

3 EMISSION/EFFLUENT SOURCES AND PATHWAYS

3.1 INTRODUCTION

Brookhaven National Laboratory (BNL) estimates potential exposures from radioactive and chemical substances that could be received by humans, terrestrial and aquatic plants, and flora and fauna through various pathways. To calculate the exposures, the character of the pollutants emitted (e.g., identity, amount, rate of release, chemical form, etc.) and how the pollutants are subsequently absorbed, retained, and passed along by the various possible exposure pathways, must be researched. Sources of radioactive and chemical emissions and effluents from Laboratory facilities are described below. A general description of the primary exposure pathways to members of the public and environment is also provided.

3.2 PATHWAYS

Chemicals and radionuclides released into the environment can move through the biosphere by several routes and can eventually lead to exposure of humans, animals, and vegetation. These routes can be direct, by the inhalation of contaminated air or ingestion of contaminated drinking water, or indirect, by involving many complex levels of the food chain and different transport mechanisms. Exposure is defined as the interaction of an organism with a physical or chemical agent of interest. An exposure pathway is identified based on the following factors:

- An examination of the type, location, and source (contaminated soil, raw effluent, etc.) of contaminants;
- Principal release mechanisms;
- Probable environmental fate and transport (including persistence, partitioning, and intermediate transfer) of contaminants of interest;
- Location and activities of potentially exposed populations.

Mechanisms that influence the fate and transport of chemical and radiological contaminants through the environment and influence the amount of exposure a person might receive at various receptor locations are listed below. While processes that move contaminants through the atmosphere and hydrosphere tend to reduce their concentrations, many pathway components or processes that move contaminants through the food chain to humans can cause bioaccumulation.

Once a radionuclide or chemical is released into the environment, it may be:

- *Transported* (e.g., migrate downstream in solution or on suspended sediment, travel through the atmosphere, or be carried off site in contaminated wildlife),
- *Physically or chemically transformed* (e.g., deposition, precipitation, volatilization, photolysis, oxidation, reduction, hydrolysis, or radioactive decay),
- *Biologically transformed* (e.g., biodegradation),
- *Accumulated in the receiving media* (e.g., strongly absorbed in the soil column, stored in organism tissues).

The atmosphere and surface water are the primary pathways for movement of radioactive materials and chemicals from the Laboratory site to the public. Figure 3-1 illustrates the potential routes and exposure pathways to humans. The significance of each pathway is determined by comparing

measurements and calculations that estimate the amount of radioactive material or chemical substances transported along each pathway with the concentrations or potential doses to environmental and public health protection standards or guides. Pathways are also evaluated based on prior studies and observations of radionuclide and chemical movement through the environment and food chains. Calculations based on effluent and emission data show the expected concentrations beyond the BNL site to be low for all Laboratory-produced radionuclides and most chemicals. Frequently, concentrations are below the level that can be accurately detected by monitoring technology. To ensure that radiological and chemical analyses of samples are sufficiently sensitive, minimum detection limits of key radionuclides and chemicals have been established at levels well below applicable health standards.

