

# 3 EMISSION/EFFLUENT SOURCES AND PATHWAYS

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## 3.1 INTRODUCTION

BNL estimates potential exposures that could be received by humans and terrestrial and aquatic flora and fauna from radioactive and chemical substances through various pathways. To predict these exposures, the character of the pollutant emitted (e.g., identity, amount, rate of release, chemical form, etc.), as well as an understanding of 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 a number of routes and can eventually lead to exposure of animals, vegetation, and humans. These routes can be direct, as in the inhalation of contaminated air or ingestion of contaminated drinking water; or indirect, 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:

- 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 also 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 radionuclide decay)
- *Biologically transformed* (e.g., biodegradation)
- *Accumulated in the receiving media* (e.g., strongly absorbed in the soil column, stored in organism tissues)

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 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.

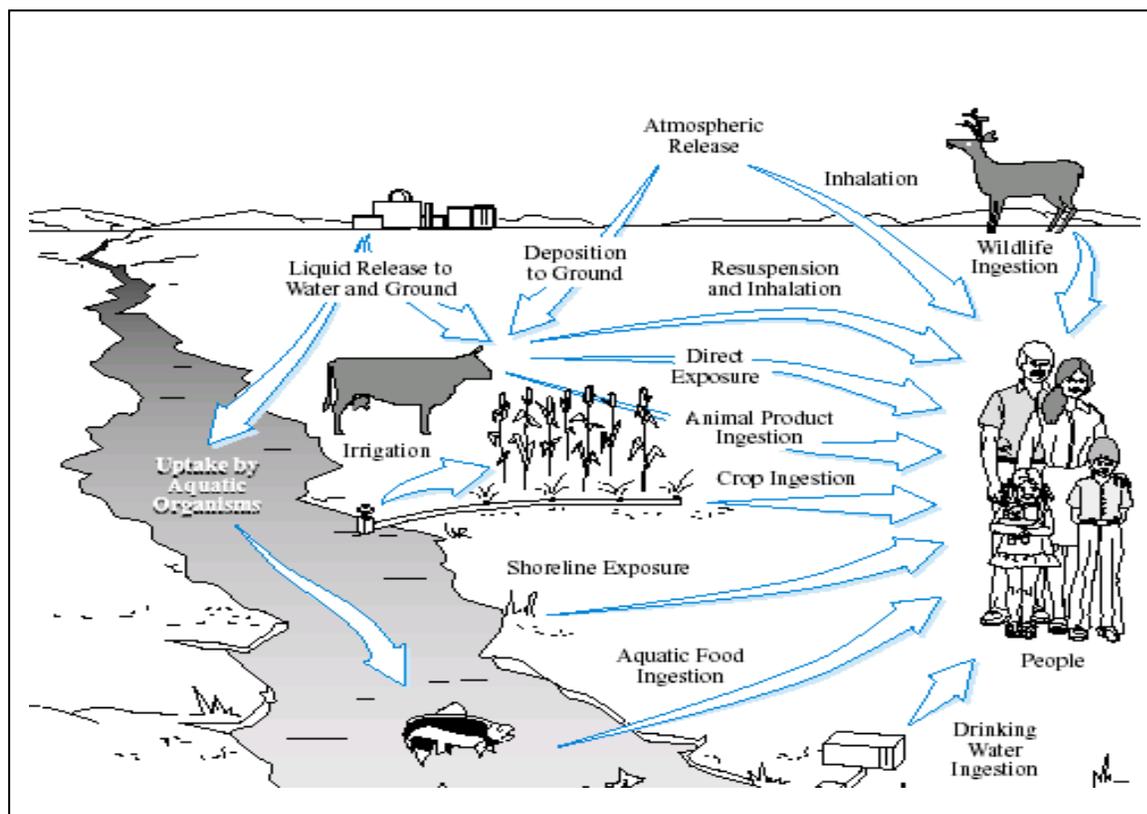


Figure 3-1. Primary Exposure Pathways to Humans.

