory. A tritium sampler also operates continuously, with weekly sample collection and analyses.

In 2005, the BLIP facility operated over a period of 17 weeks. During the year, 816 Ci of C-11 and 2,432 Ci of O-15 were released from the BLIP facility. Tritiated water vapor (5.16E-02 Ci) was also released, due to activation of the targets' cooling water. The annual EDE to the MEI from BLIP operations was calculated to be 5.30E-02 mrem (0.53 μSv).

An analysis of the past 3 years' of BLIP operating data and the real-time emissions data collected to date shows that BLIP emissions have been effectively reduced by approximately 30 percent since the installation of a sealed Lucite cover to enclose the cooling water surface, the source of most BLIP emissions. Tests completed in March 2005 with the sealed enclosure opened and then closed showed a decrease of 34 percent in emission activity at 72 micro-amps and 117 MeV energy. Additionally, while the total micro-amp-hours of operation increased by 155 percent in 2005 from the 2004 level, the EDE to the MEI increased only 20 percent, due to the effectiveness of the enclosure.

8.4.2 Brookhaven Medical Research Reactor

In 2005, the Brookhaven Medical Research Reactor (BMRR) facility was in a cold-shutdown mode and was downgraded from a nuclear facility to a radiological facility. During the year, the primary cooling water (1,850 gallons), Janus plates, control rod blades, activated hydraulic fluid from the shutters, and condensate from air handlers were shipped off site. Regular inspections of the decommissioned facility are conducted to ensure that safety and security aspects are intact and in compliance.

8.4.3 Unplanned Releases

There were no unplanned releases in 2005.

8.5 DOSE FROM INGESTION

Deer and fish bioaccumulate radionuclides in their tissues and organs, and therefore samples are analyzed to evaluate the dose contribution to humans from the ingestion pathway. As discussed in Chapter 6, deer meat samples collected off site and less than 1 mile from the BNL boundary were used to assess the potential dose impact to the MEI. Eleven samples of deer meat (flesh) were used to calculate the "off site and less than 1 mile" average for the purpose of dose calculations. Potassium-K (K-40) and Cs-137 were the two radionuclides detected in the tissue samples. K-40 is a naturally occurring radionuclide and is not related to BNL operations. The average K-40 concentrations were 3.9 ± 1.1 pCi/g (wet weight) in the flesh and 2.8 ± 0.9 pCi/g (wet weight) in the liver. The average Cs-137 concentrations were 0.8 ± 0.3 pCi/g (wet weight) in the flesh and 0.3 ±0.1 pCi/g (wet weight) in the liver ("off site and less than 1 mile average," from Table 6-2). The potential dose from consuming deer meat with the average Cs-137 concentration was estimated as 0.32 mrem (3.2 μSv) in a year. This is 3 percent of the health advisory limit of 10 mrem (100 μSv) established by NYSDOH.

In collaboration with the New York State Department of Environmental Conservation (NYSDEC) Fisheries Division, BNL maintains an ongoing program of collecting and analyzing fish from the Peconic River and surrounding freshwater bodies. In 2005, the chain pickerel samples collected in the Peconic River on the BNL site had the highest concentration (0.22 pCi/g) of Cs-137, so this value was used to estimate the EDE to the MEI (assuming consumption of 15 pounds of fish). The potential dose from consuming fish was estimated at 0.08 mrem (0.8 μSv) in a year. It is highly unlikely that an individual would consume fish with the highest concentration and from this location, but

Table 8-5. BNL Site Dose Summary for 2005.

Pathway	Dose to Maximally Exposed Individual	Percent of DOE 100 mrem/year Limit	Estimated Population Dose per year
Inhalation			
Air	0.053 mrem (0.53 µSv)	<1%	0.19 person-rem
Ingestion			
Drinking water	None	None	None
Fish	0.08 mrem (0.8 µSv)	<1%	Not tracked
Deer Meat	0.32 mrem (3.2 µSv)	<1%	Not tracked
All Pathways	0.45 mrem (4.5 µSv)	<1%	0.19 person-rem

these data were used to estimate potential maximum dose as a worst-case scenario for the MEI.

8.6 DOSE TO AQUATIC AND TERRESTRIAL BIOTA

DOE-STD-1153-2002, A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota, provides the guidelines for screening methods to estimate radiological doses to aquatic animals, terrestrial plants, and terrestrial animals using environmental surveillance data. The RESRAD-BIOTA 1.0 biota dose screening program was used to evaluate compliance with the requirements for protection of biota specified in 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 terrestrial animal and plant doses were evaluated based on 0.82 pCi/L of strontium-90 (Sr-90) in surface waters at the HM-N sampling location on the Peconic River (see Figure 5-8 for sampling stations). Soil samples were not collected this year due to a graded approach used for soil sampling (see Chapter 6 for more information). The dose to terrestrial animals was based on the surface water concentrations and calculated to be 1.62E-08 Gy/day and 3.95E-10 Gy/day to terrestrial plants. The doses to terrestrial animals and plants were well below the biota dose limit of 1 mGy/day.

For calculating dose to aquatic animals, radionuclide concentration values from the HM-N location on the Peconic River were used and both the surface water and sediment samples came from the same location. The Cs-137 sediment concentration was 103 Bq/L, and the Sr-90 concentration in surface water was 0. 03 Bq/L. The aquatic animal dose was estimated to be 7.16E-07 Gy/day; and to riparian animals, the estimated dose was 3.79E-06 Gy/day. Therefore, the dose to aquatic and riparian animals was also well below the 10 mGy/day limit specified by the regulations.

8.7 CUMULATIVE DOSE

Table 8-5 summarizes the potential cumulative dose from the BNL site. The total dose to the MEI from air and ingestion pathways was estimated to be 0.45 mrem (4.5 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). The effective dose was well below the DOE and EPA regulatory limits, and the ambient TLD dose was within normal background levels seen at the BNL site. The potential dose from drinking water was not estimated, because most of the residents adjacent to the BNL site get their drinking water from the Suffolk County Water Authority and not private wells.

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 approximately 300 mrem (3.0E-3 µSv). A diagnostic chest x-ray would result in 5 to 20 mrem (50–200 µSv) per exposure. Using natural gas in homes yields about 9 mrem (90 µSv) per year, cosmic radiation yields 26 mrem (260 µSv), and natural potassium in the body yields approximately 39 mrem (390 µSv) of internal dose. Even with conservative estimates of dose from the air pathway and ingestion of local deer meat and fish, the cumulative dose from BNL operations was well below the dose that could be received from a single chest x-ray.

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