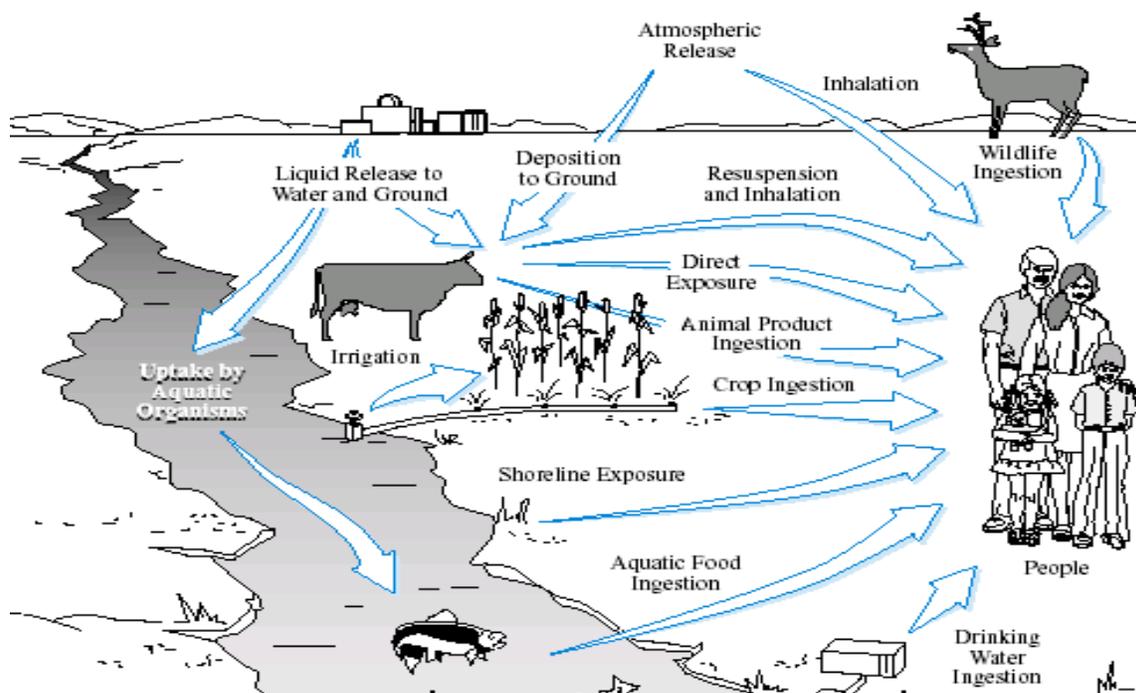


Figure 3.1. Primary Exposure Pathways to Humans

3.3 SOURCES

3.3.1 Airborne Emissions – Radioactive

Federal air quality laws and Department of Energy (DOE) regulations that govern the release of airborne radioactive material include 40 CFR 61 Subpart H: National Emission Standards for Hazardous Air Pollutants—part of the Clean Air Act, and DOE Order 458.1 Admin Chg. 4 (2020), *Radiation Protection of the Public and Environment*. Facilities with emissions that have the potential to deliver a radiation dose greater than 0.1 millirem per year to a member of the public must be continuously monitored for emissions. Facilities capable of delivering radiation doses below that limit require periodic, confirmatory monitoring. BNL's Brookhaven Linac Isotope Producer (BLIP) is one facility that is continuously monitored. Periodic monitoring is conducted at one active facility, the Target Processing Laboratory (TPL), and one inactive facility, the High Flux Beam Reactor (HFBR). Figure 3-2 indicates the location of each of these monitored facilities.

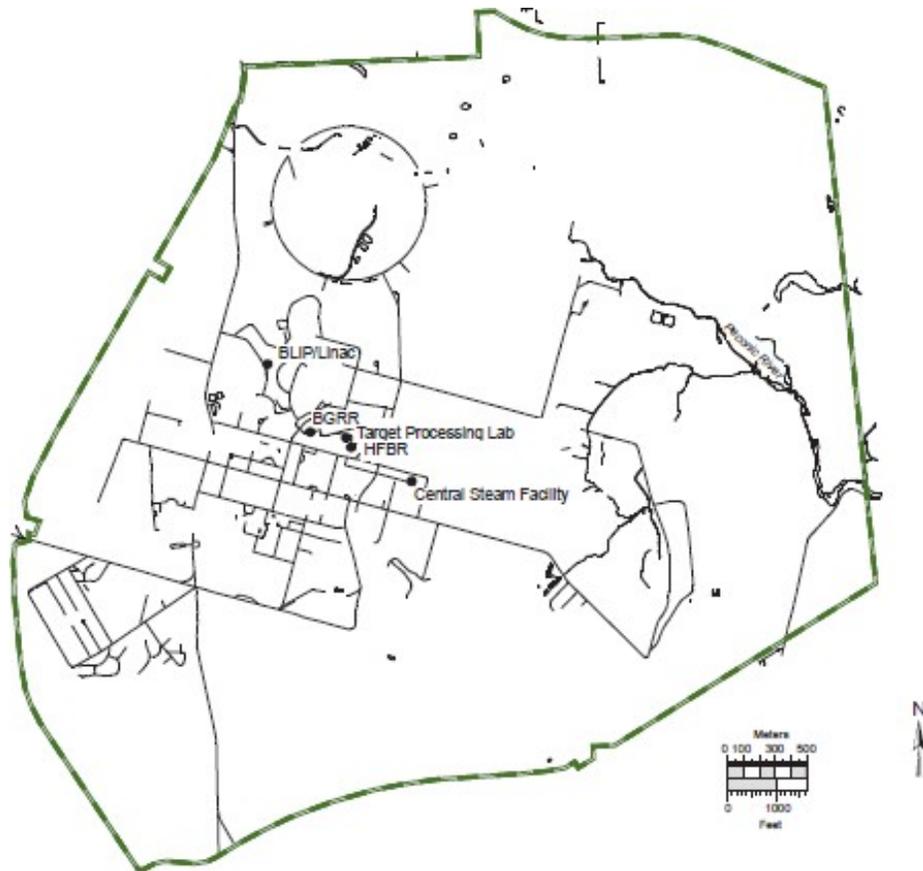


Figure 3.2. Potential Air Emission Release Points Subject to Monitoring.

