

Radiological Dose Assessment

Brookhaven National Laboratory (BNL) performs periodic reviews of site operations and research projects to ensure that the overall radiological dose impact to members of the public, workers, visitors, and the environment is “As Low As Reasonably Achievable,” referred to as ALARA. All scientific experiments, new projects, and operational processes are evaluated for safety and health, dose risk, and environmental impacts. The potential radiological dose to the public is calculated at the site boundary as the “maximum” dose that could be received by a hypothetical individual defined as the maximally exposed individual (MEI). The doses are calculated for the direct and indirect dose pathways to an individual via air immersion, inhalation of particulates and gases, and ingestion of deer meat and fish. The 2007 total Effective Dose Equivalent (EDE) from all Laboratory activities was well below the EPA and DOE regulatory dose limits for the public, workers, and the environment.

The average annual on-site external dose from ambient sources was 70 ± 12 mrem (700 ± 120 μ Sv) and 64 ± 10 mrem (640 ± 100 μ Sv) at off-site locations. Both on-and off-site dose measurements include the contribution from natural terrestrial and cosmic background radiation. A statistical comparison of the average doses measured using thermoluminescent dosimeters (TLDs) at 49 on-site and 15 off-site locations showed that there was no external dose contribution from BNL operations above the natural background radiation level. An additional nine TLDs were used to measure on-site areas known to have slightly elevated radiation dose above natural background. The results of these measurements are described in Section 8.1.2.

The EDE from air emissions was calculated as $5.96E-02$ mrem (0.60 μ Sv) to the MEI. The dose from the ingestion pathway was estimated as 3.02 mrem (30 μ Sv) from the consumption of deer meat, and 0.08 mrem (0.8 μ Sv) from the consumption of fish caught in the vicinity of the Laboratory. The total annual dose to the MEI from all the pathways was estimated as 3.16 mrem (32 μ Sv). The BNL dose from the air inhalation pathway was less than 1 percent of EPA’s annual regulatory dose limit of 10 mrem (100 μ Sv), and the total dose was less than 4 percent of DOE’s annual dose limit of 100 mrem ($1,000$ μ Sv) from all pathways.

Doses to aquatic and terrestrial biota were also evaluated and found to be well below DOE regulatory limits. Other short-term projects, such as remediation work and waste management disposal activities conducted in 2007, were assessed for radiological emissions and their potential dose impacts. There was no radiological risk to the public, BNL employees, or the environment from these projects and activities. In summary, the overall dose impact from all Laboratory activities in 2007 was insignificant above the natural background radiation levels.

8.1 DIRECT RADIATION MONITORING

Direct, penetrating beta and 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 the Laboratory are composed of calcium fluoride and lithium fluoride crystals. Accuracy is verified by exposing the TLD to a known and character-

ized 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.

A direct radiation-monitoring program is used to measure the external dose contribution to members of the public and workers from radiation sources at the Laboratory. 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 dose measurements were averaged, and then compared with each other using the statistical t-test to measure any variations in the averages and thus the contribution, if any, from Laboratory operations.