### 3.3 SOURCES

#### 3.3.1 Airborne Emissions – Radioactive

Federal air quality laws and 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 CAA, and DOE Order 5400.5, *Radiation Protection of the Public and the Environment*. Facilities with emissions that have the potential to deliver a radiation dose to a member of the public of 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. Although not required, BNL conducts continuous monitoring at the BLIP. Periodic monitoring is conducted at one active facility, the TLP, and one inactive facility, the HFBR. Figure 3-2 indicates the location of each of the monitored facilities.



**Figure 3-2. Potential Air Emission Release Points Subject to Monitoring.**

There have been significant decreases in the types and quantities of radiological emissions from BNL operations. One former source, the Evaporator Facility, has not operated since 2000. In addition, the HFBR was permanently shut down in 1999 after the discovery of tritium in groundwater near the facility. The BMRR was also permanently shut down in 2000 due to a reduction of research funding. Consequently, current emissions from these facilities are a small fraction of their previous levels, and will continue to decrease as they are officially decommissioned.

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, oxygen-15, and tritium. Table 3-1 presents the airborne radionuclide releases from monitored facilities in calendar year 2006.

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 Linac Accelerator, 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 radio-

active materials are typically used in these hoods, usually on the order of micro to millicurie quantities. Compliance with NESHAPs regulations for these sources is demonstrated annually through the use of 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.

Facility	Nuclide	Half-Life	Ci Released
HFBR	Tritium	12.3 years	4.03+0
BLIP	Carbon-11	20.4 minutes	1.28E+3
	Oxygen-15	122 seconds	3.12E+3
	Tritium	12.3 years	6.78E-2
TPL - Bldg. 801	Germanium-68	270.8 days	3.47E-9
<b>Total</b>			<b>4.42E+3</b>
Notes:			
Ci = 3.7E+10 Bq			
BLIP = Brookhaven Linac Isotope Producer			
HFBR = High Flux Beam Reactor			
TPL = Target Processing Laboratory			

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 Brookhaven Medical Research Reactor

While in operation, the Brookhaven Medical Research Reactor (BMRR) was fueled with enriched uranium, moderated and cooled by water, and operated intermittently at power levels up to 3 megawatts MW, thermal. Air from the interior of the containment building was used to cool the neutron reflector surrounding the core of the BMRR reactor vessel. As air was drawn through the reflector, it was exposed to a neutron field, resulting in activation of the argon fraction of the air. This produced argon-41 (Ar-41), an inert, radioactive gas. After passing through the reflector, the air was routed through a roughing filter and a high-efficiency particulate air (HEPA) filter to remove any particulate matter. Charcoal filters were also used to remove radionuclides produced during the fission process. Following filtration, the air was exhausted to a 150-foot stack adjacent to the reactor containment building. This air was continuously monitored for Ar-41 emissions. Since the BMRR is no longer operating, the frequency of monitoring was initially reduced from continuous to semi-annual. In 2005, monitoring at the BMRR was discontinued with the concurrence of EPA, after review of several years of data showing no emissions from the facility. Real-time monitoring was used to track argon-41 (Ar-41) air emissions, and passive filter media were used to collect and quantify radioiodines and particulate emissions. Semi-annual sampling conducted from 2000 through 2004 showed no argon emissions at zero power level with the building ventilation on and the BMRR core unchanged. Tritium emissions were estimated based upon evaporative losses from the reactor and a known tritium concentration in the remaining cooling water. To reduce further

emissions, in 2004 all fuel elements and the control rods were removed from the reactor and disposed. In 2005, all remaining reactor coolant (i.e., light water) was drained, to the best extent possible, and the reactor was put into a long-term maintenance mode pending future decommissioning. In 2006, the facility was managed as a radiological facility. During the year, all removable radioactive equipment in the reactor vessel was retrieved and shipped to a DOE-approved disposal facility.