The most significant sources of radionuclide emissions are from the BLIP and the TPL. The BLIP typically contributes the largest fraction (99 percent or more) of the total annual effective dose equivalent to the maximally exposed individual residing at the BNL site boundary. The primary radionuclide releases from Laboratory operations are carbon-11 (C-11), oxygen-15 (O-15), and tritium (H-3). Table 3-1 presents the airborne radionuclide releases from monitored facilities in calendar year 2019 (most current data).

Table 3-1. Airborne Radionuclide Releases from Monitored Facilities

Facility	Nuclide	Half-Life	Ci Released
HFBR	Tritium	12.3 years	3.85E-01
BLIP	Carbon-11	20.4 minutes	6.34E+03
	Oxygen-15	122 seconds	1.27E+04
	Tritium	12.3 years	3.77E-02
Total			1.90E+04
Notes:			
Ci = 3.7E+10 Bq			
BLIP = Brookhaven Linac Isotope Producer			
HFBR = High Flux Beam Reactor (operations were terminated in November 1999)			

Other facilities that have the potential for radiological emissions are associated with accelerator operations, such as the Alternating Gradient Synchrotron (AGS) Booster, the 200-MeV Linear Accelerator (LINAC), and associated experimental facilities. Emissions from these facilities are extremely low and are insignificant contributors to off-site dose. The other potential source of airborne radionuclide emissions is laboratory hoods, where work with dispersible radionuclides is performed. Small quantities of radioactive materials are typically used in these hoods, usually on the order of micro to millicurie quantities. Compliance with National Emission Standards for Hazardous Air Pollutants (NESHAPs) regulations for these sources is demonstrated annually using an inventory system, as allowed under Appendix D of the NESHAPs regulations. Environmental surveillance air monitoring conducted at the site boundaries also provides verification that off-normal emissions from these sources have not occurred.

New facilities or planned activities that will generate environmental releases of airborne radionuclides are reviewed for NESHAPs compliance. The review documents the details of the operation generating the release, the source term involved, proposed effluent control equipment, and the calculated dose impact from the proposed release. The evaluation is also used to assess the need for possible modifications to the environmental monitoring program.

The following sections briefly describe the primary sources of radioactive air emissions from BNL operations.

3.3.1.1 High Flux Beam Reactor

In 1997, a plume of tritiated groundwater was traced back to a leak in the HFBR spent fuel storage pool. Consequently, the HFBR was put in standby mode until November 1999, when DOE declared that it was to be permanently shut down. Residual tritium in water in the reactor vessel and piping systems continued to diffuse into the building's air through valve seals and other system penetrations, though emission rates were much lower than during the years of operation.

In 2010, the HFBR was disconnected from the 100-meter stack, and a new HFBR exhaust system was installed in 2011. Consistent with the HFBR Long-Term Surveillance and Maintenance Manual, prior to scheduled surveillance and maintenance activities, air samples are now collected from outside the HFBR confinement using a permanently installed sample port. The samples are collected by bubbling air through a container of water using a fritted sampling device to ensure better collection efficiency. Samples are analyzed in-house for tritium, to ensure that air quality within the building is acceptable to permit staff entry. Additionally, samples are collected once per month from the HFBR exhaust system using a continuously run, standard desiccant sampling system for tritium detection, and are analyzed by an off-site contract laboratory.

3.3.1.2 Brookhaven Linac Isotope Producer

Protons from the Linear Accelerator (Linac) are sent via an underground beam tunnel to the BLIP, where they strike various metal targets to produce new radionuclides for medical diagnostics. The activated metal targets are transferred to the TPL in Building 801 for separation and shipment to various radiopharmaceutical research laboratories. During irradiation, the targets become hot and are cooled by a continuously recirculating water system. The cooling water also becomes activated during the process, producing secondary radionuclides. The most significant of these radionuclides are oxygen-15 (O-15, half-life: 122 seconds) and carbon-11 (C-11, half-life: 20.4 minutes). Both

isotopes are released as gaseous, airborne emissions through the facility's 33-foot stack. Emissions of these radionuclides are dependent on the current and energy of the proton beam used to manufacture the radioisotopes.