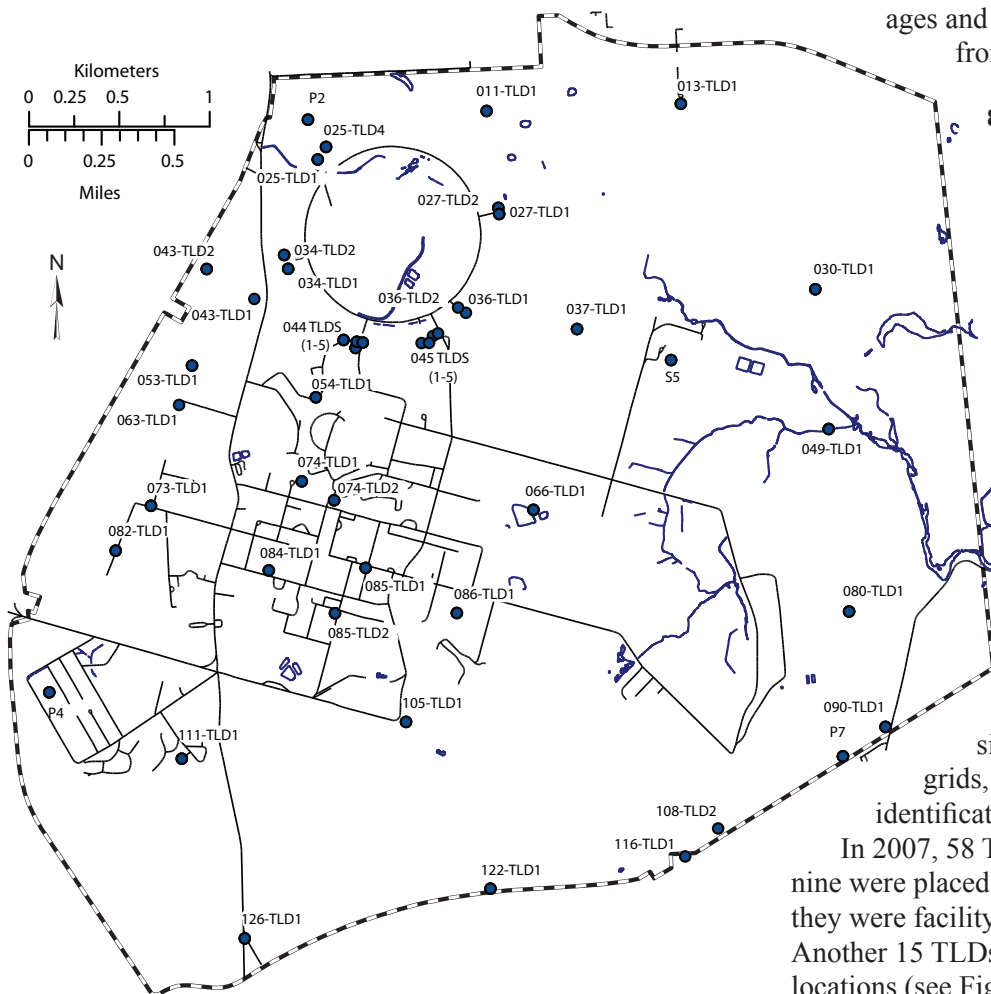


Figure 8-1. On-Site TLD Locations.

8.1.1 Ambient Monitoring

To assess the dose impact of direct radiation from BNL operations, TLDs are deployed on 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 radiation-generating facilities. The Laboratory perimeter is also posted with TLDs to assess the dose impact, if any, beyond the site's boundaries. On- and off-site locations are divided into grids, and each TLD is assigned an identification code based on these grids.

In 2007, 58 TLDs were deployed on site; nine were placed in known radiation areas (i.e., they were facility area monitors, "FAMs"). Another 15 TLDs were deployed at off-site locations (see Figures 8-1 and 8-2 for locations). An additional 30 TLDs were stored in a lead-shielded container in Building 490 for