### **3.3.1.2 High Flux Beam Reactor**

The HFBR was a small research reactor capable of operating at power levels ranging from 30 to 60 MW. Heavy water was used to cool the reactor fuel and to moderate the neutrons used in the fission process. Tritium was the main source of emissions from the facility. The primary mechanism by which tritium was transferred from the interior coolant system to the building atmosphere was depressurization of the reactor vessel and evaporative losses during maintenance and refueling operations. Diffusion of the tritium at valve seals and other fittings also occurred. Tritiated water vapor was then released from reactor systems to the building air, where it was routed to the facility's 320-foot stack.

In 1997, a leak in the pool was discovered when a plume of tritiated groundwater was traced back to it. The HFBR fuel pool was pumped out, and the HTO from the pool was properly disposed of as radioactive waste. After the HFBR shut-down in 1999, several actions occurred to ready the facility for decommissioning: the removal of all beam lines, removal and disposal of all fuel elements and control rods, and removal and disposal of heavy and light water. Decommissioning plans are under development through the CERCLA program.

As a result of putting the reactor into a "dry" state, emissions have continued to drop. Residual tritium in water in the reactor vessel and piping systems continues to diffuse into the building's air through valve seals and other system penetrations, though emission rates are much lower than during the years of operation. The tritium air emissions from the HFBR facility are monitored by sampling, which is performed one week per month.

### **3.3.1.3 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 20.48 minutes). Both of these isotopes are released as gaseous, airborne emissions through the facility's 33-ft stack. Emissions of these radionuclides are dependent upon the current and energy of the proton beam used to manufacture the radioisotopes. These values are reported annually in BNL's Site Environmental Report.

In an effort to reduce the emissions from the BLIP facility, an enclosure was constructed of Lucite. This encloses the target shaft opening and the target drive mechanism to reduce evaporative losses. Although construction was completed in 2003, limited running time in 2004 prevented collection of data to confirm the reduction rates. Testing was continued in 2005, and calculations showed that emissions were reduced by more than 28 percent from 2003, primarily due to a reduced period of operation. In 2006, BLIP operated over a period of 22 weeks. Tritium produced from activation of

the target cooling water was also released, but in a much smaller quantity. Combined emissions of C-11 and O-15 were roughly 35 percent higher than in 2005, primarily due to five additional weeks of operation.

#### **3.3.1.4 Evaporator Facility**

The Evaporator Facility was constructed to reduce the total amount of tritiated water released to the Peconic River from BNL operations through the Sewage Treatment Plant (STP). The Evaporator Facility began processing wastewater in 1995. Aqueous waste generated on site that contained residual radioactive material was processed at the Waste Concentration Facility (WCF), Building 811. At the WCF, suspended solids and a high percentage of the radionuclides were removed from the liquid using a reverse osmosis process. However, because of tritium's chemical properties, it was not removed during this process. The tritiated water that remained following waste concentration was delivered to the Evaporator Facility, where it was converted to steam and released as an airborne emission. The emission was directed to the same stack used for exhausting building air from the HFBR. This method was preferable to release via surface water because there is virtually no potential to influence groundwater (the primary drinking water source on Long Island), and the potential for this tritium to contribute to an off-site dose is minimized by atmospheric dispersion. Due to the reduced costs for off-site waste disposal and increased maintenance costs, this facility has not been used since 2001. Wastes are now processed through solidification and disposed of off-site.

#### **3.3.1.5 Target Processing Laboratory**

Metal targets that have been irradiated at the BLIP facility are transported to the TPL where isotopes are chemically extracted for radiopharmaceutical production. Airborne radionuclides released during the extraction process are drawn through multistage HEPA and charcoal filters and then vented to the HFBR stack through an underground system of duct work (see Table 3-1 for isotopes and quantities). The types of radionuclides released depend on the isotopes chemically extracted from the irradiated metal targets, which can change from year to year. Annual radionuclide quantities released from this facility are very small.

#### **3.3.1.6 Linear Accelerator (Linac)**

The Linac produces beams of polarized protons of energies up to 200 Me V for use at both the Collider-Accelerator Department (C-AD) and BLIP. Due to the composition of the beam and the energies involved, production of airborne radionuclides through air activation and/or spallation interactions is possible. The most significant production point of airborne radionuclides inside the tunnel occurs where the beam crosses an air gap as it enters the BLIP vacuum system. These radioactive products are available for atmospheric release via the tunnel ventilation exhaust stack, located adjacent to the BLIP building. However, since the exhaust fan has been turned off and the nuclides are permitted to decay within the tunnel, the potential for emissions is small.