In 2019, BLIP operated over a period of 25.14 weeks, during which 6,341 Ci of C-11 and 12,681 Ci of O-15 were released (see Table 4-1). Tritium produced from activation of the target cooling water was also released, but in a much smaller quantity, at 0.0377 Ci. Combined emissions of C-11 and O-15 were 19,022 Ci, 17.6 percent less than the combined emissions of 23,035 Ci in 2018. This decrease is primarily due to fewer days of operation at higher-than-average beam energies than in 2018, and the fact that cooling water gaps for thorium targets are up to 50 percent greater than those for rubidium chloride targets. The thorium target irradiations are in support of future actinium-225 production programs.

3.3.1.3 Target Processing Laboratory

Metal targets irradiated at the BLIP are transported to the TPL in Building 801, where isotopes are chemically extracted for radiopharmaceutical production. Airborne radionuclides released during the extraction process are drawn through multistage HEPA and charcoal filters and the filtered air is then vented to the atmosphere. The types of radionuclides that are released depend on the isotopes chemically extracted from the irradiated metal targets, which may vary from year to year. Annual radionuclide quantities released from this facility are very small, typically in the μCi to mCi range. Gamma analysis of monthly composite samples was discontinued in 2013, but is likely to resume when Ac225 processing begins in late CY2021. This decision was based on historical analytical results of TPL particulate filters that showed gross alpha/beta levels to be very low and consistent with background concentrations. Gross alpha and beta analyses of TPL emissions will continue in calendar year 2021, and periodic alpha spectroscopy will begin with the start of Ac225 processing.

3.3.1.4 Additional Minor Sources

Several research departments at BNL use designated fume hoods for work that involves small quantities of radioactive materials (in the μCi to mCi range). The work typically involves labeling chemical compounds and transferring material between containers using pipettes. Due to the use of HEPA filters and activated charcoal filters, the nature of the work conducted, and the small quantities involved, these operations have a very low potential for atmospheric releases of any significant quantities of radioactive materials.

Compliance with NESHAPs Subpart H is demonstrated using an inventory system that allows an upper estimate of potential releases to be calculated. Facilities that demonstrate compliance in this way include Buildings 197, 197B, 348, 463, 480, 490, 490A, 725, 801, 865, 815, and 901, and, among others, where research is conducted in the fields of nuclear safety, biology, high energy physics, medicine, medical therapy, photon science, advanced technology, environmental chemistry, and synthetic biology.

3.3.2 Airborne Emissions-Nonradioactive

Various state and federal regulations governing nonradioactive airborne releases require facilities to conduct periodic or continuous emissions monitoring to demonstrate compliance with emission limits. BNL's Central Steam Facility (CSF) is the only facility that requires monitoring for nonradiological emissions. The Laboratory has several other emission sources subject to state and/or federal regulatory requirements that do not require emission monitoring.

The CSF supplies steam for heating and cooling to all major facilities on site through an underground steam distribution and condensate grid. The combustion units at the CSF emit oxides of nitrogen, sulfur dioxide, oxides of carbon, and particulate matter. Continuous emissions monitors are used on two boilers to measure NO_x, and particulate (i.e., opacity). Data are reported quarterly to EPA and the New York State Department of Environmental Conservation (NYSDEC).

3.3.3 Liquid Effluents

BNL's State Pollutant Discharge Elimination System (SPDES) permit provides the basis for regulating wastewater effluents at the Laboratory. The SPDES permit establishes release concentration limits and dictates monitoring requirements.

3.3.3.1 BNL Sewage Treatment Plant (Outfall 001)

Sanitary and process wastewaters generated by Laboratory operations are conveyed to the BNL STP for subsequent treatment prior to discharge. The STP effluent (Outfall 001) is a discharge point authorized under BNL's SPDES permit. The Laboratory's STP treatment process includes three principal steps: 1) aerobic oxidation for secondary removal of biological matter and nitrification of ammonia, 2) secondary clarification, and 3) filtration for final solids removal prior to discharge to groundwater via one of four recharge beds. Tertiary treatment for nitrogen removal is also provided by controlling the oxygen levels in the aeration tanks. During the aeration process, the oxygen levels are allowed to drop to the point where microorganisms use nitrate-bound oxygen for respiration; this liberates nitrogen gas and consequently reduces the concentration of nitrogen in] the STP discharge.