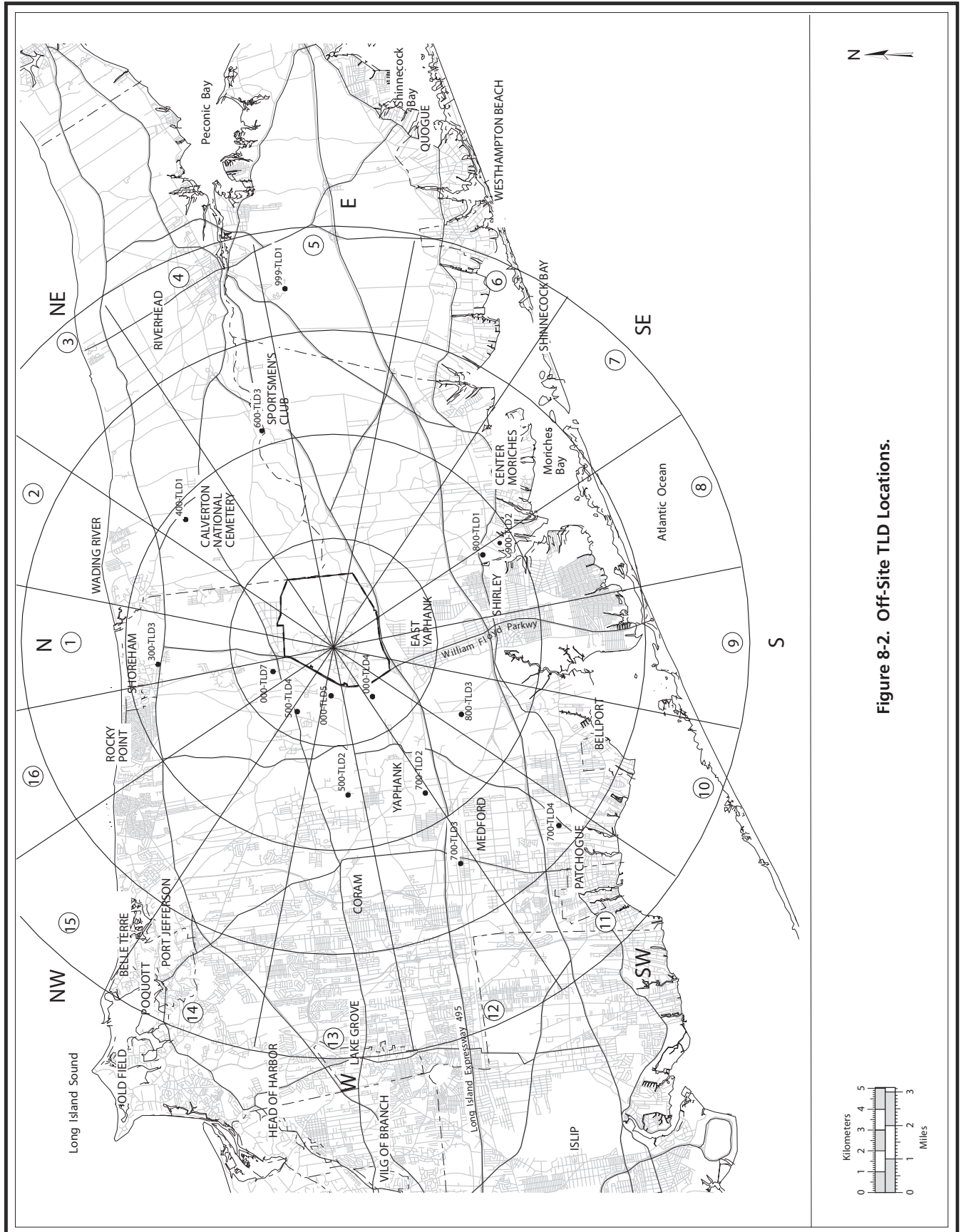


Figure 8-2. Off-Site TLD Locations.

use as reference and control TLDs for comparison purposes. The average of the control TLD values was reported as “075-TLD4” in Tables 8-1 and 8-2. Note that a small “residual” dose was reported for the control TLDs when they were annealed, because it is not possible to completely shield TLDs from all natural background and cosmic radiation sources. The on- and off-site TLDs were collected and read quarterly to determine the external radiation dose measured.

Table 8-1 shows the quarterly and yearly on-site radiation dose measurements for 2007. The on-site average external doses for the first, second, third, and fourth quarters were 19.1 ± 3.1 , 16.7 ± 3.5 , 15.9 ± 3.4 , and 18.4 ± 3.6 mrem, respectively. The on-site average annual external dose from all potential environmental sources, including cosmic and terrestrial radiation sources, was 70 ± 12 mrem (700 ± 120 μ Sv).

Table 8-2 shows the quarterly and yearly off-site radiation dose measurements. The off-site average external doses for the first, second, third, and fourth quarters were 16.9 ± 4.1 , 15.2 ± 2.7 , 15.2 ± 3.7 , and 15.9 ± 2.7 mrem, respectively. The off-site average annual ambient dose

from all potential environmental sources, including cosmic and terrestrial radiation sources, was 64 ± 10 mrem (640 ± 100 μ Sv).

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 ± 10 mrem) and on-site dose (70 ± 12 mrem) at the 95 percent confidence level. From the measured TLD doses, it can be safely concluded that there was no measurable external dose contribution to on- and off-site locations from Laboratory operations in 2007.

8.1.2 Facility Area Monitoring

Nine on-site TLDs were designated as facility area monitors because they were posted in known radiation areas. Table 8-3 shows the external doses measured with the FAM-TLDs. The environmental TLDs 088-TLD1 through 088-TLD4 are posted at the S-6 blockhouse location and on the fence of the former Hazardous Waste Management Facility (HWMF). These TLDs measured slightly higher external doses than the normal natural background

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

TLD#	Location	1st	2nd	3rd	4th	Avg./Qtr. $\pm 2\sigma$ (95%)	Annual Dose $\pm 2\sigma$ (95%)
		Quarter	Quarter	Quarter	Quarter		
(mrem)							
011-TLD1	North firebreak	17.7	12.5	12.6	14.4	14 ± 5	57 ± 19
013-TLD1	North firebreak	16.8	14.7	15.0	17.8	16 ± 3	64 ± 12
025-TLD1	Bldg. 1010 beam stop 1	18.2	16.4	14.1	16.9	16 ± 3	66 ± 13
025-TLD4	Bldg. 1010 beam stop 4	18.8	18.0	16.1	17.5	18 ± 2	70 ± 9
027-TLD1	Bldg. 1002A South	16.2	14.7	12.9	16.7	15 ± 3	61 ± 13
027-TLD2	Bldg. 1002D East	16.1	14.2	13.8	15.8	15 ± 2	60 ± 9
030-TLD1	NE Firebreak	19.8	15.3	15.0	17.0	17 ± 4	67 ± 17
034-TLD1	Bldg. 1008 collimator 2	17.5	16.3	15.8	18.5	17 ± 2	68 ± 10
034-TLD2	Bldg. 1008 collimator 4	18.0	18.9	15.4	18.8	18 ± 3	71 ± 13
036-TLD1	Bldg. 1004B East	17.3	15.5	13.2	19.5	16 ± 5	66 ± 21
036-TLD2	Bldg. 1004 East	20.3	21.2	16.2	18.8	19 ± 4	77 ± 17
037-TLD1	S-13	17.1	15.4	14.8	16.8	16 ± 2	64 ± 9
043-TLD1	North access road	20.5	16.8	16.7	18.1	18 ± 3	72 ± 14
043-TLD2	North of Meteorology Tower	18.5	17.3	17.3	18.6	18 ± 1	72 ± 6
044-TLD1	Bldg. 1006	18.1	15.8	16.7	17.8	17 ± 2	68 ± 8