#### **3.3.1.7 Alternating Gradient Synchrotron Cooling Tower 2**

Magnets used to steer the AGS particle beam experience significant heating and are cooled via a recirculating, non-contact water loop. Under certain conditions (such as high-energy proton operations), low concentrations of radioactive elements may be produced in the cooling water when it circulates in the vicinity of the beam line. Radioisotopes that exist as gases may be liberated from the water when exposed to air during circulation in the outdoor cooling tower, resulting in an airborne emission. The radionuclides that are likely to be released via this

mechanism include oxygen-14 ( $t_{1/2} = 1.2$  minutes), oxygen-15 ( $t_{1/2} = 2.1$  minutes), nitrogen-13 ( $t_{1/2} = 10$  minutes), and carbon-11 ( $t_{1/2} = 20$  minutes). Tritium is also present and may be emitted from the tower as water vapor in microcurie quantities per year. Modeling using EPA CAP88-PC software indicates that the typical annual dose to the maximally exposed individual from this source is approximately 0.00002 mrem. Note that this cooling tower is only an airborne radionuclide emission source during those times when the AGS C-line is in use. Cooling Tower 2 does not service any other beam lines.

### **3.3.1.8 Additional Minor Sources**

There are several research organizations within BNL that conduct work involving very small quantities of radioactive materials (in the microcurie to millicurie range). The radioactive material is typically used within fume hoods designated for this purpose and equipped with HEPA filters. Operations such as transferring material between containers, pipetting, and chemical compound labeling, are typical of the work conducted with these sources. Due to the use of HEPA filters, the nature of the work conducted, and the small quantities involved, these operations have a very low potential for atmospheric release of any environmentally significant quantity of radioactive materials. Compliance with NESHAPs Subpart H is demonstrated through the use of an inventory system that allows an upper estimate of potential releases to be calculated. Facilities characterized as minor sources include Buildings 463 (Biology), 555 (Chemistry), 490 (Medical Research Center), 490A (Environmental Sciences Department), 703W (Energy, Environmental & National Security), and 830 (Environmental Research and Technology Division), where research is conducted in the fields of biology, medicine, high energy physics, chemistry, applied and materials science, and advanced technology..

### **3.3.2 Airborne Emissions-Nonradioactive**

Various state and federal regulations governing nonradioactive airborne releases require facilities to conduct periodic or continuous emissions monitoring in order to demonstrate compliance with emission limits. The CSF is the only BNL 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<sub>x</sub>, and particulate (i.e., opacity). Data are reported quarterly to EPA and NYSDEC.

### **3.3.3 Liquid Effluents**

BNL's SPDES permit provides the basis for regulating wastewater effluents at the Laboratory. The SPDES permit establishes release concentration limits and dictates monitoring requirements. BNL's SPDES permit was issued in 1995, renewed in 2000, modified in 2002, and renewed again in 2005. This permit stipulates monitoring requirements and lists effluent limits for the following outfalls:

- Outfall 001 is the discharge of treated effluent from the BNL STP to the Peconic River.
- Outfalls 002, 002B, 003, 005, 006A, 006B, 008, 010, 011, and 012 are recharge basins or ground surface discharges used for the discharge of cooling tower blowdown, once-through cooling water, and/or stormwater.
- Outfalls 003, 011, and 012 do not require effluent monitoring under BNL's SPDES permit.
- Outfall 007 receives backwash water from the potable Water Treatment Plant filter building.

- Outfall 009 consists of numerous subsurface and surface wastewater disposal systems that receive predominantly sanitary waste, and steam- and air-compressor condensate discharges. NYSDEC does not require effluent monitoring of Outfall 009.