In October 2017, BNL received an updated SPDES permit that included the removal of information and requirements that did not apply since BNL was no longer discharging to the Peconic River (i.e., surface water). Among other administrative changes, several parameters were removed from the permit, including BOD₅, Total Suspended Solids, Ammonia (as N), and Settleable Solids.

3.3.3.2 BNL Recharge Basins and Stormwater (Outfalls 002–008, 010-012)

Recharge basins are used for the discharge of "clean" wastewater streams, including once-through cooling water, stormwater runoff, and cooling tower blowdown. Figure 3-3, on the following page, depicts the locations of BNL's recharge basins and stormwater outfalls. Each recharge basin is a permitted point-source discharge under the Laboratory's SPDES permit:

- Basins HN, HT-W, and HT-E receive once-through cooling water discharges generated at the Alternating Gradient Synchrotron (AGS) and Relativistic Heavy Ion Collider (RHIC), as well as cooling tower blowdown and stormwater runoff.
- Basin HS receives predominantly stormwater runoff and minimal cooling tower blowdown and once-through cooling water from the National Synchrotron Light Source-(NSLS) II and the Chemistry Department. This basin also receives treated groundwater from the Freon-11 and Building 96 Treatment Systems, which are managed by the Groundwater Protection Group, and reporting is performed in accordance with a SPDES equivalency permit.
- Basin HX receives Water Treatment Plant filter backwash water.
- Basin HO receives cooling water discharges from the AGS and stormwater runoff from the area surrounding the HFBR.
- Several other recharge areas are used exclusively for discharging stormwater runoff. These areas

include Basin HW near the NSLS-II site, Basin CSF at the Central Steam Facility (CSF), Basin HW-M at the former Hazardous Waste Management Facility (HWMF), and Basin HZ near Building 902. Recharge basins HP and RAV are used for discharge of treated water from the groundwater remediation systems and are monitored under BNL's CERCLA equivalency permits.