(continued on next page)

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

TLD#	Location	1st	2nd	3rd	4th	Avg./Qtr. ± 2σ (95%)	Annual Dose ± 2σ (95%)
		Quarter	Quarter	Quarter	Quarter		
(mrem)							
044-TLD2	South of Bldg. 1000E	18.4	16.6	15.7	17.5	17 ± 2	68 ± 9
044-TLD3	South of Bldg. 1000P	18.4	15.2	14.4	17.2	16 ± 4	65 ± 14
044-TLD4	North-east of Bldg. 1000P	19.6	16.5	15.1	20.5	18 ± 5	72 ± 20
044-TLD5	North of Bldg. 1000P	18.7	18.1	15.3	17.2	17 ± 3	69 ± 12
045-TLD1	Bldg. 1005S	21.1	16.7	16.4	16.9	18 ± 4	71 ± 17
045-TLD2	East of Bldg. 1005S	20.2	17.6	16.8	19.8	19 ± 3	74 ± 13
045-TLD3	South-east of Bldg. 1005 S	18.6	15.6	15.5	19.2	17 ± 4	69 ± 15
045-TLD4	South-west of Bldg. 1005 S	20.9	17.2	15.8	19.1	18 ± 4	73 ± 17
045-TLD5	West south west of Bldg. 1005 S	19.5	13.9	14.2	16.3	16 ± 5	64 ± 20
049-TLD1	East firebreak	20.1	16.3	14.6	17.9	17 ± 5	69 ± 18
053-TLD1	West firebreak	24.2	19.1	17.8	19.4	20 ± 5	81 ± 22
054-TLD1	Bldg. 914	18.9	18.8	12.3	19.5	17 ± 7	70 ± 27
063-TLD1	West firebreak	19.1	17.9	18.2	21.8	19 ± 3	77 ± 14
066-TLD1	Waste Management Facility	17.0	13.9	14.0	15.5	15 ± 3	60 ± 11
073-TLD1	Meteorology Tower/Bldg. 51	20.4	17.3	17.4	18.9	19 ± 3	74 ± 11
074-TLD1	Bldg. 560	20.7	17.9	18.2	19.7	19 ± 3	77 ± 10
074-TLD2	Bldg. 907	20.5	16.0	14.3	19.2	18 ± 6	70 ± 22
080-TDL1	East firebreak	20.1	18.4	18.6	19.7	19 ± 2	77 ± 6
082-TLD1	West firebreak	21.8	18.1	20.0	21.1	20 ± 3	81 ± 13
084-TLD1	Tennis courts	19.5	15.9	15.5	18.0	17 ± 4	69 ± 15
085-TDL2	Upton gas station	18.2	17.9	17.1	19.7	18 ± 2	73 ± 9
085-TLD1	Diversity Office	19.8	NP	16.7	19.9	19 ± 4	75 ± 14
086-TLD1	Baseball fields	20.6	19.3	19.0	20.5	20 ± 2	79 ± 6
090-TLD1	North St. Gate	L	15.7	16.3	16.6	16 ± 1	65 ± 4
105-TLD1	South firebreak	20.0	19.2	17.9	21.6	20 ± 3	79 ± 12
108-TLD1	Water tower	17.8	16.8	15.7	17.4	17 ± 2	68 ± 7
108-TLD2	Tritium Pole	L	20.5	19.0	24.3	21 ± 5	85 ± 21
111-TLD1	Trailer park	20.0	17.8	16.2	18.8	18 ± 3	73 ± 13
122-TLD1	South firebreak	18.5	16.2	16.0	17.1	17 ± 2	68 ± 9
126-TLD1	South gate	20.1	16.9	17.5	18.8	18 ± 3	73 ± 11
P2		18.3	13.8	13.9	15.1	15 ± 4	61 ± 16
P4		17.5	15.6	15.7	17.4	17 ± 2	66 ± 8
P7		19.2	15.8	15.2	17.3	17 ± 3	68 ± 14
S5		17.1	16.7	14.8	17.7	17 ± 2	66 ± 10
On-site average		19.1	16.7	15.9	18.4	18 ± 3	70 ± 12
Std. dev. (2 σ)		3.1	3.5	3.4	3.6		
075-TLD4	Control TLD average	9.0	8.6	9.3	8.9	8.9 ± 1	36 ± 02