### **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 to the Peconic River. In 1997, the STP underwent significant construction modifications and was upgraded from a primary plant (i.e., separation of settleable solids and floatables) to a tertiary treatment system (i.e., biological reduction of organic matter and reduction of nitrogen). This treatment process became fully functional in 1998. In 2000, additional changes to the plant and sewage system were initiated. These changes included replacing or lining the sewage collection system and replacing the former anaerobic digester with an aerobic digester. These modifications were completed in early 2002. In 2006, further changes were made to the treatment process. The primary clarifier was removed from the treatment sequence to permit the entry of all waste products into the aeration process. This change was necessary to enhance nitrogen removal by providing more nutrients for the biological organisms to be used during the denitrification step. The STP has a design capacity of 3.0 million gallons per day and receives sanitary and certain process wastewaters from Laboratory facilities for treatment before discharge into the Peconic River.

### **3.3.3.2 BNL Recharge Basins and Stormwater (Outfalls 002–008, 010, 011, and 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 depicts the locations of BNL’s recharge basins and stormwater outfalls.

- Recharge Basins HN, HT-W, and HT-E receive once-through cooling water discharges generated at the C-AD and RHIC, as well as cooling water tower blowdown and stormwater runoff.
- Recharge Basin HS receives predominantly stormwater runoff, once-through cooling water from Building 555 (Chemistry Department), and minimal cooling tower blowdown from the National Synchrotron Light Source (NSLS).
- Basin HX receives Water Treatment Plant filter backwash water.
- Recharge Basin HO receives cooling water and cooling tower discharges from CA-D and formerly from the HFBR, as well as stormwater runoff. Discharges from the CA-D consist of once-through domestic water used to cool the main magnet heat exchanger located in Building 911.

In addition, several other recharge areas are used exclusively for discharging stormwater runoff. These include Basin HW in the warehouse area, the CSF stormwater outlet, Basin HW-M at the former Hazardous Waste Management Facility (HWMF), and Basin HZ near Building 902.

### **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 printed circuit board fabrication in Building 535B (Instrumentation Division), metal cleaning operations in Building 498 (Central Cleaning Facility), cooling tower discharges from Building 902 (Superconducting Magnet Division), and miscellaneous satellite boiler blowdown. These operations are potential sources of contaminants, such as inorganic elements (i.e., metals and cyanide) and volatile and semivolatile organic compounds. Through significant improvements in the photographic developing processes conducted at Building 197, wastewater from these activities was eliminated in 2004.

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.