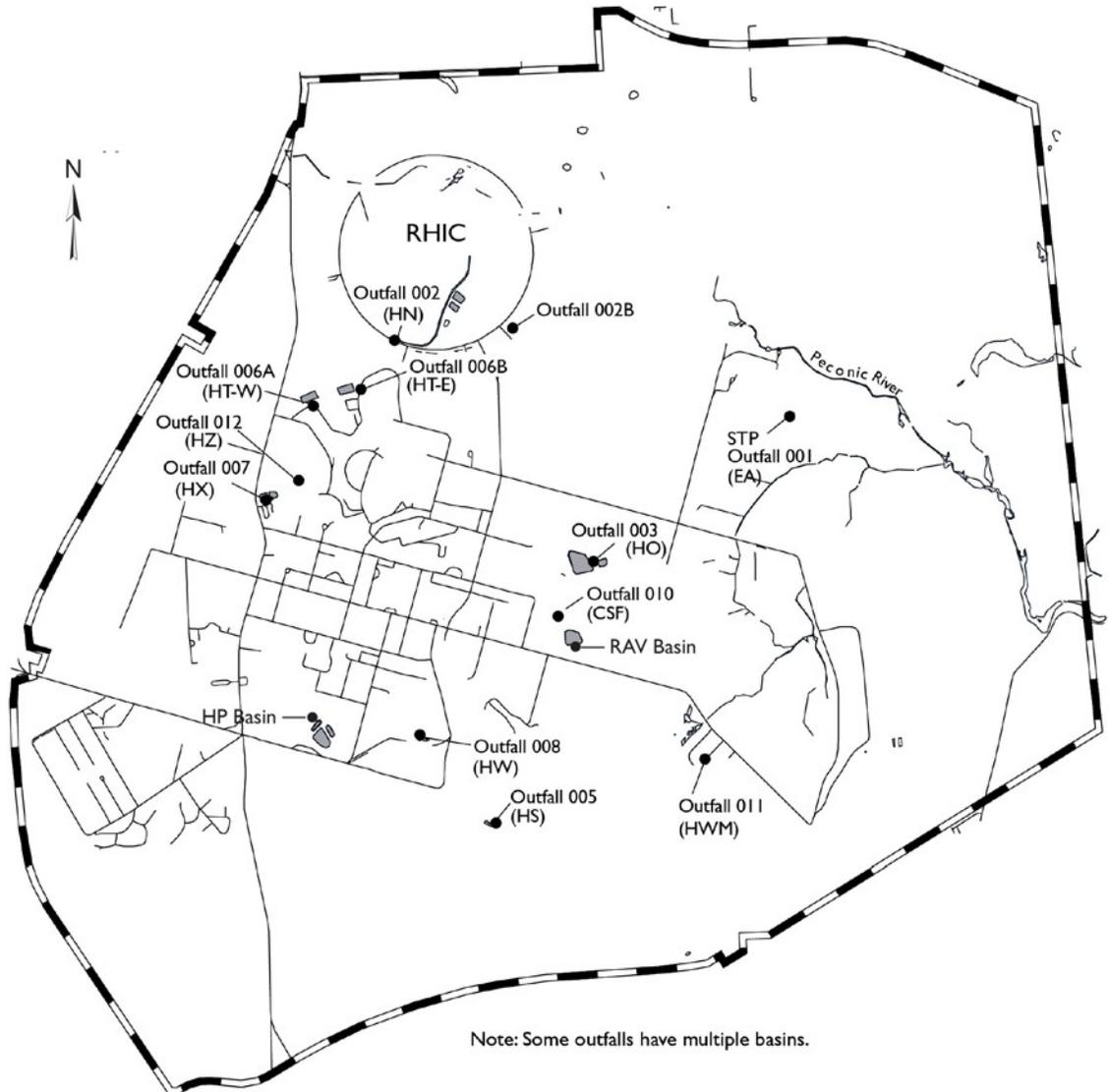


Figure 3.3. BNL Recharge Basins/Outfalls

3.3.3.3 Assessments of Process-Specific Wastewater

Wastewater that may contain constituents above SPDES permit limits or groundwater discharge standards is held and characterized to determine the appropriate means of disposal. The analytical results are compared with the appropriate limit and the wastewater is released only if the discharge would not jeopardize the quality of the effluent.

Examples of process-specific wastewater requiring routine characterization are discharges from metal-cleaning operations in Building 498 (Central Cleaning Facility) and cooling

tower discharges from Building 902 (Superconducting Magnet Division). These operations are potential sources of contaminants, such as inorganic elements (i.e., metals and cyanide) and volatile and semi-volatile organic compounds.

Process wastewaters that are not routinely monitored under the SPDES permit are held for characterization before release to the sewer system. Wastewaters that are routinely evaluated are releases from primary, closed-loop cooling water systems and water collected in berms that provide secondary containment for tanks and other industrial wastewaters. To determine the appropriate disposal method, samples are analyzed for contaminants specific to the process.

In all instances, any waste that contains hazardous levels of contaminants or elevated radiological contamination is sent to the waste management program for disposal.

3.4 ENVIRONMENTAL RESTORATION MONITORING

BNL's Environmental Restoration Group operates and maintains groundwater treatment systems to remediate contaminant plumes both on and off site. The Laboratory maintains an extensive network of groundwater monitoring wells to verify the effectiveness of remediation efforts. Modifications to groundwater remediation systems are implemented, as necessary, based upon a continuous evaluation of monitoring data and system performance. Additionally, surface water, sediment, and fish sampling are conducted to verify the effectiveness of the Peconic River cleanup efforts. Peconic River monitoring is coordinated with the Surveillance Monitoring Program to ensure completeness and to avoid any duplication of effort.

REFERENCES

- 40 CFR 61, Subpart H. 1999. U.S. Environmental Protection Agency. *“National Emissions Standards for Hazardous Air Pollutants, Subpart H, National Emission Standards for Emissions of Radionuclides Other Than Radon From Department of Energy Facilities.”* U.S. Code of Federal Regulations.
- Areas of Concern at BNL, Upton, New York. A Reference Handbook. Brookhaven National Laboratory, Upton, NY. June 1998.
- Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980, as amended, Public Law 96-510, 94 Stat. 2767, 42 USC 9601 et seq.
- State Pollutant Discharge Elimination System (SPDES) Permit No. NY 0005835. Issued by the New York State Department of Environmental Conservation, 2017.