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	2nd	3rd	4th	Avg./Qtr. ± 2σ (95%)	Annual Dose ± 2σ (95%)
		Quarter	Quarter	Quarter	Quarter		
000-TLD4	Private property	13.7	15.1	13.7	15.8	15 ± 2	58 ± 8
000-TLD5	Longwood Estate	15.6	14.8	14.7	15.3	15 ± 1	60 ± 3
000-TLD7	Mid-Island Game Farm	17.7	15.9	15.2	15.8	16 ± 2	65 ± 8
300-TLD3	Private property	16.6	NP	NP	NP	17 ± 0	66 ± 0
400-TLD1	Calverton Nat. Cemetary	21.2	18.0	19.5	17.9	19 ± 3	77 ± 12
500-TLD2	Private property	16.3	13.0	14.4	15.2	15 ± 3	59 ± 11
500-TLD4	Private property	NP	NP	NP	16.5	17 ± 0	66 ± 0
600-TLD3	Sportsmen's Club	18.3	15.4	15.6	16.6	16 ± 3	66 ± 10
700-TLD2	Private property	15.5	14.5	14.5	15.9	15 ± 0	60 ± 0
700-TLD3	Private property	17.6	14.3	13.3	17.0	16 ± 4	62 ± 16
700-TLD4	Private property	19.7	15.1	16.9	17.2	17 ± 4	69 ± 15
800-TLD1	Private property	18.4	15.3	16.3	12.3	16 ± 5	62 ± 20
800-TLD3	Suffolk County CD	16.4	17.7	16.0	16.3	17 ± 1	66 ± 6
900-TLD2	Private property	14.0	14.2	12.3	14.8	14 ± 0	55 ± 0
999-TLD1	Private property	15.6	14.4	NP	NP	15 ± 2	60 ± 7
Off-site average		16.9	15.2	15.2	15.9	16 ± 3	64 ± 10
Std. dev. (2 σ)		4.1	2.7	3.7	2.7		
075-TLD4	Control TLD average	9.4	8.7	8.7	9.2	9.0 ± 1	36 ± 3

Notes:

See Figure 8-2 for TLD locations.

CD = Correctional Department

NP = TLD not posted for the quarter

radiation doses measured in other areas of BNL. The elevated external dose measured at the former HWMF can be attributed to the presence of small amounts of soil contamination. However, a comparison of the 2007 dose rates to doses from previous years show that the dose rates have declined significantly since the removal of most of the radioactive soil. As Table 8-3 shows, the dose is currently just slightly above natural background levels. The former HWMF is fenced, access is controlled, and only qualified staff members are allowed inside the facility.

Two TLDs (075-TLD3 and 075-TLD5) near Building 356 showed higher than normal quarterly averages: 29 ± 1 mrem (290 ± 10 μSv) and 30 ± 6 mrem (300 ± 60 μSv), respectively. The yearly doses were measured at 114 ± 5 mrem (1140 ± 50 μSv) for 075-TLD3, and 118 ± 25 mrem (1180 ± 250 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 from Building 356 is attributed to the “sky-shine” phenomenon. Although it is conceivable that individuals who use the parking lot adjacent to Building 356 could receive a dose from this source, the dose would be minimal due to the limited time an individual spends in the parking lot.

In previous years, two FAM-TLDs placed on the fence northeast and northwest of Building 913-B (the Alternating Gradient Synchrotron tunnel access) showed higher than normal ambient external dose. The second-quarter dose was measured at 48.1 mrem for 054-TLD2. For the three remaining quarters, both TLDs showed dose slightly above normal background radiation.

Table 8-3. Facility Area Monitoring.