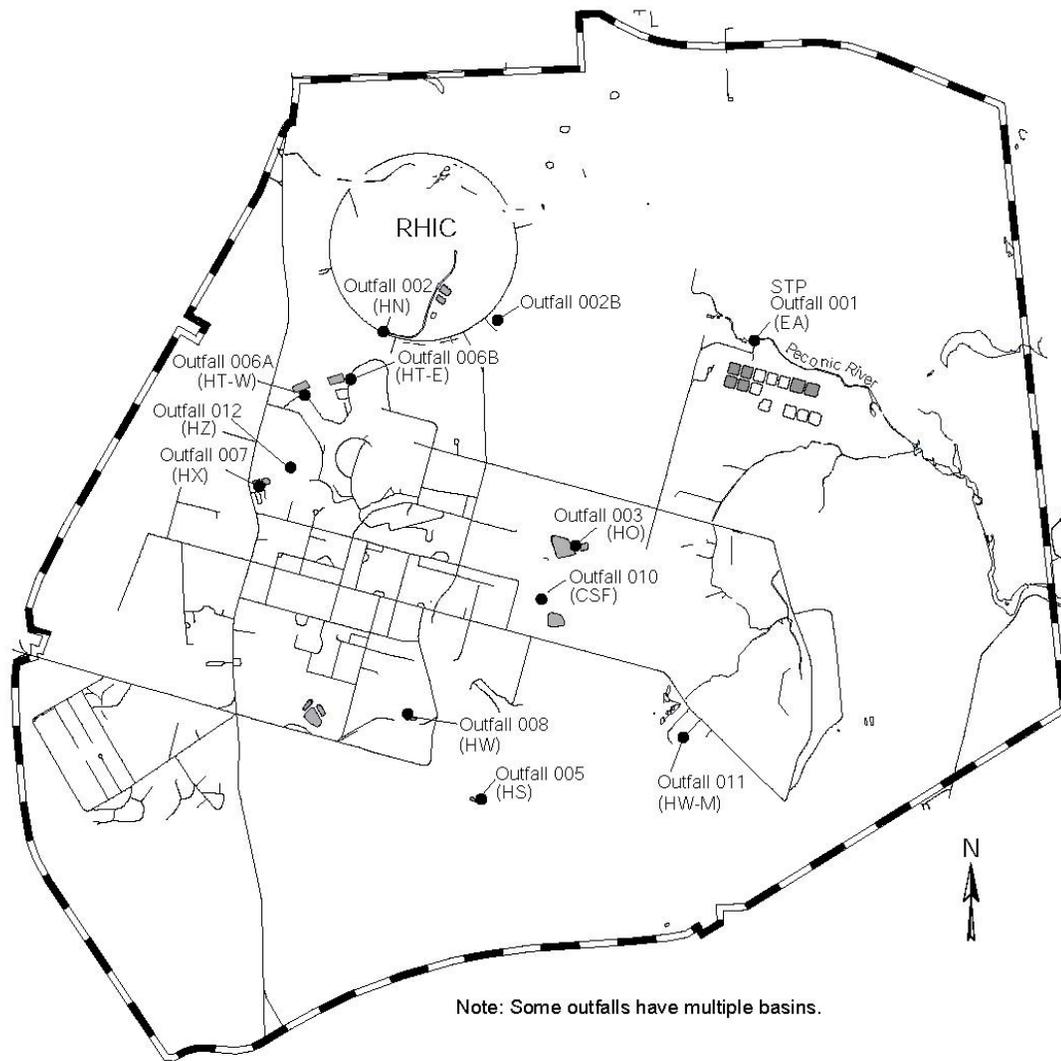


Figure 3-3. BNL Outfall Map.

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 PROGRAM MONITORING

In 1980, the U.S. Congress enacted the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, also known as Superfund) to ensure that sites with historical contamination were cleaned up and to hold the responsible party liable for the cleanup. CERCLA established the National Priorities List (NPL). The NPL is a list of sites nationwide where cleanup of past contamination is required. In November 1989, BNL, as one of a number of sites on Long Island, was listed on the NPL. Much of the contamination at the Laboratory is due to past practices for handling, storing, and disposing of chemical and radiological materials, as well as to accidental spills.

Since BNL's Environmental Restoration (ER) program was established in 1991, ER program staff have been characterizing and removing sources of contamination (e.g., underground tanks and pools) or treating the groundwater and soil contamination resulting from past practices. Historical facility records and sampling were used to determine where contamination might be present on the site today, and these areas were geographically grouped into Operable Units (OUs). ER groundwater cleanup efforts have included monitoring existing groundwater wells, overseeing the installation of new, permanent groundwater monitoring wells, installing groundwater treatment systems, and extending public water service off site to replace the use of private potable supply wells. Soil cleanup efforts have identified contaminated soils through sampling and resulted in various programs involving soil removal and treatment. Several landfills have been capped, 55 waste pits have been excavated, the Peconic River clean-up has been completed, and the Former HWMF has been decontaminated. In 2005, the ER program completed its original mission, which culminated in a project close-out celebration attended by federal politicians, local civic leaders, and DOE Management. In 2006 and beyond, the ER mission will be to complete decommissioning of the reactor facilities and ancillary structures. The former ER program now enters a long period of surveillance and maintenance, which is being implemented by the Long-Term Response Action (LTRA) Group.

Many remediation techniques can result in temporary increases in contaminant effluents or emissions and therefore require monitoring to minimize the potential impacts. The BNL Environmental Monitoring Program supports restoration activities by selecting monitoring locations and determining what media samples will best assist the ER staff to evaluate the impact of restoration activities to public health and the environment.

### REFERENCES

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