TLD#	Location	1st	2nd	3rd	4th	Avg./Qtr.	Annual
		Quarter	Quarter	Quarter	Quarter	$\pm 2\sigma$ (95%)	Dose $\pm 2\sigma$ (95%)
(mrem)							
054-TLD2	N/E of Bldg. 913-B	22.7	48.1	15.0	25.1	28 \pm 28	111 \pm 112
054-TLD3	N/W of Bldg. 913-B	29.2	25.3	13.9	21.5	22 \pm 13	90 \pm 51
S6		21.0	17.6	17.1	21.6	19 \pm 5	77 \pm 18
088-TLD1	FWMF-50' East of S-6	19.6	18.3	17.4	19.2	19 \pm 2	75 \pm 8
088-TLD2	FWMF-50' West of S-6	21.5	20.5	19.6	22.2	21 \pm 2	84 \pm 9
088-TLD3	FWMF-100' West of S-6	22.0	19.5	19.3	22.8	21 \pm 3	84 \pm 9
088-TLD4	FWMF-150' West of S-6	19.7	17.9	19.8	18.5	19 \pm 2	76 \pm 7
075-TLD3	Bldg. 356	29.1	27.6	29.0	28.4	29 \pm 1	114 \pm 5
075-TLD5	North Corner of Bldg. 356	26.8	30.0	27.6	33.8	30 \pm 6	118 \pm 25

Notes:
See Figure 8-1 for TLD locations.
FWMF = Former Waste Management Facility

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 and monitoring requirements for reporting 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 μ Sv) 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 the emissions are 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. Any new processes or activities are 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, 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 dose modeling software and the Clean Air Act Assessment Package-1988 (CAP88-PC), Versions 2.1 and 3.0. 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 radio-

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	ND	(b)
490	Medical Research	BNL-489-01	6.01E-12	(b)
490A	Energy and Environment National Security	None	ND	(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	ND	(b)
750	High Flux Beam Reactor	None	6.68E-6	(c)
801	Target Processing Lab	None	1.14E-8	(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	5.96E-2	(c)
938	REF/NBTF	BNL-789-01	ND	(g)
942	Alternate Gradient Synchrotron Booster	BNL-188-01	ND	(h)
---	Relativistic Heavy Ion Collider	BNL-389-01	ND	(d)
Total Potential Dose from BNL Operations			5.96E-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 2007.
 (e) NO = Not operational in 2007.
 (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.

nuclide concentrations in air, rate of deposition on ground surfaces, and intake via the food pathway (where applicable). CAP88-PC calculates both the 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 the purpose 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 cal-

culations are based on very low concentrations of the environmental releases and 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 the Laboratory's meteorological

tower. These measurements include 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, these residents are 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 fish and deer containing radioactivity attributable to Laboratory operations based on projections from the New York State Department of Health (NYS-DOH). 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 dose modeling program, Versions 2.1 and 3.0. 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/yr) 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 the 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 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 $5.0E-02 \text{ rem}/\mu\text{Ci}$, as set forth in DOE/EH-0071. The dose was calculated as: $\text{dose (rem/yr)} = \text{intake (kg/yr)} \times \text{activity in flesh } (\mu\text{Ci/kg}) \times \text{dose factor (rem}/\mu\text{Ci})$.

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 quantity of deer meat ingested during the course of a year was estimated as 64 pounds (29 kg) (NYSDOH 1999).

8.3 SOURCES: DIFFUSE, FUGITIVE, “OTHER”

Diffuse sources are described as releases of radioactive contaminants to the atmosphere that do not have a well-defined emission point such as a stack or vent. Such sources are also known as nonpoint or area sources. Fugitive sources include releases to the air not through an actively ventilated air stream (i.e., leaks from vents are fugitive sources). As a part of the NESHAPs review process, in addition to stack emissions, any fugitive or diffuse emission source that could potentially emit radioactive materials to the environment is evaluated. Although CERCLA-prompted actions, such as remediation projects, are exempt from the procedural requirements to obtain federal, state, or local permits, any BNL activity or process with the potential to emit radioactive material must be evaluated and assessed for dose impact to members of the public. The following radiologi-

cal sources were evaluated in 2007 for potential contribution to the overall site dose.

8.3.1 Medical Department

In the Medical Department (Building 490), Room 9-830 was used for bio-assay, lysis of cells, immuno-precipitation, separation of recoverable radioactive proteins by electrophoresis, and the incorporation of radio-labeled tracers by injection into experimental animals to investigate certain scientific principles and perform research. Very small quantities of radioactive tracers were used in the research project with low levels of radioactivity; between 2 to 20 millicurie quantities. A single or combination of the following radiotracers were used in the process: carbon-14 (half-life: 5730 years), fluorine-18 (half-life: 109.74 minutes), carbon-11 (half-life: 20.48 minutes), and phosphorus-32 (half life: 14.29 days). The research experiments can be repeated from 10 to 200 times over the course of a year. Room 9-830 is equipped with a fume hood with a HEPA filtration system to control the particulate emissions. The work was performed in accordance with a radiological work permit and the health and safety protection procedures of the facility.

The radioactive source term was based on the maximum quantity of radioactive materials used with the number of injections in a given year. In 2007, iodine-131 (half-life: 8.0917 days) was used 20 times, with a maximum activity of 20 microcuries (mCi); iodine-125 (half-life: 60.14 days) was used 20 times, with a maximum activity of less than 10 mCi; tritium and tritiated compounds were estimated to be used approximately 200 times, with a maximum activity of 20 mCi; carbon-14 was used approximately 100 times, also with a maximum activity of 20 mCi; and fluorine-18, carbon-11, and phosphorus-32 were used approximately 10 times, with a maximum activity of 100 mCi each. The estimated source quantities were corrected for the emission factor because of their low probability for becoming airborne and because they were tagged tracers.

The effective dose equivalent to the MEI resulting from research operations in Room 9-830 was estimated to be 2.08E-05 mrem/year at BNL's southeast MEI location. The EDE was

well below the 10 mrem/year annual limit specified in 40 CFR 61, Subpart H.

8.3.2 Waste Loading Area

The former Hazardous Waste Management Facility was a Resource Conservation and Recovery Act (RCRA)-permitted facility used for processing and storage of RCRA waste, radioactive waste, and mixed wastes generated at BNL. Currently, the former HWMF is fenced and categorized as a radiological facility under a surveillance and maintenance program of the Environmental and Waste Management Services Division. It is located south of Brookhaven Avenue in the southeast wind sector of the Laboratory. The project requirements were to excavate the remaining contaminated soil that was left at the waste loading area (WLA) during the 2005 remediation action plan for the former HWMF. The residual contamination was left in a 122 by 84 meter surface area that was designated to be used as the loading dock for other remedial activities at a later date. However, a decision was made in 2007 to proceed with the remediation of the WLA area. Therefore, a NESHAPs evaluation was performed to evaluate the dose risks to the members of the public during the remediation activities.

An excavator was used to scrape the top layers of soil and a front-end loader was used to load the contaminated soil into rail cars for off-site disposal. To minimize airborne dust particles and the resuspension of particulates, workers used suppression control techniques such as water mist spray and laying a tarp cover over the soil. Water mist was also sprayed over dirt roadways and the excavated work areas before the contaminated soil was loaded into rail cars. Excavation and soil loading activities were suspended during conditions of sustained high wind (>20 mph). An air particulate filter sample collection system was set up in the upwind direction (as a control sampler) and in the downwind direction to monitor particulates released from the excavation and loading activities.

The potential source term was defined as the amount of radioactive material, in grams or curies, based on the material-at-risk (MAR) that could get released into the environment. The

MAR was defined as the maximum amount of radionuclides available to be acted upon by a given physical stress (in this case, decontamination and decommissioning activities), with some probability of release. The MAR values represented the maximum quantities of radionuclides present in the soil samples during the characterization activities. The following radionuclides were used in the NESHAP evaluation: tritium (0.2 pCi/g), cobalt-60 (0.4 pCi/g), strontium-90 (33.1 pCi/g), cesium-137 (395 pCi/g), uranium-235 (7.4 pCi/g), uranium-238 (0.73 pCi/g), plutonium-238 (0.06 pCi/g), plutonium-239/240 (3.4 pCi/g), and americium-241 (4.6 pCi/g).

The radiological dose and risk to the MEI were assessed using the Clean Air Act Code CAP88-PC, version 3.0 modeling program, to show compliance with 40CFR 61.93 (a) of the CAA regulations. The total annual dose to the MEI resulting from the remediation project in the WLA was estimated to be 5.90E-2 mrem, well below the 10 mrem/year annual limit specified in 40 CFR 61, Subpart H.

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 EPA limit (i.e., 0.1 mrem, or 1.0 μ Sv). 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 recirculating water in a 16-inch-diameter shaft. The principal gaseous radionuclides produced as a result of activation of the cooling water are O-15, N-13, and C-11. Because the BLIP facility has the potential to exceed 1 percent of the EPA 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 analytical 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 frequency.

In 2007, the BLIP facility operated over a period of 20 weeks. During the year, 837 Ci of C-11 and 1698 Ci of O-15 were released from the BLIP facility. A small quantity of tritiated water vapor from activation of the targets' cooling water was also released: 4.92E-02 Ci. The EDE to the MEI was calculated to be 5.96E-02 mrem (0.60 μ Sv) in a year from BLIP operations.

Anticipating an increase in operating hours for the BLIP facility in 2008 because of greater demand for medical diagnostic isotopes and reduced production at the Los Alamos National Laboratory production facility, an application for a NESHAPs permit was prepared. That application will be submitted to EPA in early 2008.

8.4.2 High Flux Beam Reactor

In 2007, the HFBR facility was in a "cold" shutdown mode and was downgraded from a nuclear facility to a radiological facility. Tritium samples were taken monthly and the dose contribution was determined to be 6.68E-6 mrem (7 nSv) in a year.

8.4.3 Brookhaven Medical Research Reactor

In 2007, the Brookhaven Medical Research Reactor (BMRR) facility was in a "cold" shutdown mode. Tritium sampling and analyses were completed inside the building to quantify the tritium contents in the humid enclosed air. The tritium concentrations in the building were found to be very low—insignificant from a dose risk point of view and there was no dose contribution from the BMRR.

8.4.4 Unplanned Releases

There were no unplanned releases in 2007.

8.5 DOSE FROM INGESTION

Because deer and fish bioaccumulate radionuclides in their tissues, bones, and organs, tissue samples were 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. Four samples of deer meat (flesh) were used to calculate the “off site and less than 1 mile” average at 0.81 ± 0.20 pCi/g; however, the maximum concentration of 2.1 pCi/g was used for the purpose of MEI dose calculations. Potassium-40 (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. In 2007, the average K-40 concentrations in tissue samples (off site < 1 mile) were 3.7 ± 0.9 pCi/g (wet weight) in the flesh and 2.7 ± 0.4 pCi/g (wet weight) in the liver. The maximum Cs-137 concentrations were 2.1 ± 0.2 pCi/g (wet weight) in the flesh and 0.5 ± 0.1 pCi/g (wet weight) in the liver (see Table 6-2). The potential dose from consuming deer meat with the average Cs-137 concentration was estimated as 3.02 mrem (30 μ Sv) in a year. This is less than 30 percent of the health advisory limit of 10 mrem (100 μ Sv) 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 2007, chain pickerel samples collected in the Peconic River at the Schultz Road site had the highest concentration of Cs-137, at 0.24 ± 0.03 pCi/g; this was used to estimate the EDE to the MEI. The potential dose from consuming 15 pounds of brown bullhead annually was calculated to be 0.08 mrem (0.8 μ Sv)—well below the NYSDOH health advisory limit of 10 mrem.

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 site-specific environmental surveillance data. The RESRAD-BIOTA 1.0 biota dose level 2 program was used to evaluate compliance with the requirements for pro-

tection of biota specified in DOE Order 5400.5 (1990), Radiation Protection of the Public and the Environment, and DOE Order 450.1, General Environmental Protection Program.

In 2007, the terrestrial animal and plant doses were evaluated based on 4.47 pCi/g of Cs-137 found in the surface soils on the lawn of Building 515. The dose to terrestrial animals was calculated to be 0.22 mGy/day, and to plants, 0.02 mGy/day. 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 Swan Pond were used for both the surface water and sediment samples from the same location. The Cs-137 sediment concentration was 1.04 pCi/g, and the Sr-90 concentration in surface water was 1.0 pCi/L. The aquatic animal dose was calculated to be $3.96E-07$ Gy/day and the calculated dose to riparian animals was $3.92E-06$ 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 in 2007. The total dose to the MEI from air and ingestion pathways was estimated to be 3.16 mrem (32 μ Sv). In comparison, the EPA regulatory limit for the air pathway is 10 mrem (100 μ Sv) and the DOE limit from all pathways is 100 mrem (1,000 μ Sv). The cumulative population dose would be 0.19 person-rem (2 person-mSv) in a year. 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 Laboratory 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 rather than 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 ($3.0E-3$ μ Sv). A diagnostic chest x-ray would result in 5 to 20 mrem (50–200 μ Sv)

Table 8-5. BNL Site Dose Summary.

Pathway	Dose to Maximally Exposed Individual	Percent of DOE 100 mrem/year Limit	Estimated Population Dose per year
Inhalation			
Air	0.06 mrem (0.60 μ Sv)	<1%	0.19 person-rem
Ingestion			
Drinking water	None	None	None
Fish	0.08 mrem (0.8 μ Sv)	<1%	Not tracked
Deer Meat	3.02 mrem (30 μ Sv)	<4%	Not tracked
All Pathways	3.16 mrem (32 μ Sv)	<4%	0.19 person-rem

per exposure. Using natural gas in homes yields approximately 9 mrem (90 μ Sv) per year, cosmic radiation yields 26 mrem (260 μ Sv), and natural potassium in the body yields approximately 39 mrem (390 μ Sv) of internal dose. Even with worst-case 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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